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Constructing urban life : a study of automobile dependency in 148 mid-size U.S. cities.

Chad Paul Frederick
University of Louisville

CONSTRUCTING URBAN LIFE:
A STUDY OF AUTOMOBILE DEPENDENCY IN 148 MID-SIZE U.S. CITIES

By

Chad Paul Frederick
M.U.E.P., Arizona State University, 2012
B.A., Individualized Studies in Sustainability, Metropolitan State University, 2010

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A Dissertation Approved on

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By the following Dissertation Committee:

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Dr. John ‘Hans’ Gilderbloom, Dissertation Director

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Dr. David Simpson

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Dr. Steven Koven

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Dr. Matthew Ruther

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Dr. Matthew Hanka

DEDICATION

This research, the culmination of eight years of study, I dedicate to my wife, Olga. I would not have even started it, if it were not for you. I also dedicate this to our daughter, Paulina, who already prefers to walk to the coffee shop: Cars are indeed “yucky.”

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ABSTRACT

CONSTRUCTING URBAN LIFE:
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Chad P. Frederick

April 22, 2016

Automobile-dependent sprawl remains the dominant urban development paradigm in the United States. One reason for this is that the automobile is assumed to be more beneficial to the local economy than it is detrimental to society. Both sides of this assumption are wrong. First, local economies do not benefit much from automobile dependency. On the contrary, multimodal cities have lower unemployment, higher wages for African-Americans, and more efficient property markets. In addition, while it is true that multimodality means slightly higher taxes, the total value of living in multimodal cities far surpasses automobile-dependent cities with a massively improved quality of life. Second, while automobile-dependent cities have been shown to foster obesity, the full range and intensity of automobile dependency's health impact has been grossly understated. This research provides compelling evidence that multimodal cities not only have lower rates of obesity, but also better overall health, and significantly lower rates of premature death. Urban research has much to blame for this misunderstanding: How we look at problems largely shapes the answers we generate. By distinguishing between the independent effects of sprawl and automobile dependency, and by using municipalities

themselves instead of massive urbanized regions, this research more accurately assesses the full range and depth of the benefits of transportation multimodality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER ONE: INTRODUCTION

“People know what they do; frequently they know why they do what they do; but what they don't know is what what they do does.” —Michel Foucault, Madness and Civilization: A History of Insanity in the Age of Reason

Background

The social and environmental impacts of automobile dependency (AD) in the United States has been a central concern of urban researchers for the past few decades. Despite research efforts, public policy has failed to address the effects of this dependency. While compelling examples of alternatives to car-dependent urban development exist (*e.g.* Smart Growth, Strong Cities, New Urbanism, etc.) the modern pattern of car-dependent urban development has hardly changed since the explosion of the automobile-oriented suburb in the early 1950s. There are many reasons for this, and a full account is beyond the scope of this dissertation. However, a significant part of the problem has to do with the ways in which researchers study the situation. For example, urban planning and design researchers have understandably given considerable attention to the social effects of the more obvious differences in urban spatial forms, *i.e.* urban sprawl. This is not surprising, considering that urban sprawl and its opposite (the “walking city”) are linked to differing amounts of automobile use. Still, the impacts of urban forms—while certainly associated with automobile dependency—are not the same as the impacts of automobile dependency itself.

Research in transportation and urban affairs has focused more on the impact of automobile *use*. This research falls into three different fundamental genres. The first genre focuses on detailed case studies of particular cities at the level of the *metropolitan statistical area* (MSA). These are typically vast regions that encompass not only the central city, but also its “edge” cities, satellites, and bedroom communities, as well as multiple counties and dozens of special governments. The case study approach to research has provided important insights into how a region might cope with its built environment and transportation regime. These studies are useful, but because they focus on a particular case at the metropolitan scale, they suffer from a lack of generalizability. In addition, there is no governing body at the MSA level, and therefore policies are rarely written at this level. As such, this research reflects a wide variety of oftentimes contradictory policies written by dozens of policy-making bodies. Thus, unable to identify which particular policies are working, planning practitioners and government officials in other MSAs might be reticent to apply findings from areas they feel are dissimilar to their own.

The second genre concerns the generation and comparison of compelling national statistics, such as vehicle deaths *per capita* and commute times in Europe, Asia, and the United States. These reports and studies have produced sets of facts as alarming as they are numerous. Nevertheless, their findings are typically un-actionable: The chance of a national urban transportation reform policy emerging from one (or all) of these studies is infinitesimally small. In addition, municipalities—while rightfully concerned with the findings—have no way to translate national statistics into local policy aside from vague general directions such as “increasing transit.” These statistics do not provide cities with insight into how automobile dependency shapes urban life, leaving local policy fixes without clear targets.

The third genre involves statistical analyses of groups of cities. With few exceptions, these studies usually focus on a relatively small group of large cities. Very often these studies make use of arbitrary classifications such as “the 30 largest U.S. cities” or “global cities.” Like the case studies, these also tend to use the MSA as the unit of analysis. The upshot is typically the formulation of an index (*e.g.* the Green Cities Index, etc.) based on a weighted aggregation of oftentimes categorically incompatible variables. These authors then use these indices to rank their cities from, say, one to 30, or group them into a descriptive typology. Studies such as these can help city hall, planners and citizens work toward an ideal development strategy. However, as there is no governing body at the MSA level, it is almost certain that policies based on MSA-level findings would be plagued with problems. Among them would include problems stemming from the unaccounted-for interactions between the policies of various municipal, county and special-purpose governments within the MSA.

Even meta-analyses of research in this area are not entirely helpful. While some scholars have gathered together large samples of urban transportation research into meta-analyses to get a broad and useful picture of the automobile’s impact on urban life, nearly every one of the individual studies has some methodological attribute which makes its comparison at least problematic: There are a vast array of variables and data that researchers have used to measure and assess automobile use. Again, despite this large body of work, no meta-analysis of research has focused specifically on automobile *dependency*.

Finally, automobile dependency has mostly been used as a dependent variable in transportation and sprawl research. Not only does this approach fail to consider the impact of automobile dependency itself, it brings into question findings which have been attributed to sprawl: Are these impacts actually a result of sprawl, or are they better attributed to automobile use and dependency? This research instead uses a measure of AD as an independent variable.

Contribution to Research

What we do know is that cars are harmful, to both human health and environmental quality, but also to the economy and even the stock of civic and social capital. What we do not know is to what extent, or in which ways these harms are perpetrated, as well as how automobile *use* and *dependency* influence these outcomes differently (Dannenberg et al., 2003).

This difference between use and dependency points to two more related issues in research which contribute to inaction on urban development. First, different academic disciplines approach the topic of automobile dependency from dissimilar perspectives. The “siloization” of objective knowledge production regarding socio-ecological phenomena has considerable drawbacks, as well as compelling benefits. While disciplinary specialization allows for a powerful but tight focus on a comparatively narrow issue, it also tends to separate the object of study from its interactions with the broader set of possible social and environmental phenomena.

This drawback has become more apparent in recent decades with the realization that lone academic disciplines are unequipped to adequately address the complex and transdisciplinary issues of sustainable urban development. This is surprising since, after all, the production of cities is a transdisciplinary project. This research thus takes a more transdisciplinary approach through the inspection of social outcomes in four broad "themes" of urban life, including *human and environmental health, quality of life,* and *economic outcomes* such as jobs and housing. In addition, I explore a distinctly urban set of concerns for the sustainability of cities: *Urban character*. That is to say, "What is it like to live in one city versus another?" Each of these themes is relevant to urban sustainability.

The second, equally problematic issue with past research is the fundamentally different conceptualizations of automobile use itself that are used by researchers. For example, very often researchers use automobile use (*e.g. per capita* vehicle miles travelled, or VMT) as a proxy for automobile dependency. However, just because a citizen drives a lot does not mean that they *have* to, or that they depend on their vehicle for their livelihood. While work trips are embedded in VMT data, VMT cannot distinguish work trips from the considerable amount of unnecessary driving which is included in VMT. These two concepts, VMT and AD, while clearly related, are not synonymous. Since most people *have* to get to work, this research therefore uses *the percentage of residents who use a single-occupied vehicle for their daily commute to work* as a measure of dependency.

Researching transportation from a sustainability perspective complicates matters even further, even after adopting a nuanced position on the overstated problem of defining sustainability. First, cities are stuck in a paradox: What is sustainable for the city may not necessarily be sustainable for the planet (Campbell, 1996). Consider the ideas of competition for investment and economic growth as critical for the survival and flourishing of individual cities (Peterson, 1981). As economic growth is currently closely tied to carbon emissions, this strategy for urban sustainability collectively harms the planet. There are many examples of this disconnect between the urban and global with regards to sustainability.

Furthermore, conceptual frameworks for urban sustainability tend to underestimate or even ignore the role of cities' relative attractiveness to firms, as well as to workers. This attractiveness, in turn, helps determine which cities capture the flows of labor and capital necessary to maintain competitiveness (Brotchie, Batty, Blakely, Hall, & Newton, 1995; Florida, 2010). These frameworks tend to emphasize the role of the environment and the economy at the expense of critical social factors such as equity; *e.g.* how environmental amenities are distributed. While it may seem that sustainability is dominating urban research, if a study does not centrally locate equity in the conceptual framework, then it is by definition not sustainability research, but is instead merely environmental or economic research. Regarding the sustainability of *cities*, researchers tend to ignore the variation among cities regarding their creativity and civic atmosphere. However, both of these factors impact whether cities can attract the talent and investment necessary for urban sustainability in the global context of the knowledge economy.

All of this has led scholars to focus almost entirely on the impacts of car use, and largely ignore the impacts of multimodality: If car dependency generates certain social and environmental outcomes, what kind of social outcomes does variety in transportation facilitate? Finally, while it is assumed that automobile use produces more greenhouse gases and other toxic chemicals which damage environmental quality, research often uncritically assumes that multimodality presents no new, non-environmental barriers to urban sustainability.

Central Research Question

All of this leaves urban planners, developers and the general public with an inability to consider the many intercity differences between multimodal "green" cities (*i.e.* those with more transportation options) and auto-dependent "brown" cities. The central research question of this dissertation is, "How are green, multimodal cities different from brown, automobile-dependent cities?"

The primary goal of this work is to illuminate these differences. Armed with knowledge about the specific relationships that transportation modality can have on urban social outcomes, policymakers can advance more powerful arguments for the sustainable production and operation of the built environment.

A secondary goal is to identify some limits of multimodality. Knowing the limits of multimodality is almost as helpful as knowing what it *does* affect, as it allows policy goals to be more pragmatic. Why burden a policy with social changes that it cannot produce or deliver? Additionally, it has often been asserted that practicing sustainability as the new paradigm for urban development will alter our civilization's unsustainable trajectory. While this may be true, charging *specific* policies for sustainable development with the weight of *general* social progress can only lead to local disappointments, and harm the larger project of urban and global sustainability in the long run.

Significance

This research can provide urban planners, property developers and others with more clarity about the relationship between automobile dependency and social outcomes.

Focusing on municipalities as opposed to large MSAs provides policymakers with a more appropriate level of analysis than case studies, national statistics on automobile use, or studies of urban sprawl more generally. Identifying the impacts (and limits) of reduced automobile dependency lets policymakers match policy to reasonable expectations.

Additionally, this work provides both planners and the public with a straightforward and meaningful indicator of sustainable urban development in its use of multimodality. Many cities have a sustainability indicator program with which they measure their progress towards sustainable development. This study provides strong evidence that multimodality should be prioritized in these indicator programs.

At a more prosaic level, this work also provides information with which people can arm themselves when making the critical choice of where to live that suits their values. This holds for many professionals who make firm location decisions, as well. For example, one common question put to people is, “In which city would you rather live?” This question is easy to answer poorly if you do not know how these two basic types of cities differ; that is, if it is unclear how your choices differ in terms of quality of life, economic vitality, and human and environmental health.

Conceptual Framework

The dominant model of sustainable development (SD) is comprised of three major dimensions: the environmental, the economic, and the socially-equitable (Kates, Parris, & Leiserowitz, 2005). The Venn-type diagram of this model has been called “the three E’s of sustainable development” (see Figure 1.1). In theory, the equity component is central to the model. In practice, little has been studied regarding the equity dimension of sustainable development (Agyeman & Evans, 2003). Part of the reason for this is that equity as a goal of SD is contested, and normative arguments asserting the centrality of equity to SD have been fairly undeveloped (Smith, Whitelegg, & Williams, 2013, pp. 140-149). Similarly, at the metropolitan scale the social dimension is often treated as the least important of the three by urban planners and others (Saha & Paterson, 2008). Political scientist Kent Portney (2003) observed that, "If equity issues are important conceptual components of sustainability, then sustainable cities initiatives in the U.S. do not seem to take it very seriously" (175). The Venn-type model contributes to this problem through an assumption of their separation:

> " … [this] separation and even autonomy of the economy, society and environment from each other … The separation distracts from or underplays the fundamental connections between the economy, society and the environment. It leads to assumptions that trade-offs can be made between the three sectors, in line with the views of weak sustainability that built capital can replace or substitute for natural resources and systems …" (Giddings, Hopwood, & O'brien, 2002)

For many reasons, SD is more often engaged from a growth-oriented, economic perspective (see, for example, WCED, 1987). Such approaches to sustainable development privilege economic outcomes first, environmental outcomes second, and equity issues a distant third (Brugmann, 1997; Portney, 2003; Yanarella, 1999). However, economic models are ill-equipped to evaluate both the social component of SD, and the critical linkages between the three dimensions of SD (Litman, 2002).

Additionally, as remarked by Giddings, Hopwood, & O'Brien, much of the sustainability discourse employs a weak definition of sustainability that presents sustainable development as marginal technical improvements to the management or practice of socio-ecological systems (*cf.* "bolted on," in Thomas, 2009). For example, many see it as improving the performance of the critical components of an unsustainable system, *e.g.* replacing heavy, gasoline-powered cars with lightweight, electric cars, as opposed to simply reducing the role of cars (see Binswanger, 2001; Lovins, 1988). While environmental benefits are certainly possible by "greening" the fleet, no amount of "green" cars will obviate the social problems that automobile dependency itself creates: Technical fixes for environmental sustainability are unlikely to be adequate for addressing social equity issues (Ratner, 2004).

Sustainable Cities. Answering the question of urban sustainability in the 21st century requires a finer grain of analysis than the "three E's" framework can support. Consider the complexity of sustainability problems; for example, the notion of *access*. Planning scholars Berke and Manta-Conroy (2000) assert that "[equitable] access to social and economic resources is essential for eradicating poverty and in accounting for the needs of least advantaged." Consider that the modern city is largely a place of cultural and commercial consumption (Zukin, 1998). Berke and Conroy's notion of "fit between people and the urban form" that "encourage(s) community cohesion" includes a range of concerns, not the least of which are cultural amenities such as the theater, museums, arts and entertainment. Without cultural and civic amenities, cities are considered unlikely to attract firms and an educated workforce, and thus, risk decay (Bayliss, 2007; Grodach, 2013; van Vliet, 2002). This transdisciplinary issue of *quality of life* has only recently become a central consideration in the sustainability of cities, as have the roles of equity and social justice (Boone, 2014; Lorr, 2012; Mitra, 2003; Sandercock, 1998). A sustainably-developed, or "just" city will allow fair access to these recreational and civic spaces (Fainstein, 2010).

Beyond the 'Three Es.' This work reserves the term "sustainability" as an umbrella term for the various properties of social and physical systems, such as *resilience* and *diversity* (*sensu* Holling, 1973, 2001). While both terms mentioned have recently been critiqued in the field of urban and public affairs, it is important to remember that these system properties have no inherent benefit outside of the context of human values; *e.g.* many institutions and practices can be unjust as well as environmentally or economically sustainable, but also very resilient to change (Marcuse, 1998). In contrast, a *sustainability science* perspective recognizes that questions of social equity are embedded in the environment and the economy, and not in the terms used to describe them.

Nor is environmental sustainability alone a sufficient condition for the sustainability of human society. Agyeman, Bullard, and Evans write that,

> "Sustainability ... cannot be simply a 'green or 'environmental' concern, important though 'environmental' aspects of sustainability are. A truly sustainable society is one where wider questions of social needs and welfare, and economic opportunity are integrally related to environmental limits imposed by supporting ecosystems" (Agyeman, Bullard, & Evans, 2002, p. 78).

Sustainable *urban* development is thus the production of urban space which not only recognizes the central role of social equity, but goes further to consider (and critique) the needs of cities in the current global socioeconomic context.

The current system of automobile dependency lowers urban resilience, represents a lack of diversity, is fundamentally unfair to significant portions of the population, and contributes to global climate change. I therefore consider automobile *in*dependence to be a robust measure of the sustainability of urban built environments (Calthorpe, 2011; Kunstler, 1994; Newman, Beatley, & Boyer, 2009). Because of the transdisciplinary character of automobile dependency *across* the "three E's" of sustainable development, as opposed to *within* or *between* the three dimensions, I replace the more common Venn-like diagram with a different conception which allows for "fuzzy" relationships between elements of the social and material world (Giddings et al., 2002). This "fuzzy" model assumes that these three dimensions, instead of being separate or even opposing (see, for example, Campbell, 1996), are in fact dependent on each other hierarchically. They are also unevenly distributed, context-dependent, and mutually constitutive (see Figure 1.2). This conceptual framework will be used to support four basic hypotheses:

a) "Different levels of automobile dependency have a measureable relationship to differences in cities' *human and environmental health*."
b) "Different levels of automobile dependency have a measureable relationship to differences in cities' *qualities of life*."
c) "Different levels of automobile dependency have a measureable relationship to differences in cities' *economic conditions*."
d) "Different levels of automobile dependency have a measureable relationship to differences in cities' *urban characters*."

Dissertation Structure

Now that a background of the substantive issues in researching automobile dependency and urban sustainability has been outlined, a literature review will inspect the current research. First, the review provides insights into how automobile dependency has been measured, and identifies the set of outcome variables used to assess these measurements. The review then explores how sustainable urban development has been measured, and the social outcomes related to variations in sustainable urban development. These measurements will be used to assemble a broad, substantive selection of dependent variables with which the scope and impact of multimodality can be assessed. The third chapter provides a description of a methodology I used to reduce some of the problems of MSA-level research. A methods section then details the requirements and assumptions of the tests used. The fourth chapter details the findings that this methodology produced. Finally, the fifth chapter develops narratives around these findings and explores their possible policy implications. I also offer some limitations of the variables and the research, and identify areas of future study.

CHAPTER TWO: LITERATURE REVIEW

This dissertation explores the relationship between automobile dependency and sustainability-related outcomes in U.S. cities. The central research question is, "How are green, multimodal cities different from brown, automobile-dependent cities?" Two questions help focus this review of the literature:

- "Which indicators have researchers used to measure urban sustainability?"
- "How have researchers measured automobile dependency and its impacts?"

The result should be a logical connection between the two: How can we measure AD in such a way as to explain differences in urban sustainability outcomes? This research assumes multimodality is a fundamental measure of urban sustainability.

Research on the impact of SD generally focuses on connections between various measures of sustainability (e.g. resilience, diversity, energy production, material consumption), and social, economic or environmental outcomes (e.g. health disparities, project efficiency, greenhouse gas emissions). However, the Venn-type model of sustainable development—which depicts the economy, environment and social equity as distinct—does not illustrate the centrality of equity issues which are embedded in a wide set of sustainability concerns, particularly those at the urban scale. Therefore, this research examines four themes of urban life comprised of variables related to social equity:

- Human and Environmental Health
- Costs of Living and Income

- Quality of Life
- Urban Character

To inform my methodology, this chapter reviews a sample of research in two areas: sustainable urban development and automobile dependency. First, I review research on automobile use in order to adopt an appropriate measure of urban automobile dependency, as well as identify dependent variables that have implications for urban sustainability. Following this, I review research in sustainable urban development to identify a set of indicators used to define its scope. In other words, which measures of urban life have been used to adduce the presence or impact of sustainable urban development?

Automobile Dependency

Automobile dependency is difficult to define, and impossible to capture in a single metric. For example, some researchers, such as Zhang (2006) and Turcotte (2008), focus on probabilities, writing that "Automobile dependence is defined and measured as the probability that a traveler has the automobile as the only element in the choice set of travel modes" (Zhang, 2006). Other researchers focus on the importance of the built environment in determining travel modes (see Ewing & Cervero, 2010). Litman and Laube (2002) conceptualize it as "... high levels of per capita automobile travel, automobile oriented land use patterns, and limited transport alternatives."

Within this context of problematic measurement a considerable amount of research has focused on land-use (*cf.* Cervero & Kockelman, 1997; Frank & Pivo, 1994). In this line of work, AD is often a used as a *dependent* variable. For example, Haas and colleagues (2013) compared the importance of socioeconomic and built environment factors in determining AD and transit use by relating "... independent spatial variables (household density, block size, access to transit and employment, among others) and independent household variables (income, size, workers per household) to the three dependent variables (auto ownership, auto use, transit use)."

Automobile dependency has been inferred by comparing interurban differences in two fundamental characteristics of cities: *sprawl* and *density*. Additionally, urban indicators are also common, such as *vehicle miles travelled, fuel consumption* and *commute times*. The first two characteristics are primarily measurements of the built environment, and as such, merely imply different levels of AD. The three urban indicators more directly analyze data on automobile use. Both approaches tell us, if only indirectly, about the many different social and environmental causes and aspects of AD.

Sprawl Research. Most urban development in North America continues to be dominated by auto-centric development patterns, which perpetuates problems of regional and planetary sustainability (Newman et al., 2009). The extent of the social problems and benefits associated with urban sprawl has been well-researched and long-debated (Bruegmann, 2006; Burchell, Downs, McCann, & Mukherji, 2005; Burchell & Shad, 1998; Gordon & Richardson, 1989, 1997, 2000; Newman & Kenworthy, 1989, 1999). Still, sprawl is a difficult concept to define and operationalize (Berlin, 2002). A recent report by Smart Growth America (Ewing & Hamidi, 2014) suggests that sprawl is associated with fewer transportation options for residents. In the 51-page report, sprawl is measured by four factors: *residential and employment density*; *neighborhood mix of homes, jobs and services*; *strength of activity centers and downtowns*; and *accessibility of the street network.*

However, despite sprawl being most obviously a *spatial* phenomenon, the Smart Growth America definition does not include measurements of distance, or proxies such as commute time. That said, there is no necessary link between land use and travel modes: Even dense, compact cities can be more auto-dependent if they lack basic infrastructure (Eidlin, 2005). Handy (1996) further recognizes the critical considerations beyond land use to include the availability of transportation choices, and how they shape behavior. She writes,

> " ... finding a strong relationship between urban form and travel patterns is not the same as showing that a change in urban form will lead to a change in travel behavior, and finding a strong relationship is not the same as understanding that relationship." (Handy, 1996)

This is particularly true when looking for how that relationship shapes social outcomes. Despite being related, the inference that automobile dependency is an effect of sprawl is problematic: AD and sprawl each make distinct impressions on the urban fabric. Indices of sprawl that aggregate data make it hard to identify the roles that each component plays, leaving policymakers unable to disambiguate between the impacts of sprawl and automobile dependency. It leads to the question, "What, precisely, about sprawl is unsustainable?"

While sprawl implies some amount of automobile use, automobile dependency is a separate issue. Sprawl may reflect increased physical distances in accessing a rewarding social life (and its accompanying alienation), and diminished access to services. Still, a significant part of these outcomes may actually reflect the influence of automobile dependency. Sprawl is difficult to define and hard to quantify, and is an inappropriate construct for adequately assessing the effects of automobile use to the level required by urban policymakers.

Density Research. Related to sprawl, density is also a common proxy for automobile dependency in urban sustainable development research. Higher population densities generally support greener mass transit, as well as result in lower energy consumption per unit of housing, and are therefore considered to be the more environmentally sustainable urban form by urban planners and others. Beginning with the works of Jacob Riis and others, density has also been derided for at least a century: Despite the comparative success of modern sanitation, density is still associated with unhealthy living. While density can be measured in a variety of ways (Malpezzi, 1999), it is a somewhat more objective measurement than sprawl. Thus, it is more common in transportation research than is sprawl.

Again, a sustainable low-density city is not inconceivable, nor are dense but automobile-dependent cities (Eidlin, 2005). However, like sprawl, low-density development is *in practice* generally auto-dependent. Thus, since some of the impact of AD is embedded in the measurement of density, important insights about automobile dependency can be uncovered by observing density's effects.

Some have argued that compact urban development creates broad economic problems, such as costly traffic congestion, expensive development, stifling taxes and poor air quality (Gordon & Richardson, 1998). Others have relied on economic theory to advance the notion that densifying urban development is necessarily expensive, and thus retards financial investment which, in turn, puts the project of environmental health in jeopardy (Solow, 1991; Taylor, 2002). In contrast, the compaction of mixed-use neighborhoods has also been shown to increase access to local markets (Williams, Burton, & Jenks, 2000, pp. 351-352). That said, the *social* impacts of density are less compelling. For example, research suggests that while increased density is associated with more robust economic conditions, this comes at the cost of reduced access to green space (Williams, 2000, pp. 36,44).

Alexander and Tomalty (2002) used density to research 26 cities in British Columbia. They wrote that increased densification in suburbs, infill development and sprawl reduction are generally assumed to result in several environmental, social and economic benefits. These include less automobile use and shorter commutes; fewer climate-changing emissions and less pollution; more customers and a larger labor pool for businesses; higher quality of life for carless residents; more access to basic services; less consumption of energy and natural resources; higher economies of scale in infrastructure; and increased variety in housing stock. They found that despite high housing costs in the central city being offset by lower transportation costs, density does not strongly correlate with housing affordability or green space. In fact, density was *negatively* correlated with both housing affordability and green space, at least in British Columbia.

Compactness is a property of density that has been championed by Smart Growth strategies, as well as New Urbanism and other approaches to sustainable urban development. This characteristic of density has been analyzed for its relationship to socioeconomic outcomes. Burton (2000) attempted to verify many of the claimed social benefits of physical compaction and mixed-use development. Dividing compactness into the three properties *density*, *mix of uses*, and *use intensity*, she attempted to identify changes resulting from increases in these properties from 1981 to 1991. Burton's unit of analysis was the neighborhood level, sampled from 25 cities in the United Kingdom.

Burton (2000) found that compaction reduced access to affordable housing and reduced living space. Compaction's relationship with other economic concerns—such as wealth distribution, job access and availability—had mixed results. Some key indicators, such as job accessibility, were found to be more strongly related to socioeconomic variables. Importantly, there was no control for the type and amount of transportation modalities available to these communities.

The link between density and social equity implied in sustainable development has been inconclusive in many respects (Burton, 2002). Compactness, while clearly beneficial in certain ways, is not a sufficient condition for the equity required by sustainable urban development. Cities must also increase energy and material efficiency, reduce consumption and waste, improve quality of life, and increase access (Guy & Marvin, 2000, pp. 11-13). Like sprawl, we cannot make determinations about the impact of automobile dependency on urban economic outcomes based on the results of the impact of density: Different amounts of automobile dependency can be found in cities with a wide range of densities. The question is, "for which of these outcomes—and to what extent—is automobile dependency the contributing factor in issues of equity, distinct from density?" Density is easier to define and quantify, but it is an inappropriate construct from which to draw strong conclusions about automobile dependency.

Research Using Commute Times. Commute time plays a frequent role in the production of sustainability indices. Siemens "USA and Canada Green City Index" (EUI, 2011) includes commute time as part of its transportation component, weighted at 20 percent. Interestingly, without explanation, the presence of waste-reduction policies is weighted at more than twice that, at 50 percent. Even the number of LEED-certified buildings per 100,000 people is weighted more than commute times, at 33 percent. Clearly, the impacts of automobile use are undervalued in such indices.

This is surprising since commute times may be central to predicting a wide variety of social outcomes. Pitt (2010) used commute times as a measure of AD to complete a statistical model predicting an urban climate change mitigation policy score. In this research, automobile dependency was defined by the percent of "nonpublic transportation commuters" whose travel time exceeds 30 minutes. Of the 16 diverse variables (e.g. "community environmental activism" and "price of electricity") used by Pitt, he found that this measure of AD was correlated to variables as diverse as income, voting history, college town status, air-quality non-attainment of Federal guidelines, and coastal location. Nevertheless, this commute-time measurement was not predictive of the presence of mitigation policy in the ordinary least squares (OLS) regression model, and only just reached significance in the negative binomial model. It was nonsignificant for the other four policy-related dependent variables, which included the presence of policies for energy efficiency, renewable energy, and, importantly, sustainable land-use and transportation policy.

Commute times are easy to quantify, and they are associated with latent factors such as economic and spatial concerns, which are also related to AD. However, the landscape of the built environment, infrastructural efficiency and density all play a strong role in commute times; as such, it reflects too much about the geography and infrastructure of the city to be representative of automobile dependency (Shen, 2000).

Research Using Fuel Prices and Consumption. In one early study, Newman and Kenworthy (1989) used fuel consumption as a proxy for automobile use. They found evidence that variation in fuel prices contributed less to differences in fuel consumption than did physical infrastructure and properties of the built environment generally (e.g. density). Handy (1996) critiques their study, writing that,

> "... average density for a city (besides being hard to measure consistently) is a simple characterization of urban form: average density masks variations in density within the city and masks differences in land-use patterns and design between places with the same density." (Handy, 1996)

While Handy is correct that the distribution of densities within the city can be as important as the city's overall density (Malpezzi, 1999), few if any urban dwellers exist in and experience only a single census tract. On the contrary, most people travel amongst various neighborhoods of different densities. A consumer's fuel consumption is unlikely to occur in a specific neighborhood, but rather across the various neighborhoods of the city. Supporting Newman and Kenworthy, Courtemanche (2011) matched data from the Center for Disease Control's Behavioral Risk Factor Surveillance System (BRFSS) telephone survey and state fuel prices from the Energy Information Administration (EIA) to illustrate how raising fuel prices by one dollar could reduce obesity in the United States by as much as 10 percent over seven years.

Some scholars have argued that fuel prices are related to modal choice, and most agree that increasing costs of fuel should shift commuters towards transit. However, prices also reflect the larger urban economy. For example, high fuel prices also deflate economic activity, which impacts the availability of jobs, and thus, the need to travel (Winston & Maheshri, 2007). As such, prices are on both sides of the equation—a problem for statistical models. So, while fuel prices are good predictor of automobile use, they are also causal in too many other important aspects of urban life to be an adequate proxy for automobile dependency.

Research Using Vehicle Miles Traveled. This variable may be the most common measurement of automobile use in current research. The role of *vehicle miles traveled* (VMT) has been explored for its relationship to a wide range of urban features, such as density, land-use diversity, transit access, neighborhood type and design (Ewing & Cervero, 2010).

Salon (2016) looked at three price levels of the housing market in 12 major U.S. metropolitan areas to ask "within a metropolitan area, is it cheaper to live where you have to drive a lot (even counting the cost of that driving) than it is to live where you don't?" If auto-dependent neighborhoods are more affordable than multimodal neighborhoods, then people will be more likely to choose those car-dependent neighborhoods.

Salon writes that, while it seems that auto-dependent neighborhoods are more expensive, this can easily be explained by housing size. Distance from the central business district (CBD) is correlated with costs per room and VMT. However, this pattern is largely explained by the variation in housing unit size: Housing costs per room drop as one moves away from downtown, while VMT rises. When looking at costs alone, she finds that it is indeed cheaper to live in high VMT neighborhoods, particularly in areas with more affordable housing. Still, if one includes time costs of commuting, then it becomes less clear. Salon provides some evidence that in areas with high home values the result flips, with the upper quartile of households finding it more expensive to live where VMTs are high.

Garceau and colleagues (2013) used a sustainability framework to evaluate the various costs of auto-dependent transportation systems at the state level. They found that those states with higher rates of automobile commuting had higher per capita VMT, emissions and household transportation costs. Furthermore, higher VMTs were associated with more government spending, possibly due to the expense of road maintenance and expansion. These states suffered higher rates of death from car accidents; in fact, the death rate increases super-linearly with VMT.

For Cervero and Murakami (2010), VMT is strongly related to the percent of commuters using a single occupant vehicle (*i.e.* the lack of *multimodality*), which, in turn, is a function of complex relationships between the built environment and social factors such as household income, population density, road and rail density, and job access. Using a structural equation model, they found that the percent of commuters who used a SOV was by far the single most important factor of the total coefficient for VMT, surpassing population density, income, road density, job access and several additional variables.

Still, VMT does not tell us how many people in a geographic unit require a car to maintain an adequate lifestyle. The measurement of VMT includes shopping trips, joy rides, trips to the country and other recreational activities which are all much more elastic than work trips. These types of trips make a much larger percentage of VMT than those that are *required* for work. In 2001, work commutes were only 15 percent of the total number of trips (Brownson, Boehmer, & Luke, 2005). Other limitations of VMT include the confounding effect from carpooling, which can be considerable: VMT statistics frequently contain trips that actually reflect a reduction in per person VMT. VMT does not reflect a regular pattern of travel, nor a common experience of local automobile dependency. Driving does not mean that you are necessarily automobile dependent.

In short, VMT is easy to quantify, and may be a better indicator of automobile dependency than sprawl, density and commute time, but it still reflects too much about all of the various reasons people might travel, and too little about automobile dependency.

Measurements of the Impact of Automobile Dependency

With a few notable exceptions, comparatively little work has been done to directly analyze the relationship between automobile dependency and social outcomes. While the research using proxies of AD is considerably flawed, each study contains within its findings some influence of AD. Therefore, this literature review considers their choice of variables as useful for choosing an appropriate set of variables with which to capture the constructs represented by the four themes.

Economic Impacts of Automobile Dependency. Automobile use has been long assumed to contribute to regional economic flourishing. This is likely rooted in the historical correlation between increased automobile use and economic growth (see, for example, Vasconcellos, 1997). However, this growth has been found to have decreasing benefits (Litman & Laube, 2002), and even costs:

> "Empirical evidence also indicates that excessive automobile dependency reduces economic development. Although automobile use often increases with wealth, there is little evidence that automobile dependency *causes* economic development. Economic growth rates tend to be highest before a region becomes automobile dependent, after which growth rates usually decline." (Litman & Laube, 2002, emphasis in original)

Furthermore, regarding the benefits of different transportation projects (e.g. rail vs. roads), for many economists the question is one of *efficiency*: Which improvements lead to the best economic outcomes with the least investment? In terms of the costs and benefits of a single transportation project, such as a commuter rail expansion, results that monetize qualitative benefits can easily be measured (particularly with arbitrary weightings) to favor more automobile infrastructure versus multimodality.

Cervero (2005) and Litman (2015) remark on the recent shift away from the monetization of benefits, and towards measuring *access*. Measurements of efficiency are unable to capture the presence of equitable distributions of access. Efficiency is a categorically different kind of measurement than are measures of regional economic vitality and equity, whereas access can be more illustrative of these important urban attributes. Litman and Laube (2002) argue that, “Regions with balanced transportation systems appear to be most economically productive and competitive.” It also seems to be the case that, “... total transportation costs decline as transport and land use becomes multi-modal...” They explain this regional affect as a function of average household transportation costs. When costs decline, not only are more people able to participate in the economy, but the resources of already-participating families and individuals are also freed up to be spent on other products and services, increasing local economic activity:

> “An automobile-dependent transportation system maximizes mobility (movement of people and goods), while a balanced transportation system can optimize access (the ability to obtain goods, services and activities).” (Litman & Laube, 2002)

What happens when more people can access the local economy and the urban amenities that improve quality of life? One question we might ask is, which transportation model supports more employment? Litman and Laube linked automobile dependency to lower employment and wages. One observation is that different industries related to transportation provide different local and regional employment opportunities.

Car use supports those economic sectors related to motor vehicle production, sales and service; low-value manufacturing; imports; and geographically-isolated businesses. Industries that are harmed by auto use include sectors related to alternative modes of transportation; high value manufacturing; the communications and information sector; and local production.

In British Columbia, for example, transit infrastructure employs twice as many workers as petroleum and automobile services industries combined, per million dollars of expenditure (Litman, 1999). Due to the internationally-distributed nature of automobile production, fuel manufacturing and distribution, and other related services, the economic benefits of these activities do not add up at the national level: Much of this benefit is carried overseas (Litman, 1999).

Litman (2002) also distinguishes between consumer costs and external costs, writing that automobile dependency creates negative land-use practices. Automobiles require much larger spatial commitments (e.g. three times as much as do “walkable” cities) for roads and parking. This has diverse economic impacts, especially on the supply (and thus, the cost) of land. Since road space requirements vary across cities, those which are dominated by automobile use may reflect property values that have been impacted by an artificial scarcity of land.

This is particularly important for cities, with implications for housing and rental values. We should be careful to judge costs when looking only at housing costs alone: Disaggregating housing costs from transportation costs is misguided. City dwellers do not just occupy and pay for their homes, they also—and always—pay to move about the city. Hamidi and Ewing (2015) found that,

> "…in compact areas, the portion of household income spent on housing was greater but the portion of income spent on transportation was lower. Each 10% increase in a compactness score was associated with a 1.1% increase in housing costs and a 3.5% decrease in transportation costs relative to income." (Hamidi & Ewing, 2015)

So, housing can be expected to be more expensive in cities that have dedicated more space to automobile infrastructure. At the same time, compact city dwellers can be expected to save more money overall, since transportation costs tend to decrease faster than property values rise. Of course, home values reflect demand for these properties as well. This body of literature leaves the relationship between housing and mobility relatively ambiguous.

Equity Impacts of Automobile Dependency. Sustainable urban development is not only concerned with "which" benefits a project might produce (e.g. reduced emissions), but more importantly, "who" benefits. Race and segregation play large, but often ignored, roles in transportation-related outcomes. With notable exceptions, studies looking at the impacts on minorities as a result of living in AD cities are practically absent from the literature. Guiliano (2003) writes that " ... our understanding of travel behavior is largely an understanding of the white majority population, which dominates analysis when race/ethnicity is not explicitly considered." She finds that as many as 1 in 5 African-Americans made *zero* trips in her study; the average trip rate was also lowest for African-Americans.

As with many urban issues, race matters in both transportation mode choice and commute times. Brownson, Boehmer, and Lake (2005) found that:

> "There are important differences in mode choice by race/ethnicity. For example, walking for nonwork-related travel is twice as likely in Blacks (10.6% of person-trips), Asians (10.8%), and Hispanics (9.8%), when

> compared with Whites (5.1%) (54). Also, commute times are higher for minority groups when compared with Whites." (Brownson, Boehmer, and Lake, 2005)

Shen (2000) also found that commute times are usually longer for minorities than for other commuters. The urban spatial structure was more predictive than commute time, resulting in longer trips for "low-income minorities than for other residents of the central city." So, what happens when African-Americans live in multimodal cities?

Research indicates that transportation is connected to social mobility, with auto-dependent sprawl being associated with a lack of upward mobility (Ewing, Hamidi, Grace, & Wei, 2016). Building on the limitations of prior research which used commute times as a proxy for sprawl in simple correlational research, Ewing et al. applied more comprehensive indices of sprawl. Using factor analysis, they found a strong direct effect of sprawl indicating poor job accessibility, which in turn prevents upwards mobility. This factor was stronger than even segregation's indirect effect. These findings leave the researchers to conclude that,

> "…investments in our transportation systems should go beyond functionality and mobility concerns. Transportation infrastructures should be planned as 'enablers'. The imperative is to ensure a sound spatial coordination of land-uses and transportation infrastructures to create an 'enabling' physical environment for low incomes to improve their social and income status. (Ewing et al., 2016)

If segregated and marginalized people live in less-multimodal environments, then that would help explain the cyclic poverty associated with segregation, regardless of some marginally-better access to transit. It also points to a policy route out of this cycle by addressing the lack of access that transportation systems can contribute to intergenerational poverty. On the other hand, of course, sprawl did not explain the lack of mobility for every causal pathway. Thus, again, it is unclear to what extent the level of automobile dependency that is embedded in this sprawl plays in the variation of these outcomes.

To conclude, in contrast to economists, for urban planning academics and planning professionals—not to mention for many residents—the question is broader than economic growth and efficiency as goals unto themselves, but rather how to invest in transportation such that cities maximize environmental and social benefits while not adversely impacting economic activity. Litman (2014) writes, "Within developed countries there is a negative relationship between vehicle travel and economic productivity" and provides evidence that "… per capita economic productivity increases as vehicle travel declines" while "GDP tends to increase with per capita transit travel." Indeed, Kelbaugh (2001) calls automobile dependency "... a large and growing tumor feeding on most regional economies ..."

Health Impacts of Automobile Dependency. Over the past 100 years, the car has become the dominant form of transportation, and has reshaped our cities by contributing to sprawl and creating greater racial and income segregation by neighborhood (Dreier, Mollenkopf, & Swanstrom, 2016; Ewing et al., 2016). While the car had many perceived benefits, its use has generated health problems, anomie, and loss of community, and has also increased pollution and sedentary lifestyles (Doyle, Kelly-Schwartz, Schlossberg, & Stockard, 2006; Putnam, 2000; Sallis, Frank, Saelens, & Kraft, 2004).

Obesity and Health Quality. Overall, while the causal processes are complex, the association between obesity, the built environment, and transportation has been well-established. Indeed, Ewing, et al. (2008) write that:

> "There are many literature reviews focused on the built environment and travel … and on the built environment and physical activity, including walking and bicycling … In fact, the literature is now so vast it has produced two reviews of the many reviews ..." (Ewing, et al, 2008, pg. 155)

Ewing and colleagues have illustrated a significant association between urban form and both physical fitness and related health effects (Ewing & Cervero, 2010; Ewing et al., 2008). They found that, "Those living in sprawling counties were likely to walk less, weigh more, and have greater prevalence of hypertension than those living in compact counties." While this research looks at the relationship between sprawl and health, automobile use itself was not an explanatory factor.

These findings confirmed the work of Frank and colleagues (2006), who identified a correlation between land use and physical fitness. Using data from the 13-county Metro Atlanta region, Frank studied the probability that one would become obese based on density, connectivity, physical activity and mix of land uses (e.g. residential, commercial, office and institutional). Across the board, for age and gender there was a decrease in the likelihood of obesity with incremental increases in the mix of land use. The study recommended strategies to increase land use mix and reduce time spent in cars, stating that,

> "Each additional hour spent in a car per day was associated with a 6% increase in the likelihood of obesity. Conversely, each additional kilometer walked per day was associated with a 4.8% reduction in the likelihood of obesity." (Frank et al., 2006)

Considering studies such as Frumkin (2002) and Ewing, et al. (2008), this research expects to see a positive relationship between transportation multimodality (MM) and obesity. Still, it is important to remember that while there are many studies showing the association between obesity, transportation and the built environment, none have linked obesity directly to automobile dependency, but rather to various proxies which each have unique limitations.

Mental Health. Regarding mental health, Sturm and Cohen (2004) provided evidence that, while sprawl does have health impacts, mental health outcomes are not among them: "Sprawl significantly predicts chronic medical conditions and health-related quality of life, but not mental health disorders" (Sturm & Cohen, 2004). Despite the conventional wisdom that states otherwise, there is scant evidence of a connection between road use and stress. For example, those ticketed for speeding and reckless driving rarely believe their mood or stress was a contributing factor (Boyle, Dienstfrey, & Sothoron, 1998). Indeed, with the ethos around driving such as it is in the United States, car use may overall produce a *calming* effect. Consider such tropes as the "escape" messaging that is commonly advertised—substantive psychological rewards may be embedded in even the most mundane driving trip. More research (and better theory) is needed, particularly research assessing the mental health impacts of different urban forms (Dannenberg et al., 2003).

Pre-mature Death. Physical design affects pedestrian and bicyclist safety, as well as the amount of walking and biking that takes place. Wide roads, as found in many subdivisions in the United States, encourage rapid vehicular travel that diminishes the safety of bikers and walkers. Swift, Painter and Goldstein (1998) found that vehicle speed increases as road width increases. Conversely, a decrease in road width increases the safety of neighborhoods for walk and play. Many roads were designed at 38 feet across, a distance that encourages speed and increases risk. Even with buffers between the street and sidewalk, this platform is not safe for pedestrians.

Beyond the impact of the physical form that facilitates automobile use, automobile use itself has not only been shown to have a negative impact on specific measures of health quality, but also on health in general. Using the measurement of pre-mature death, *Years of Potential Life Lost*, Litman (2003) reports that automobile accidents contributed far more to early death than perinatal complications, suicide, murder or HIV/AIDS. As important as such findings are, a focus on accidents might underrepresent the car's impact; even short-term exposures to automobile emissions such as ozone and particulate matter have been closely linked to acute respiratory illness and poor health of urban inhabitants (Bell, McDermott, Zeger, Samet, & Dominici, 2004; Pope III et al., 2002).

Autos, Environmental Degradation, and Human Health. The actual role of automobile use in contributing to environmental degradation is often subtle and underestimated. For example, the production of automobile–related products, particularly with such items as rubber tires, toxic lubricants, and brake linings, is often left out of the evaluation of automobiles' total social and health costs.

One line of research in this field has illustrated the connection between urban environmental quality, industrial production (e.g. toxic brownfields) and disparities in health outcomes. Gilderbloom and colleagues (2016) studied longitudinal changes over time in premature deaths, and compared them against the environmental dis-amentity represented by brownfields in "Rubbertown," an industrial zone in West Louisville historically dominated by tire manufacturers and petroleum refining. Rubbertown is directly adjacent to a vulnerable residential neighborhood. Controlling for various urban characteristics of the built environment (distance to CBD, etc.) and social variables (crime, demographics, et al.), this study revealed that residents were "... more likely to die prematurely in neighborhoods with EPA brownfield sites." Such environmental hazards have been found to be distributed inequitably within and between cities, with poor people and people of color bearing disproportionate amounts of risk (Brulle & Pellow, 2006; Pastor, Sadd, & Hipp, 2001).

Toxic chemicals from automobile exhaust seep into soil and groundwater, which make their way into peoples' bodies (Hartley, Englande, & Harrington, 1999). Even the routine activity of fueling vehicles exposes people to dangerous chemicals found in gasoline with significant health impacts (Vayghani & Weisel, 1999). While not related directly to automobile dependency, *per se*, these findings illustrate the subtle, diverse and understated impacts that automobiles can have on health outcomes.

Quality of Life

Unlike health and economic issues, quality of life (QoL) is an urban concern that has not been researched in the context of automobile dependency. More often, QoL is linked to spatial variables, which only imply levels of automobile use and dependency. Furthermore, QoL is largely undefined; proxies for QoL are wide-ranging, and include constructs such as "happiness" and "well-being."

Population density is assumed to be more sustainable, *ceteris paribus.* Density is, of course, an insufficient condition for either urban sustainability or human flourishing. On the other hand, economist Ed Glaeser (2011) provides a compelling argument that dense cities help foster happiness. Furthermore, recent research has shown slight correlations between broad measures of SD (which usually include a measure of population density), and indices of human well-being. For example, researchers have attempted to connect happiness in U.S. cities to the presence of sustainable urban development policies and amenities such as utilities, resources, and the built environment (Bieri, 2013; Cloutier, Jambeck, & Scott, 2014; Cloutier, Larson, & Jambeck, 2014).

Cloutier et al. (2014) looked at the MSA-level using four established indices of urban sustainability: The Green City Index, Our Green Cities, Popular Science's U.S. City Rankings and the SustainLane U.S. Green City Rankings. Their dependent variable was the Gallup-Healthways Well-Being Index. Some modest correlations between the sustainability indices and the WBI were uncovered, but the connection is less than conclusive: Two of the indices were correlated, and two were not. Of the two which were correlated, "Our Green Cities Index" focuses on the presence of civic programs for environmental stewardship (a good indicator of the political policy atmosphere in the city—recall Pitt [2010]), while the "Popular Science Index" includes "green living" and "green perceptions" in a limited scope (only four measured categories). The two uncorrelated indices, "SustainLane" and the "Green City Index" (GCI), are more comprehensive, and rely more on objective performance indicators, and less on perceptions of sustainability.

From this work, Cloutier, Jambeck and Scott (2014) developed the "Sustainable Neighborhoods for Happiness Index" (SNHI). This research developed a set of indicators to "assess and compare how well individual cities, towns, neighborhoods and communities embrace sustainable practices and how these practices translate to opportunities for residents to pursue happiness" (ibid.). The variables used to comprise the index are diverse, and include several qualitative assessments of municipal initiatives for SD. Categories of variables include energy management (e.g. electricity consumption per unit GDP/per capita), urban design (e.g. green space, density), buildings (e.g. LEED-certified buildings), transportation (e.g. percent transit users, transit miles), waste management (e.g. percent recycled), water management (e.g. per capita consumption gallons/day, leaks), food management (e.g. farmers markets, community gardens), business and economic development (e.g. green business incubators, farmers markets per 100k pop., LEED per 100k pop.), and governance (e.g. city's green action plan, public participation in green management). A set of variables was drawn from two of the indices in the research above; one was correlated (GCI) to the Gallup-Healthways Well-Being Index (WBI), and one was not correlated (Sustainlane.com).

The overall WBI score contains a wide variety of subsections. Using the aggregated WBI score may mask the importance of subcategories of the index, which might have closer ties to particular manifestations of urban sustainability. Disaggregation seems a better approach: Which aspects of sustainable development have associations with which genres of well-being?

One of these subsections of the WBI is *access*. Public access to amenities, leisure and services, for example, is a critical component to the distribution of quality of life, and plays a role in urban sustainability. The automobile is assumed to maximize access; however, not everyone can or wants to drive a car. Thus, it is no surprise that the spatial compaction of mixed-use neighborhoods has been shown to increase equitable access to services and markets (Williams et al., 2000, pp. 351-352).

The increased practice of sustainable development has been shown to be related to improvements in many aspects of civic well-being (Bieri, 2013). However, the nature of this relationship is broad and vague. Measuring sustainable development is difficult, and research findings are strongly dependent on the definition of sustainability used, and the measurements that the definition derives.

Urban Character

Little research has been done to compare the experience of living in "sustainable" versus "unsustainable" cities. In fact, there is very little theory on the various social atmospheres that cities can project. What does exist tends to focus on the relative availability of green spaces and other environmental amenities, as well as environmental health. Rarely asked is how cities with less automobile dependency foster a different sense of community than do car-reliant cities. While none of these variables alone captures this vague construct of *urban character*, taken together they paint a picture of what it is like to live in the different cities. This research gives an opening exploration of which variables this construct might contain.

Civic Associations. Sociologist Robert Putman has argued convincingly that the automobile-focused land development paradigm—represented by the sprawling suburb—has helped destroy the stock of American social capital, and continues to produce social anomie and disconnection (Putnam, 2000). Central to his argument is the decline in the number of civic organizations: With the rise of the automobile suburb, the extensive network of civic and social groups that once characterized American society have all but disappeared. However, sprawl has many characteristics. What is it about suburban living that harms civic life, if anything?

Commute Times. The length of commute time is an important aspect of urban life, and many cities are notorious for their traffic. It is also likely to be a worsening urban phenomenon (Downs, 2005). Turcotte (2008) found by studying Canadian cities that commute times were rising for both transit users and SOV commuters:

> "From whatever angle the situation is examined (region, transportation mode used, population that does errands versus population that does not), it emerges that workers' average travel time between home and workplace has generally increased since 1992 ... the average duration of the round trip for workers living in the largest cities is longer, on average, than for workers living in smaller communities." (Turcotte, 2008)

The length of the commute is often assumed to be an economic variable, especially when determining the relative value of the commute, or the opportunity costs of switching modality (e.g. from a car commute to, say, a rail commute) (Geurs & Van Wee, 2004; Redmond & Mokhtarian, 2001). Relative *utility* has been central to the quantification of qualitative preferences. For example, long SOV commute times may contribute to mode-switching towards transit and other modalities, while reductions in daily SOV commute times can be worth as much as $30 per travel hour (Brownstone, Ghosh, Golob, Kazimi, & Van Amelsfort, 2003). Nevertheless, measuring what people *do* is not always a good indication of what people *value.*

Furthermore, the increasingly important issues of personal identity, social connectedness, and values—particularly in the context of an evolving urban telecommunications network (*cf.* Graham & Marvin, 2002)—do not lend themselves to quantification (Collins & Chambers, 2005; Johansson, Heldt, & Johansson, 2006). For example, some speculate that young people are moving to multimodal cities because they can use that commute time to be, perhaps ironically, more socially connected (Ben-

Akivai, Bowman, & Gopinath, 1996; van der Waard, Jorritsma, & Immers, 2013). Thus, when determining qualitative differences between commute times and city life in automobile dependent or multimodal cites, an economic approach is less appropriate.

Migrant Age. Much has been made of the Millennial generation and the "return to the city" (Gallagher, 2013; Sakaria & Stehfest, 2013). Younger people have been shown to be drawn to sustainable cities, with a preference for transportation options that supplants a desire for car-ownership (Chapple, 2014; Ellard, 2015). Others suggest that the Great Recession of 2007 has more explanatory value for this phenomenon (Deal, Altman, & Rogelberg, 2010).

In either event, if attracting Millennials and younger generations as migrants is critical to the vitality of cities, then the average age of the new resident becomes an urban sustainability issue. If younger people generally have different tastes regarding the preferred practices of social life than older generations, and if young people are both mobile and socially connected, then where they migrate to can point towards critical issues in valuations of different types of urban character.

Climate. Another fundamental issue tightly woven into the disposition of urban life, particularly with making choices for different transportation modalities, is climate. Different climates produce different built environments, with implications for variation in urban character. For example, many people assume that the weather is a determining factor in mode choice. In contrast, researchers have found that the climate's impact is overstated (Stinson & Bhat, 2004). The Netherlands and Denmark, for example, have harsh winter climates, and yet non-motorized transportation is the dominant urban travel mode. We might expect "sun-belt" cities in the United States to have more people using alternative transportation than “frost-belt” cities in the North. However, the urban form of sun-belt cities leans towards sprawl, supporting car use.

Housing Vacancy Rates. Few factors are as telling about a city’s “character” than the number and percent of vacant buildings. Factors that play a role in housing vacancy rates are extremely complex, including new housing construction rates, demolition, price, income and desirability. The housing crisis of 2008, which left many houses vacant, was in large part due to automobile dependency of the suburbs around large cities. At the same time, denser, more walkable areas in city centers had much lower rates of foreclosure (Dong & Hansz, 2016; Gilderbloom, Riggs, & Meares, 2015).

Sprawl is predicted to be the less-desirable urban form as baby boomers become a smaller proportion of the population, leading to increased housing vacancies in automobile-dependent cities (Pitkin & Myers, 2008). Still, transit-oriented and compact development is not a sufficient condition for a vital housing market. In one case study, the more compact “transit villages” in New Jersey were associated with higher housing vacancy rates than were areas with comparable demographics, whether in low-income or more affluent towns (Renne & Wells, 2003). What role, if any, does AD and multimodality play in the rate of vacancy?

Conclusion: Automobile Dependency from a Sustainability Perspective

While automobile dependency (AD) is often related to certain health and regional economic outcomes, it is rarely conceptualized as a causal factor in other social analyses; rather, it tends to be used as an outcome variable. However, the burgeoning scholarship in sustainability is addressing this by recognizing the importance of AD in determining issues of urban equity (Boone, 2014; Boone & Modarres, 2009; Newman et al., 2009).

How are automobile dependent cities different than multimodal cities? What criteria can be used to make this assessment? How does multimodality and, conversely, automobile dependency impact urban life?

Bhat, Sen, and Eluru (2009) argue that automobile dependence has important, widespread and understated impacts across scale, from the household to the community and region beyond. These impacts are difficult to assess because they manifest differently at scale. Cars tend to increase an individual's access, and yet are expensive for households, increase social stratification for neighborhoods, and limit economic development regionally. The large (albeit limited) scholarship on automobile dependency shows it is generally detrimental to urban outcomes.

Researching the link between automobile dependency and social outcomes from a sustainability perspective is difficult. Defining sustainable development is subjective, and the literature points to a diverse set of indicators between, within and across the "three E's" of sustainable development. Furthermore, researchers often conceptualize automobile use as an outcome variable—a choice to be made from among many modalities, with various trade-offs and externalities. This misses an assessment of the impacts of automobile-focused infrastructure. Thus, while well-studied, it is not at all conclusive the extent of what automobile dependency does, *viz.* how automobile dependency shapes urban life. In the next chapter, I present a methodology that is informed by the literature review regarding the unit of analysis, the measure of automobile dependency and a set of outcomes which reflect concerns in sustainable urban development.

CHAPTER THREE: METHODOLOGY

The work on this dissertation was conceptualized, developed and completed in the Department of Urban and Public Affairs at the University of Louisville between January 2015 and March 2016. The central question of this research asks, "If transportation multimodality represents sustainable urban development, how does multimodality impact urban life?" This concept originated from concern over the inability of current research to connect sustainable development in the built environment to life outcomes. Central to the research approach is the definition of sustainable urban development used in the conceptual framework outlined in the literature review in Chapter Two.

Unit of Analysis

There are tens of thousands of cities in the United States, and they exhibit a great deal of variety in size, population and even purpose (e.g. bedroom communities, central cities). Studying them all would invite innumerable and insurmountable confounds. New York City and Dothan, Alabama, for example, represent such different experiences of urban life that they hardly belong in the same category for nearly any type of analysis.

Furthermore, many modern cities are "embedded" in vast conurbations: It is often hard to decide where the influence of one city's policies ends and the influence of another's begins. Cities in these large urbanized areas typically share resources, job markets and services—particularly those such as public transportation and waste management. The question, then, is which group of cities to study, and at which scale.

Regarding scale, there are a number of reasons to study municipalities instead of metropolitan statistical areas (MSAs), urbanized areas (UZAs), or even counties. As the latter three are aggregations of governments and geographies, nearly as much variation can be found within them as between them. Substantive differences might be more easily identified between central cities than between MSAs. Cities have only one municipal government; MSAs and counties often contain dozens, many in competition with one another for resources and political power. Their governments may also have contradictory policies. Furthermore, regarding the issue of governance, there are very few powerful (i.e. redistributive) MSA-level councils of governments or similar bodies in the United States. Using municipalities as the scale of analysis will point more directly to cities as products of governance, culture and the particular habits of citizens than would a focus at the MSA-level.

Furthermore, cities are not mere aggregations of U.S. Census tracts. While census tracts and blocks are often used to represent neighborhoods, neighborhoods themselves have little to do with census units. Studying cities as organic wholes is consistent with research in sustainability. Unfortunately, the federal government does not gather data for many important measurements at the city level: Due to stipulations in the U.S. Constitution, cities are seen as a state-level concern. The smallest unit of government upon which the federal government collects information is the county. Counties often contain a full range of built environment typologies.

This research is inspired by Appelbaum's classic work in urban sociology, "Size, growth, and U.S. cities" (1978). Whereas Appelbaum was concerned with the relationship between size and growth and indicators of urban outcomes, this study focuses on the relationship between sustainable development and the quality of urban life. Throughout this section references will be made where there are similarities and departures from that study.

The Molotch and Appelbaum Technique

In order to reduce bias when exploring variation among cities, I use a technique to select cities where the relationship between transportation policy and urban outcomes is more clearly identifiable. The technique begins with a well-reviewed pair of decision-rules used in the seminal academic work "Size, growth, and U.S. cities" (Appelbaum, 1978). In this approach, the universe is all U.S. "places" (i.e. municipalities and Census-designated places, or CDPs) defined by the U.S. Census. The decision rule has two simple conditions. First, the urbanized area must contain a "central city with a population of 50,000 or more." There were 792 such cities in the United States in 2013. This selection criteria is coupled with the method of comparing the "best" performing cities to the "worst" performing, as found in one of the most cited works in the field of urban affairs, "The city as a growth machine" (Molotch, 1976).

Appelbaum limited his sample to cities with populations under 400,000 (Appelbaum, 1978, pg. 12). He was criticized for this limit. This work will consider this and other critiques. For example, there does not seem to be any explicit reason for an upward limit, and so in this work there is none. Toledo, Ohio was the largest city in Appelbaum's analysis, ranked 34th nationally in 1978. In this work, Jacksonville, Florida is the largest at 836,087, and was the 12th largest city in the United States in 2013. This work includes four other cities with populations above 400,000: Columbus, Ohio; El Paso, Texas; Louisville, Kentucky; and Colorado Springs, Colorado.

This work includes an additional decision rule at this stage: the presence of an elected government at the metropolitan level. This rule excludes the majority of "Census-designated places" (CDPs) from the study, as they are merely populated areas within a county. There are 69 such "cities" included among the 792. The main purpose of the "Appelbaum strategy" for identifying a population to study is to remove uncertainty so processes and relationships can be better understood. Including a subset of cities that have minimal governing structures (such as CDPs) might introduce another source of error. Two exceptions to this rule are the Town of Tom's River, New Jersey, and the City of Honolulu, Hawaii. These are a special case of CDP in that they have an elected mayor. For this reason, they are included in the dataset.

Appelbaum's second rule is that the central city must be "…at least 20 miles from the nearest central city of 50,000 or more" (Gilderbloom & Appelbaum, 1987). This reduces the number of cities under study from 792 to 148; a considerably larger number than the 115 cities comprising Appelbaum's early work. As was the case in Appelbaum's study, this 148 should be considered as "not simply a sample; they constitute all such places in the [continental] United States" (Appelbaum, 1978, pg. 13). In short, the relatively isolated and independent U.S. city with a population of over 50,000 is the basic unit of analysis.

Roughly half of the cities that fit the decision rules for Appelbaum's work remain on the list, while half of the current cities are new to the list. Appelbaum reported that, in 1970, 26.8 percent of all Americans lived in the metropolitan areas of his cities, with an additional 15.6 percent living in the nation's largest cities, and the remainder (about half) living in towns with less than 50,000 population, and in rural areas. Comparatively, fewer than 20 million people live in the 148 cities included in this dataset, which is a relatively small proportion of the U.S. total population, at around 6.25 percent. On the other hand, over 38 million people live in the counties that house these cities' central business districts. Over 78 million people live in the metropolitan statistical areas (MSAs) of which these cities are the core. This represented about 25 percent of the total U.S. population in 2013.

Over 300 of the 792 U.S. cities with a population over 50,000 share county-level data: There is typically very little continuity between municipal and county boundaries. While most cities with over 50,000 people are contained within a single county, nearly all large cities (with populations of over 250,000) span across two or more counties. Some span across four counties, or even five (i.e. New York City and Dallas, Texas). This makes aggregating county-level data for the largest municipalities extremely problematic.

In this work, because of the distance rule, each city is generally associated with a single county. In comparison to the other 644 U.S. cities with populations over 50,000, only 22 cities of the 148 in the dataset stretch beyond a single county. Only one county encompasses the downtown CBD in any of the 148 cities. Only a few cities in this study contain territory in a second or third county (e.g. St. Cloud, Minnesota would be the best example). Also, there are only two cases in the dataset where two cities share the same county: Bakersfield and Delano in Kern County, California, and Santa Barbara and Santa Maria in Santa Barbara County, California. Five cities stretch into three counties, and one is spread over four counties (Corpus Christi, Texas).

In this research, when a city spans more than a single county, the primary county is considered the one that contains the downtown CBD. A visual inspection confirms that only a tiny fraction of these second counties overlaps municipal territory. In nearly every case, it is clear that the municipality annexed some distant and uninhabited territory which contains some resource, such as a reservoir or an airport. In short, using the modified Molotch and Appelbaum method, isolated cities' county-level and MSA-level data adheres to the central city far more closely than it does in most comparable studies.

Mapping Green and Brown Cities

To identify the spatial distribution of the cities, Moran's I was calculated in ArcGIS. The 148 cities in the study are *randomly* dispersed around the United States (see Map 3.1). They are neither "clustered" geographically, nor "evenly" distributed.

The media, public and even academic researchers tend to focus on familiar or well-known cities; e.g. the "50 largest U.S. cities," "global cities" and other similar samples. Since the cities in this dataset are less recognizable, I provide the names of those cities in the descriptive statistics that are extreme examples of either end of the spectrum in the distribution, along with those cities that characterize the mean value. This is done to provide readers with a sense of how these variables play out in concrete terms.

Data Collection Methods

Another departure from Appelbaum's work is in the vastly different context of data availability. In the mid-1970s data gathering was considerably more difficult than it is today, so it is admirable that Appelbaum used 18 dependent variables grouped into four different themes, and analyzed them according to nine test variables. The increased availability of data in the early 21st century has allowed this research to expand into a number of directions. This, of course, does not mean that ideal data is available for every interesting construct.

Furthermore, as in all research with an interest in maintaining a comprehensible focus, many areas of interest are left unanalyzed. Variables were chosen from extant literature according to importance, relevance and the availability of adequate data, and then balanced against comprehensiveness. As such, this work employs 46 DVs grouped into four themes, which are controlled along seven independent variables, including the key test variable, multimodality.

Measuring Sustainable Urban Development: "Why Multimodality?"

Unfortunately, there are few excellent measurements of the sustainability of urban built environments. Population density is frequently used as a measurement of urban sustainability, because higher density implies lower per person carbon footprints and other sustainability benefits. Population density also assumes a lot about variation in the use of key built environment structures (e.g. mobility, housing):.Are people using the structures less in sustainable cities, or are the structures more efficient? Measuring outputs such as carbon emissions—while excellent environmental measures—suffer the same ambiguity as population density for determining the sustainability of urban structures.

One fundamental aspect of the built environment is how people move through it, with enormous implications for the disposition of urban life. Given the deliberate structuring of the urban form to accommodate the automobile as the primary mode of transportation in modern U.S. cities, and given the proven impacts of the automobile on human and environmental health and cities' economic reliance on the automobile, variations in the use of the automobile for daily work commuting among U.S. cities is an adequate and defensible measure of sustainable urban development. While no single metric can capture the sustainability of urban transportation, how workers get to work does capture the daily experience of most city inhabitants, and strongly influences non-work travel as well. Taking a cue from Cervero and Murakami (2010), this research takes the inverse of the percentage of workers who use some mode of travel other than the single-occupant vehicle (SOV) commute (i.e. multimodality), and presents it as an independent variable.

Multimodality is a U.S. Census measurement of the percent of workers who use some means of transportation other than the SOV commute. The means of transportation to work describes the main travel mode that a worker uses to get from home to work.

Urban indicators should be *integrating*, *forward-looking*, *distributional* and developed by *multiple stakeholders* (Maclaren, 1996). Because automobile use impacts so many aspects of urban life, it is *integrating*. In addition, “mode-switching” (viz. the shift from SOV commuting to some other mode) are easily measured across time, so multimodality can be considered (although not in this work) as *forward-looking*. This research suggests that multimodality is a *distributional* indicator; that is, it helps explain intragenerational differences in social outcomes. Also, any useful metric should consist of reliable data that is widely available. Multimodality fits this description. For all of these reasons, multimodality is a deemed to be an outstanding measurement of urban sustainability. One minor caveat is that MacLaren (1996) also suggests that sustainability indicators be developed by *multiple* stakeholders. As multimodality is a U.S. Census-derived measurement, it cannot be said to have emerged as the result of some community consensus.

Connecting Impacts: Why Four Themes?

Having identified an appropriate set of cities, and a measurement of sustainable urban development, it can now be asked which outcomes can be studied. While there are innumerable ways to evaluate urban life, and while this research is concerned with the range of sustainable development's impacts, social research should be narrow enough to be coherent. The four hypotheses are propositions, which consider the relationship between sustainable development and broad but consistent themes in urban life:

- Health Outcomes
- Economic Conditions
- Urban Character
- Quality of Life

These themes represent complex sociological concerns that cannot be adequately measured using a single metric. Some urban processes will reveal relationships with sustainable development more clearly than others, while some will not be identifiable at all. Therefore, the themes are assembled using a range of elements that, when used together, approximate the constructs identified in the hypotheses. The elements which comprise the themes are tested individually; the results are then used together to assess the truth condition of each hypothesis, and estimate the scope of sustainable development's impact on each theme.

Model Selection

The central purpose of this section is to understand the measurements with which the cities will be analyzed. The central test variable in the regression models is the *percentage of commuters using alternative transportation*, or "multimodality" (MM). Six traditional control variables are used in the regression analyses: latitude, density, population, median household income, percent population African-American, and the percent population with bachelor's degrees or higher.

While city land size in square miles may be a useful control, it is used only for descriptive purposes in this study. Its use as a control would create issues of multicollinearity and redundancy when used along with population and density. Population and density seem to be more suitable controls than size when investigating social outcomes. It is assumed that these six control variables comprise an adequate model allowing for observing multimodality's relationships with diverse urban concerns.

Data Used

For many of the dependent variables in this study, measurement occurs at the level of "place" gathered by the U.S. Census. In some cases (e.g. health), data is gathered at the county level, and in a few cases (e.g. quality of life surveys), it was gathered at the level of the MSA. As discussed above, the nature of the isolated city makes these cross-scale proxies less problematic than in the general universe of American cities. Unless otherwise stated, all U.S. Census data is derived from 3-year estimates published in 2013; 3-year data is used as a compromise between the timeliness of the 1-year estimates and the accuracy of the 5-year estimates. Other data sources are gathered from a wide range of public, non-profit, and private courses (see Table 3.1). Due to the wide variety and number of sources used, each source is explained in further detail in a later section where necessary. Geo-coded place identifiers are used to link data from the various sources. Since not all constructs are measured at the level of place, measurements at the county and MSA level are inevitable.

Concerning the idea of *instrumentation* in research, U.S. Census data is fundamentally survey data. Issues around the use of survey data are beyond the scope of this research, and it is assumed that—despite limitations—such data can be used to provide insights into the objective state of the world. Because of the wide variety of data sources used in this work beyond Census data, additional issues of instrumental limitations are covered individually below.

Variables

When necessary, brief descriptions of the variables' instrumentation are provided, including details of the data sources, how the variable is calculated, and some elaboration on the intended construct to be measured. Most of the variables attempt to capture the constructs identified in the literature review. While a few are new, nearly all of them have been used in scholarly research on either automobile dependency or sustainable urban development. The 53 variables used in this study are summarized in Table 3.1. The table reports on four basic characteristics: the years represented; the unit of measurement; the data source; and the geographic scale of the measurement.

Key Test Variable: Multimodality. Rooted in changes beginning nearly 100 years ago, the modern paradigm in the United States for getting to work is single occupant car commuter, and this has been the case for over 50 years (Kunstler, 1994). Alternative modes of transportation include carpooling, bicycling, walking, cabs and mass transit, including trains, buses and trolleys, and finally, working from home. It is not that all of the different modes of travel in multimodality are so similar that we can categorize them as one, but rather that the structural nature of their opposite, the paradigm of urban travel (the single-occupant automobile commute), is so monolithic.

The data is found on U.S. Census file DP03; the variable is calculated when the percent of people who use a single-occupant car to get to work is subtracted from 100. The percentage of alternative commuters ranges from 10 percent in Dothan, Alabama, to nearly half of all commuters in Pittsburgh, Pennsylvania. The median value of MM in this dataset is 20.7 percent. The mean of 22 percent is found in such cities as Eau Claire, Wisconsin and Bowling Green, Kentucky.

Control Variables. This research uses control variables commonly found in urban sociological and geographical research. The choice of seven independent variables allows for a robust ratio of about 20:1 between cases and variables in regression analyses.

Latitude. This variable is used as a proxy for Northern ("frost belt") and Southern ("sun belt") states' development patterns, as well as a proxy for climate. Due to its relationship to energy consumption, climate is a central concern in sustainability science. Geography has also been shown to be a significant explanatory factor in urban processes and policies. For example, Southern cities have been shown to be qualitatively different from Northern cities along a variety of factors, including housing (Ambrosius, Gilderbloom, & Hanka, 2010).

We should recognize that the difference between Northern and Southern cities on the West coast is of a different type than the difference between cities on the East coast. Unfortunately, the introduction of a variable for longitude would be an additional control, and one lacking strong theoretical support. Latitude captures both climatic and geographical concerns to a sufficient degree. While a dummy variable that focused on geographic regions could be used, this would necessitate the addition of another variable for climate.

The climate is generally cooler as latitude increases, regardless of longitude. However, most measures of climate are subjective, with different weightings for rain vs. snow and types of storms, and it can be difficult to capture the combination of frequency *and* amount of precipitation. Latitude, on the other hand, is objective. The data is gathered from U.S. Census File G001. There are two outliers, one at either end of the distribution: Honolulu, Hawaii (South), and Anchorage, Alaska (North). Louisville, Kentucky is the city closest to the mean latitude.

Population. Population shapes innumerable urban processes, although they may not all be linear relationships related to economies (and diseconomies) of scale. In any event, large cities are assumed to be substantively different from small cities. The data for this common control variable is found on U.S. Census file B01003. The average city population size in this study is approximately 135,000, and is represented by cities such as Columbia, South Carolina and Clarksville, Tennessee. The range is between 50,002 (Grand Island, Nebraska) and 836,000 (Jacksonville, Florida).

Density. Density has been used as a proxy for urban form, and as an explanatory variable in countless studies. Dense cities have come to epitomize the urban experience, while low-density cities have become associated with suburbs and sprawl. These "isolated cities" range from the geographically vast Anchorage, Alaska to the small, denser Reading, Pennsylvania. Pensacola, Florida and Bend, Oregon are closest to the mean density. This value was taken from 2010 U.S. Census File G001.

Median Household Income. Different levels of wealth tend to imply different levels of services and amenities, and thus have been used to explain many types of differences in the quality and character of cities. The cities closest to the average household income for the dataset are Sioux City, Iowa, and Jonesboro, Arkansas. Youngstown, Ohio is the lowest on this metric, while Anchorage, Alaska is the highest. Data is taken from U.S. Census Table DP03.

Percent Population African-American. Differences in the proportion of minority populations have been used explain differences in cities, and African-Americans have come to epitomize this difference in the urban experience. The percent population of Black Americans in these “isolated cities” ranges from less than 1 percent in Idaho Falls, Idaho, to about 81 percent in Jackson, Mississippi. The mean of 17 percent is slightly higher than the national proportion of 13 percent, and is represented by cities such as Waterloo, Iowa, and Knoxville, Tennessee. Data is taken from U.S. Census Table DP05.

Percent College Educated. Differences in the proportion of a population with a college education have been used to explain differences in a wide range of urban processes. A great deal of research and theory revolves around the important role that the (mostly) educated creative class plays in the modern urban economy (Florida, 2005; Florida, Mellander, & Stolarick, 2008).

In this study, the average percent of the population with a bachelor’s degree or higher is about one third, and close to the national average, which recently passed 30 percent for the first time in 2012. The lowest percentage is 7 percent in Delano, California, while the highest percent was found in the college town of Ann Arbor, Michigan. Data is taken from U.S. Census Table DP02.

Theme – Urban Character. What is it like to live in a particular city? What makes a city distinctive? While there is no single variable that measures such a qualitative construct, it is hoped that the following variables, when taken together, will sketch out some intersections of automobile dependency and cities' affect.

Land Size, square miles. This variable is used purely for descriptive and correlational purposes. It is useful for recognizing basic differences in types of urban form, but is not an appropriate dependent variable in this research. More appropriate would be using land size as an explanatory variable for differences in levels of multimodality. The largest city, by far, is Anchorage, Alaska, which has annexed vast stretches of untouched land. The smallest footprint belongs to dense Lancaster, Pennsylvania. Examples of mid-range cities include Jonesboro, Arkansas, and Toledo, Ohio. Data is taken from 2010 U.S. Census File G001.

Sperling's Climate. Sperling's Best Places collects and aggregates data on a broad range of categories for urban life by analyzing dozens of variables in over 400 metropolitan areas. Data is gathered from scores of different public and private sector sources. Sperling's partners with hundreds of corporations and academic researchers to publish industry analyses and livability studies. Cities are scored from a low of 0 to a high of 100. Six of their rankings are used in this study to estimate areas of interest for which single source metrics are difficult to find. For the same reasons as geographic size, climate is inappropriate as a dependent variable for regression analysis when multimodality is an explanatory variable. Therefore, it is used only in descriptive and correlational analyses. Sperling's calculates the climate score by using average temperature, altitude, precipitation, hazards and other factors such as comfort (e.g. humidity, sunshine).

WalkScore. This variable has been used in a number of recent studies by leading academics to measure foot transportation. WalkScore measures pedestrian access by using population density and other characteristics of the built environment like block length, number and types of third-space destinations, and intersection density through a scoring of 1 (least walkable) to 100 (most walkable). Data is gathered from Google, Open Street Map, the U.S. Census and a participatory element similar to Wikipedia. Recent grants from the Rockefeller Foundation and the Robert Wood Johnson Foundation have been used to increase their algorithm's validity. The data is gathered by entering the city names one at a time on the WalkScore website, and collecting them on a spreadsheet for importation into the main dataset. The most walkable city in this study is Lancaster, Pennsylvania (80), while the least walkable is Lake Havasu City, Arizona (15). The average walkability is 36, represented by cities like Santa Fe, New Mexico and Youngstown, Ohio.

Median Age of New Residents. The age of new residents will be considered a measure of urban vitality and demand. Young people characterize vigor and creativity. They are also the most mobile group of American adults. The city with the lowest median age of new residents is Harrisonburg, Virginia, while the oldest new residents moved to Lake Havasu City, Arizona. In the middle are cities such as Duluth, Minnesota and Peoria, Illinois. Data for this variable is found on U.S. Census Table S0701.

Mean Commute Time. Long commute times represent lost production from time spent in traffic, as well as the increased production of greenhouse gases and other pollutants. The data for the commute time variable are found on U.S. Census Table S0804. Four cities provided no data. Due to the nature of isolated cities, cities in this dataset have a lower percentage of "mega commuters" (viz. those who spend over an hour in transit) than do the largest U.S. metros, and also have a considerably shorter average commute than the national average of 26 minutes. The longest average commute for all commuters is found in Pittsburgh, Pennsylvania, at just over a half an hour, while the shortest is in Grand Forks, North Dakota, at 15 minutes. In the middle are cities such as Green Bay, Wisconsin and Toledo, Ohio (22 minutes).

Single Occupant Vehicle Commute Time. These commuters represent the bulk of all commutes. At just over 15 minutes, Pocatello, Idaho has the shortest car commute of all 148 cities, while Pittsburgh, Pennsylvania again has the longest at 31 minutes. In the middle are the cities of Green Bay, Wisconsin and Wilmington, North Carolina.

Transit User Commute Time. Bowling Green, Kentucky has the shortest average transit commute at a quick 13 minutes, whereas Idaho Falls, Idaho is well over an hour. The average transit commute time is considerably higher (12 minutes) than single occupant auto commutes: Las Cruces, New Mexico and Corpus Christi, Texas are close to this long 36-minute average. Interesting to note is that the standard deviation for the average commute and the mean auto commute are quite narrow at less than three minutes, while at about 11 minutes, the variation in transit commutes is about four times as large. This shows a strong similarity in car commutes across cities, and simultaneously, great diversity in cities' transit efficiency.

Percent Single, Detached Homes. Differences in the deployment of housing are critical, even central to the character of cities. Housing data used in this research can be found on U.S. Census Tables CP04, DP04, and B25071. The city with the largest percentage of single detached homes is suburban Tom's River, New Jersey (about four in five), while the lowest percentage is Reading, Pennsylvania (about one in 10). Cities near the mean are Lafayette, Indiana, and Baton Rouge, Louisiana.

Percent Rental Properties. The proportion of properties which are available for rent impacts the urban character. The city with the smallest proportion of rental properties is again Tom's River, New Jersey, and the highest proportion is found in the college town of Bloomington, Indiana. The average is about 47 percent, and can be found in cities such as St. Cloud, Minnesota and Akron, Ohio.

Owner and Rental Vacancy Rates. While under-utilized housing is a concern for sustainable development, these variables are also commonly used as measures of socioeconomic health and urban vitality. The lowest owner vacancies are found in Rochester, Minnesota (under 1 percent), and the highest are in Youngstown, Ohio (8.8 percent). The average owner vacancy rate for these cities is 2.5 percent, and can be found in cities such as Toledo, Ohio and Amarillo, Texas. The lowest rental vacancy rate (under 1 percent) is found in Ames, Iowa, with the highest found in Gulfport, Mississippi (15.7 percent). The cities of Redding, California and Montgomery, Alabama have rental vacancy rates near the average of 6.9 percent.

Theme—Economy: Costs. Due to the number and diversity of economic measurements used in this research, I distinguish between those which can be easily thought of as costs, and as income.

Percent Overspending, Renters and Owners. These variables represent the percent of population who spends over 30 percent of their income on housing. The city with the lowest proportion of "over-spenders" is Flint, Michigan (29 percent), while the highest proportion can be found in Bismarck, North Dakota (63 percent). The mean proportion (46 percent) is found in places such as Grand Junction, Colorado and Springfield, Missouri. The data for these variables are calculated from data found on Table CP04 of the U.S. Census.

Tenure Gap. This increasingly-explored variable in housing studies reflects the difference in the percent of income spent on housing between owners and renters. The lowest tenure gap is found in Flint, Michigan where—like 14 other cities in the study—there are actually more affordable rents than mortgages when measured as a percent of income. Thus, Flint's score is negative (-52 percent). The highest gap is in Bismarck, North Dakota, where it is 73 percent. Average scores (30 percent) are found in Roanoke, Virginia, and Chattanooga, Tennessee.

While this construct can been measured in different ways, here it is generated by dividing the percent of renters who overspend by the percent of owners who overspend and subtracting from 1. In Bismarck, North Dakota, for example, 62.9 percent of renters spend over 30 percent of their income on housing, while only 16.9 percent of owners spend over 30 percent. Dividing the latter by the former results in .26, that is, the number of "owner over-spenders" is only 26 percent of the number "rental over-spenders."

Subtracting this number from 1 gives a percentage, allowing for the expression of a tenure gap.

Median Home Value and Median Rent. These figures are often used as proxies for the relative wealth of cities, and the demand for property. Desirable cities have both high rents and high home values. The lowest home values are found in Flint, Michigan and the highest are located in Santa Barbara, California. The mean home value is represented by cities such as Charleston, West Virginia, and Greenville, North Carolina. The lowest median rents are found in Youngstown, Ohio, while the highest are again in Santa Barbara, California. Average rents are found in Augusta, Georgia and Rochester, Minnesota.

Median Rent as Percent of Income. This variable measures the relationship between income and rental costs. This can be used as a proxy for disposable income, and can have an important impact on the wealth and vitality of the city. The lowest ratio is in Bismarck, North Dakota (23 percent), and the highest is in Flint, Michigan (46 percent). The mean is just over the federal guideline of 30 percent, and is found in towns like Portland, Maine, and Rockford, Illinois.

Sperling's Cost of Living. This variable is calculated by considering data on taxes, housing and "necessities" like health care, utilities and food costs. The city of Salinas, California reaped a zero on this metric, while Casper, Wyoming scored highest. Pueblo, Colorado and Rocky Mount, North Carolina were close to the average.

Theme—Economy: Income.

Long Term Median Unemployment. Unemployment is used as a proxy of urban vitality and economic health. This variable is calculated from county-level data provided by the Bureau of Labor Statistics. I wanted a measure of the cities' performance under the best of conditions. In order to remove geographical, industrial and other effects, I used data from the years 1990, 1995, 2000, and 2005. These years help locate the best guess of the lowest unemployment a community had to offer since the 1980s: In these years the national unemployment in the four years chosen is relatively low in comparison to neighboring years. For example, this selection minimizes the influence of the economic shock and restructuring after September, 11, 2001, and the Savings and Loan Crisis and recession in the early 1990s. National unemployment was high from 1991 to 1994, from 2001 to 2004, and from 2008 to 2013. Unemployment in 1990 was fairly high still; it provides a fourth data point with which to develop an average. Going too far in to the past (i.e. beyond the 1990s) would introduce employment levels that fewer residents experienced. Furthermore, after 2006, revisions to the survey complicate comparison to earlier years.

In short, isolating the analysis to those four years between 1989 and 2006 reflects the strongest example of the national economy, thus giving the cities the best opportunity to reveal their contribution to that condition. Including the three major national economic downturns, each of which occurred for different reasons, and unevenly across different geographies, would introduce additional uncertainties into the analysis. The results conform to intuition: the lowest performing city is Yuma, Arizona, and the best performing is Madison, Wisconsin. Cities near the average include Akron, Ohio and Lawton, Oklahoma.

State Minimum Wage. This variable is derived from Department of Labor data on State minimum wages (visit http://www.dol.gov/whd/state/stateMinWageHis.htm). The state's minimum wages are calculated as a percent above the federal wage. It is then converted to a z-score and summed for the years 2006 through 2013. States with minimum wages below the federal level, split minimums, or those without a minimum wage are set at the federal minimum. This was done to avoid penalizing economies having a larger portion of their labor force not covered by federal minimum wage law; those jobs are generally few, and do not accurately characterize the entire workforce. As expected, the highest performing states are Oregon and Washington, which together contain five cities. An additional 80 cities are in states that have had at least some percentage above the federal minimum wage since 2006. The remaining 63 cities were located in states that shared the lowest score possible.

State and Local Tax Burden. This variable is obtained from the Tax Foundation's 2011 data (visit http://taxfoundation.org/article/state-and-local-tax-burdens-all-states-one-year-1977-2011). The data represents the total amount of state and local taxes collected by state residents compared to the total state tax income gathered from property, income, sales and other taxes, including taxes paid to other states. It is used here as a measure of citizen funding of government. Again, the results conform to expectations: The lowest "burdened" cities were the two located in the State of Wyoming, while the highest burdened cities were the three located in New York State. The average burdened cities were those five located in the State of Iowa.

Median African-American Household Income. This variable uses data from U.S. Census Table B19013B. The highest performing city is Laredo, Texas, while the lowest performing city is Eau Claire, Wisconsin. Black household incomes closest to the mean are found in the cities of Pensacola, Florida and Lincoln, Nebraska. Eleven cities provided no data.

Percent Population in Poverty. Increasing proportions of poor residents means both greater strains on social services and fewer resources for civic improvements. Affluent Tom's River, New Jersey has the lowest proportion of citizens in poverty, whereas Flint, Michigan has the highest. In the middle are cities such as Medford, Oregon, and Columbus, Ohio. The data can be found on U.S. Census Table B14006.

Sperling's Economy and Jobs. This variable is calculated at the MSA-level by combining data on per capita income, employment and other variables gathered from the U.S. Census, the Bureau of Labor Statistics, and private sources such as Claritas, Inc. According to Sperling's, Yakima, Washington and Salinas, California scored poorest on economy and jobs, while St. George, Utah scored the best. Waterloo, Iowa and Lancaster, Pennsylvania scored near the median.

Theme—Quality of Life. Comprehensive measures of quality of life are difficult to find even for large municipalities, much less medium-size cities. Thus, this study uses two groups of variables that are measured at the scale of the metropolitan statistical area (MSA). Five of the MSAs in this study are missing from Sperling's Cities Ranked and Rated (*n*=143), while data from the Gallup/Healthways Well-Being Index is only available for 68 of the MSAs. While this sample size of isolated cities is low, it is a sufficient sample size for a complimentary analysis.

The Gallup/Healthways' Well-Being Index (WBI) offers a good compliment to the Sperling's data for two reasons. First, unlike Sperling's, which calculates the presence of amenities and other items associated with well-being, the WBI is survey data, which has been continuously gathered by Gallup by polling over 500 Americans per day, excluding holidays, since 2008. About 2 million surveys have been completed nationwide by both landlines and cellphones. The organization only publishes new data on MSAs where a sufficient number of surveys have been completed.

The second reason the WBI is a good compliment is that instead of being independently *scored* like the Sperling's data, MSAs are comparatively *ranked* from 1 (best performing) to over 300 (worst performing). This makes use of an additional methodology. In order to maintain a consistent directionality with other data, ranks were multiplied by -1.

Sperling's Overall. Sperling's calculates this by considering the scores of several metrics, including some not represented in this study, such as crime, climate, health care and public education. Yuba City, California scored the lowest of the 148 on this metric, whereas Gainesville, Florida scored highest. Mid-range cities included Ames, Iowa and Pensacola, Florida.

Sperling's Leisure. This variable is calculated by considering data on dining, shopping, outdoor recreation, professional sports, parks, coastline and attractions like aquariums and zoos. Frederick, Maryland scored best on leisure, and St. Joseph, Missouri and Jackson, Mississippi tied for the lowest score. Erie, Pennsylvania and Fort Wayne, Indiana were close to the mean score.

Sperling's Quality of Life. This comparatively subjective variable is calculated by considering a diversity of data on the physical attractiveness of cities, their civic heritage, and reported stress levels. While hard to operationalize, the results conform to intuition: Several cities sit close to the mean score, including Louisville, Kentucky and Rochester, New York. Yuma, Arizona and Albany, Georgia rank lowest, while Santa Barbara, California and Madison, Wisconsin share the top spot with three other cities.

Sperling's Arts and Culture. This variable is calculated by considering data on museums, performing arts, libraries and listener-supported radio. Laredo, Texas scored a zero on this metric along with a few other cities, such as Yuba City, California. At the other end of the spectrum are Pittsburgh, Pennsylvania and Frederick, Maryland. The cities of Flagstaff, Arizona and St. Cloud, Minnesota can be found near the middle of this metric.

Gallup/Healthways' Overall. The G/H WBI generates this score by combining the scores for all of their subcategories—including many not being analyzed by the model (e.g. crime). The best performing MSA contained the City of Honolulu, Hawaii, while the worst performing contained Charleston, West Virginia. Average MSAs included Pittsburgh, Pennsylvania and Canton, Ohio.

Gallup/Healthways' Life Evaluation. This section of the survey attempts to capture residents' perspective on their "... present life situation and anticipated life situation." The highest reporting city is Ann Arbor, Michigan, and the lowest is a tie between Cheyenne and Casper, Wyoming. Average examples included Erie, Pennsylvania, and Tom's River, New Jersey.

Gallup/Healthways' Work Environment. This variable is described as "... job satisfaction and workplace interactions." Lincoln, Nebraska enjoyed the best reports along this metric, while Fayetteville, North Carolina residents reported the lowest score. Springfield, Missouri, and Conway, Arkansas typify average towns.

Gallup/Healthways' Basic Access. This variable measures reports of "... feeling safe, satisfied, and optimistic within a community." Madison, Wisconsin again ranked highest, with Bakersfield and Delano, California tied for the bottom spot. Average MSAs include the towns of Evansville, Indiana, and Greenville, South Carolina.

Theme—Health: Environmental Health. Like the diversity of economic variables, there are a number of ways to evaluate environmental health, including air, water and soil quality. Airborne emissions are strongly correlated to automobile use, and tend to be the most noticeable. While proximity and concentration of airborne emissions are measurable concerns, unlike brownfields and water quality that disproportionately affect particular neighborhoods within cities, air tends to be more evenly distributed across large geological features such as river valleys.

Airborne Emissions. This data is gathered at the county level by the Environmental Protection Agency, which was last updated in 2011. The EPA provides data on a wide range of emissions, such as volatile organic compounds. In this study "Total Emissions" only includes particulate matter at the 10-micron and 2.5-micron size, and sulfur oxides, nitrogen oxides and carbon monoxide. These were chosen for their relationship to transportation. Emissions are presented in three ways: as total weight in tons, in tons per square mile, and in tons per capita.

In addition to automobile use, particulate matter is also generated in dry, dusty environments, and in areas with high amounts of construction. Particulate matter is much heavier than the gaseous emissions. This helps explain how cities with the highest total emissions are the dry, Western cities of Flagstaff, Arizona and Bakersfield, California. The lowest are the independent cities of the relatively verdant and humid State of Virginia. Tom's River, New Jersey and Manchester, New Hampshire have the lowest levels of NO_x per capita, while Duluth, Minnesota and Lake Charles, Louisiana are at the other end of the spectrum. Average per capita emissions of this type are found in St. Cloud, Minnesota and Louisville, Kentucky. The lowest per capita carbon monoxide emissions are found in Tom's River, New Jersey, and the highest are in Flagstaff, Arizona. Average per capita town emissions are exemplified by St. George, Utah, and Pueblo, Colorado.

Theme—Health: Human Health. The following three variables are acquired through County Health Ranks and Roadmaps, which gathers county-level information from a wide range of respected and validated sources such as the Centers for Disease Control and Prevention. The most recent publication of these data was in 2015. However, the data is collected by the gathering agencies at various times, and is noted in each instance.

Years of Potential Life Lost, per 100,000 population. This variable is a measure of premature death, and is acquired from the National Center for Health Statistics Mortality files from the years 2010-2012. The reference age from which the years are considered prematurely lost is 75 years old. Higher years of life lost reflect less attainment of life expectancy. The top-performing county with the lowest years of potential life lost contains Ames, Iowa, and the worst includes Augusta, Georgia. Counties near the mean include the cities of Canton and Akron, Ohio.

Percent Population Below Average Health. This data is acquired from the Behavioral Risk Factor Surveillance System for the years 2006-2012. It measures the age-adjusted reports of survey respondents who consider themselves to be in below average health. The lowest percentage of the population with poor health is reported in Rochester, Minnesota, and the highest percentages of reported poor health are in El Paso and Laredo, Texas. Counties near the mean include Lafayette, Indiana and Redding, California.

Percent Population Obese. Data for this variable is gathered from the Center for Disease Control and Prevention's Diabetes Interactive Atlas for the year 2011, and includes adults who report a BMI of 30 or more. The lowest percentage of such adults is found in Santa Fe, New Mexico, and the highest is in Saginaw, Michigan. Average counties along this measure contained the towns of Bowling Green, Kentucky and Knoxville, Tennessee.

Gallup/Healthways's Emotional Health. The WBI website states that these survey questions capture the constructs of "... daily feelings and mental state." The best-ranked city along this metric is again Ann Arbor, Michigan, and the worst is another tie between Casper and Cheyenne, Wyoming. Cities near the mean include Asheville, North Carolina, and Columbus, Ohio.

Gallup/Healthways's Physical Health. The WBI describes this variable as the "... physical ability to live a full life." Madison, Wisconsin takes top place for self-reported physical health. The two cities of Wyoming are again tied for last place, this time in a three-way tie that also includes Charleston, West Virginia. Mid-range MSAs included the cities of Rochester, New York, and Columbus, Ohio.

Gallup/Healthways's Healthy Behaviors. This survey block attempts to measure "... engaging in behaviors that affect physical health." Bellingham, Washington's MSA reported the highest scores, while three cities in North Dakota reported the lowest: Bismarck, Fargo, and Grand Forks. Reports from the residents of Pittsburgh, Pennsylvania, and Clarksville, Tennessee put these cities near the mean.

Descriptive Statistics—148 Mid-size U.S. Cities

The purpose of this section is to understand how these variables play out among the cities of the dataset. Descriptive statistics describe the distribution of the data amongst the cities. Unfortunately, there is not enough space to consider how the group under study either resembles or contrasts with U.S. cities as a whole: It is assumed that there is nothing remarkable about this group of cities. A summary of the descriptive statistics can be found in Table 3.2. Variables are again grouped together by theme. The minimum and maximum value for each variable is provided, along with the mean and standard deviation. The geographic scale of measurement is again provided as a reminder of how to interpret the results.

The central informative characteristic of a variable is the distribution of the cities around the mean: Do most of the cities sit close to the mean, or are they equally scattered about the range of values? Some variables have balanced data—with values equally well-represented on either side of the average score (viz. the *mean* value)—while others have "skewed" data, with examples far from average in only one direction.

In this set of cities, three measures of the built environment (viz. percent single detached homes, WalkScore and size) point towards the dominance of single, detached homes deployed in a relatively unwalkable form with an average size slightly larger than the City of Minneapolis (58.4 sq. miles). Therefore, these cities are on average unremarkable with regards to the built environment, and conform to the standard pattern of modern urban development in the United States.

As expected, the percentage of vacancies is lower for owner-occupied properties than for rentals. With an average of 47 percent rental properties, there is considerable balance between the two forms of tenure. Regarding Tenure Gap, the average city in the dataset has a difference of 30 percent in terms of the percentage of renters who are overspending versus homeowners who are overspending. While there are a few cities where it is less expensive to rent, this is far from the norm. This supports the idea that home ownership has financial benefits for those who can afford it. Median rent and median home values both have a strong rightward skew toward high property values.

Unemployment varies widely, with a few cities at the extremes. The average long-term unemployment rate of 5 percent resembles the country as a whole. The low mean for state minimum wage score reveals the dominance of the federal minimum, but the high maximum value also reflects the presence of high minimum wages in states like Oregon and Washington.

More balanced data is found in state and local tax burden, with a range of high and low tax loads. The median age of new residents has a lower boundary cutoff of 18, so the data is naturally skewed rightward towards the few examples that tend to attract retirees. The percent of the population in poverty is perhaps the most balanced data of all: Nearly every city has some impoverished residents. In contrast, the African-American median household income shows a wide variety with extreme values in both directions.

There is little variety in commute times for SOV commutes, which are, on average, considerably shorter than the national mean of 25 minutes. The domination of the SOV mode of commute is reflected in the similarity between the SOV times and the overall commute times, which include mass transit. Transit commuters face nearly twice the average commute time than do SOV commuters, and are subject to much more variety, as revealed by the high standard deviation. Thus, the experience of transit users concerning expected time commitments varies much more than it does for SOV commuters.

The regional indicators—Gallup/Healthways and Sperling's—both make use of composite scores for their variables. That is, individual scores are comprised of more than one measurement. As such, they generally offer well-balanced data, with the means in the middle of the distribution and small standard deviations. Recall that Sperling's data is scored from low to high, while Gallup/Healthways' Well-Being Index is ranked, with low values being more desirable. The WBI only offers data for 68 of the cities, and while generalizations cannot be made with these results, this still provides an acceptable figure with which to contrast the results of other analyses.

In contrast, the single-measurement emissions data show an incredible amount of variation, with ranges spanning orders of magnitude, even when referenced to size and population. In many cases the standard deviation is nearly as large as the mean. Of note is the relative importance of the poisonous gas carbon monoxide, which represents almost half of the total weight of measured emissions at 35,556 tons versus 82,439 tons. Consider that the latter figure includes the comparatively heavy 2.5μ and 10μ particulate matter. This is county-level data, and so it should be remarked that significant sources of these emissions may be placed outside the city limits. Some cities, such as Louisville, Kentucky may have much of this emission being generated in industrial sectors of the city which are adjacent to or extremely close to residential sectors, while in other cities they are generally emitted on the fringes of the county. This difference in location would certainly impact health outcomes differently. Finally, consider that particulate matter emissions are higher in dry, dusty environments, or in growing cities with high levels of construction.

Variables in the human health theme maintain even distributions of data. One point of interest is the nearly 30 percent average rate of obesity, which mirrors the national average. Still, some cities are as low as 15 percent. The range of Years of Potential Life Lost has a low of about 4,000 to nearly 11,000 years per 100,000 people.

Latitude and median household income show the most balance among the control variables. Density levels support the variables in the theme of urban character by showing the propensity for lower-density urban form: Most cities are between 1,000 and 3,600 people per square mile. There is much more variety in the percent of the population that is African-American (including a few outliers) and rates of college education. The key variable of interest, multimodality, shows a slight leftward skew toward SOV commutes. Finally, unlike many "global cities" such as New York City and Chicago, the highest percentage of multimodal commuters in any city is still well under half of all commuters.

We can speculate as to the differences and impacts that might arise if an isolated city were to pass this threshold in favor of the multimodal commuter. The paragon of multimodality, New York City, might provide some insights (Owen, 2009).

Data Analysis Methods

Quantitative methods in general, and statistical analysis in particular, are useful for identifying the presence of relationships. First, a t-test is used to compare the two groups of cities that lay on either side of the median of multimodality. Next, following the approach used by Molotch (1976), cities are grouped into "exemplars" of the two different transportation paradigms: The 25 cities performing best on the metric of multimodality are "green" cities, while the worst-performing 25 are referred to as "brown" cities. All analyses were completed using SPSS 22.0.

T-Test: Use and Assumptions. The independent t-test function in SPSS 22.0 is used to compare two groups against a continuous dependent variable. One central assumption of the t-test is that an individual observation of the dependent variable is *independent* of the other observations of the dependent variable. Isolated cities by their very nature are well-suited to such an analysis. Second, the test assumes that the data in the dependent variable is normally distributed, with the same variance in each group. Fifteen of the 45 tests have unequal distributions between the groups according to Levene's Test for the Equality of Variance. Therefore, the findings presented in Tables 4.2 and 4.2 use those results which are not dependent on equal variances. Still, the t-test is robust to violations of the assumption of normality: Deviations from normality do not generally increase Type I error (the "false positive" —rejecting a hypothesis when it is in fact true), especially when the groups are of the same size, which is the case here.

Multiple Regression Analysis: Use and Assumptions. The regression analyses used in this work will be focused on *explanations*, and not *predictions* (Pedhazur, 1997, pp. 195-198). Multiple regression analyses are used to uncover the relationships between multimodality and the 46 dependent variables, after controlling for the influence of six common control variables. Variables are entered into the model normally (i.e. "at once"), as the sample size is too small for stepwise regression, and there are too few variables to warrant backwards removal. More importantly, there is no reason to think that any of the control variables should be entered in a particular order, or, as Mueller, Schuessler, and Coster (1977) state, "In multiple regression analysis, no assumptions need to be made about the causal structure linking the predictor variables" (pg. 310). The model will be tested as a multiple linear regression model to find the association, if any exist, between dependent variables, y_1 through y_{46} and the seven explanatory variables (including the test variable, multimodality), x_1 through x_7 in the form:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n + \varepsilon$$

where

$\beta_0, \beta_1 .... \beta_n$ are the coefficients, and ε represent errors of variability.

Sample Size. In OLS regression, sample size should exceed 50 + 8*m*, where *m* is the number of independent variables (Tabachnick, Fidell, & Osterlind, 2001). The population of 148 (and 143 for the Sperling's data) is well above the minimum threshold of 106 suggested by the formula. One exception is the Gallup/Healthway's data, for which there are only 68 cases. Generalizations will not be made from this data, although results will be compared to the outcomes of tests that use the full complement of cases.

Distribution, Normality, and Transformations. Analyses were performed to identify the skewness and kurtosis of the variables, univariate and multivariate normality, violations of the independence of residuals and homoscedasticity, multicollinearity, and lastly, the presence of outliers and their influence. The Shapiro-Wilk Test was used to determine which variables did not approach a normal distribution. There were many variables that failed the approximation, and data transformations were applied to improve the distributions. There is no requirement that the independent variables be distributed normally (Tabachnick et al., 2001), but one assumption of regression analyses is that the dependent variable be normally distributed.

Unfortunately, data typically found in the social sciences is rarely normally distributed. A suite of transformation techniques have emerged to present data distributions from a different perspective. There are a number of reasons *not* to use transformations, including forcing outliers to conform. However, transforming independent variables in order to improve model fit is an acceptable rationale. In addition, reducing skewness is another valid rationalization. Finally, increasing comprehensibility is a sufficient justification. The seven independent variables in this study are from a wide variety of sources, with different scales, constructs and measurements, and as such, conform to these rationales.

Log-transformation and reflecting variables help data meet the assumptions of multiple regression, reduce the skewness of the independent variables, improve the fit and streamline interpretation. About half of the transformed variables used a *log*10 transformation, and the remainder used the natural log (see Table 3.3). While all of the transformed variables benefitted from reduced skew, there was very little difference between the two regarding overall fit. Instead of using Tukey's Ladder of Transformations for DVs, which did not approximate a known *log*-normal distribution, a Box Cox transformation was used to estimate the best value for ʎ. In the interest of simplicity, for independent variables, those based on percentages were transformed using the natural log, while counts and measurements employed *log*10.

Scatterplots provided by the explore function in SPSS were used to plot saved studentized residuals and unstandardized predicted values to check for violations of independence. Only a small fraction of the many relationships observed showed any sign of heteroscedasticity, and all of them were relatively minor; most are well-distributed in scatterplots in the form of a rectangle and have no noticeable indications of curvilinearity or clustering. Reviewing the Normal Probability Plot (P-P) of the Regression Standardized Residual also showed the residuals to be acceptably distributed: Residuals conformed well to the diagonal axis of the plot (Stevens, 2012, p. 110). Studentized residuals were explored for normality again using Shapiro-Wilks, which provided evidence of a normal distribution.

Correlations. In multiple regression analysis, there should be some correlation between the independent variables, but not overwhelmingly so. It is important to know which variables are correlated and to what degree, and which are not. While correlations are technically findings, since there is an assumption of correlation for regression, the results are presented in this methods chapter.

A two-tailed Pearson correlation analysis is performed on the seven independent variables to better understand their relationships. While there are many modest correlations among the seven control variables, none are over .60 and, with the exception of population, every variable is significantly correlated to at least one other variable (see Table 3.4).

Latitude is negatively correlated with population, indicating smaller city populations in the North. Latitude is also negatively correlated to percent population African-American. Latitude is weakly and positively correlated to density. This corresponds to the conventional wisdom, which suggests cities in the sunbelt tend toward sprawl. The population of the Northern cities seems to be lower, as well.

Multimodality is positively correlated to both percent college educated and density, whereas college education and density themselves are uncorrelated. Multimodality is also slightly negatively correlated to percent population African-American, the opposite of what we might expect in traditional research using Northern and coastal post-industrial megacities.

Incomes increase slightly with northerly latitudes, which also indicates smaller proportions of African-American residents. Neither college education nor multimodality is correlated to latitude.

Density is not correlated to population, and is weakly and negatively correlated to college education, household income and, perhaps interestingly, the percent of the population that is African-American. Not surprisingly, density and multimodality are the most strongly correlated variables of the seven. Population is not significantly correlated to any other independent variable, including multimodality.

The second strongly—and negatively—correlated pair of variables is median household income and percent population African-American. Median household income is moderately and positively correlated to education, but not correlated to multimodality.

The percent of the population that is African-American is not significantly correlated to levels of college education, but slightly and negatively correlated to multimodality. Interestingly, the percent of college-educated citizens has a sizeable and positive correlation to multimodality.

Multicollinearity. Two values are initially observed for uncovering violations of multicollinearity: Tolerances and Variance Inflation Factor (VIF). Tolerances are all well above the critical threshold of .10, with the lowest being .56. Meanwhile, the VIFs never exceed 10; in fact, no VIF exceeded a value of 2. Both of these tests indicate a comfortable distant from unacceptable limits. Furthermore, although unnecessary given the preceding results, the presence of competing dependencies was also explored and determined to be negative: In no case did two variables both show values above .40 on the variance proportion table.

Endogeneity. Where issues of endogeneity present themselves, the offending explanatory variable is simply removed from the model. For example, in the model explaining poverty, median household income is removed. For the WalkScore DV, density is eliminated.

Univariate Outliers. With any sample size greater than 100, univariate outliers are to be expected (Stevens, 2012, p. 16). They do, however, impact analysis, and therefore must be addressed. Importantly, the 148 cities comprise the entire population of isolated cities, so issues of sample bias do not apply. The source data is from established sources, so range and measurement error is low or unlikely. These factors point towards retaining the data in the event of statistical outliers. Furthermore, in this study, outliers can provide important examples regarding alternatives to the mean. Trimming outliers from the dataset can remove important information from the study.

Therefore, the technique of “Winsorizing” is used to deal with the small number of outliers (see Table 3.5). In this technique, the outlier value is given a replacement value of 1 plus the last non-outlier value (Ghosh & Vogt, 2012). It therefore retains the order that is true to the data, but the difference between the outlier and the last normal value is reduced.

For example, with latitude, the two outliers on either side of the distribution are given values equal to the last non-outlier value +1 or -1, as necessary. This allows the case to remain in the dataset without skewing the overall regression fit. The rationale for this approach is that the *impact* of the measurement of most scores, even one such as latitude, is not linear. That is, Honolulu, Hawaii's latitude of 21.33 is not 22 percent “worse” than Laredo, Texas’ latitude of 27.55, nor is Anchorage, Alaska’s latitude of 61.17 half-again “worse” than Bellingham, Washington’s latitude of 48.75. Thus, these values have been changed to 26.55 and 49.75, respectively.

In practice, the dependent variables are analyzed in SPSS by saving their standardized scores and looking for values above the critical value of 3.29, three standard deviations from the mean. Variables are Winsorized to match the scale of unit change: Standard numbers are shifted by 1; logged variables are moved in increments of .1 when the scale is ranged from 0-9, and 1 when ranged from 10 and higher.

Multivariate Outliers. The critical value used for Cook’s D is often set at 1. More conservative approaches use 4/N, or alternatively, 4/(N-k-1), where k is the number of explanatory variables (Stevens, 2012, p. 127). For this data set, the values derived from these formulas are much lower than 1, at 0.027 and 0.029, respectively. The approach to this study is to retain data. Thus, only outliers with Cook's distances >1 are flagged as being influential. Those with values between 0.027 and 1 will be retained, but identified in order to later understand what makes them so different. Anchorage, Alaska presents the only multivariate outlier. Removing it from the models does not noticeably improve fit (r-square changes less than 0.01), so it is retained for every model.

Reliability and Validity. The final dataset was verified by two graduate research assistants working independently of one another with funding provided by the University of Louisville's Center for Sustainable Neighborhoods (SUN). The research assistants discovered six additional cities with populations over 50,000 that also fit the 20-mile rule, and found two that had been erroneously included into the dataset despite their proximity to another city. They also verified the data itself, row by row and column by column, ensuring the valid transfer from the various data sources.

Summary

Grouped into four themes, the wide variety of variables enables a broad survey of the cities in the data set. The themes are diverse, and the variables present a comprehensive but not exhaustive set of concerns within each theme. Importantly, they provide some insight into the nature of the relationship between differing levels of sustainable transportation and the outcomes of different basic concerns of life in the modern city.

The methodological approaches used in this research are well supported in the literature. The process for identifying the cities to be studied is expected to better reduce uncertainties than approaches such as examining "the largest 100 cities" or "global cities." In these latter approaches, disambiguating the role and importance of vast suburbs, neighboring industrial towns and bedroom communities and their relative place in the global market of cities can hardly be changed after the fact.

The control variables used are uncontroversial, and can commonly be found in social research. The central test variable, multimodality, is uncomplicated and straightforward, and captures a fundamental aspect of urban form that can illustrate the important impacts the built environment has on everyday life. No study can be all things to all people, so choosing an appropriate number and a sufficient type of dependent variables is important to measure the impacts of multimodality. This work thus attempts to balance the need to capture a wide survey of potential relationships between multimodality and urban life with an additional need to be comprehensible and focused. Multiple regression is a satisfactory analytic tool to observe these relationships, and the data gathered is adequate for use in regression analysis.

CHAPTER FOUR: FINDINGS

The central concern of this study is the reach and importance of multimodality in urban life. This is explored by observing statistical relationships between multimodality and a series of dependent variables grouped into four themes: health, quality of life, urban character and economics. This chapter presents the results of the t-tests and regression analyses that were described in the previous chapter. The t-test is used to show simple relationships between multimodality and the dependent variables. Multiple regression is then used to see if the relationships hold after introducing six common sociological and geographical control variables. Each of the four themes is explored using several regression models where each model focuses on a unique dependent variable.

Bivariate Analysis: Differences in Multimodality by Median

Since transportation plays such an important role in urban life, there are substantive differences between the cities that lay above and below the median of multimodality; that is, between cities with higher proportions of commuters using alternatives to the SOV, and those cities that are focused on automobile commutes.
In this study of 148 cities, the mean percentage of multimodality is 22.47 percent, with only 52 cities above the average score, and 96 below. The median percentage across the data set is 20.75 with, of course, 74 cities on either side of the median. The more conservative approach is to divide the dataset along the median: Results that hold for

dividing the cities along the median will also hold for separation at the mean, although not vice-versa.

The t-tests are first performed on the entire data set of 148 cities, divided along the median of multimodality into two groups. Commuting by bike, foot, mass transit and other means is known to produce fewer carbon-related and other airborne emissions. Therefore, for convenience, cities with higher percentages of alternative transportation will be referred to as “green,” while car-dependent cities are identified as “brown.” While the causal direction of some of the relationships can be predicted based on past research, theory and intuition, the nature of the relationship between many of the variables and multimodality is unclear. Thus, two-tailed tests are used. A map is again provided to illustrate the geographical distribution of cities that are above and below the median score (see Map 4.1). Moran’s I is used again to determine if the cities are either evenly or randomly distributed, or clustered: Both green and brown cities are randomly distributed across the continental United States.

In Table 4.1, the variables are grouped according to theme, along with the geographic scale of measurement. The mean of each variable is listed for green and brown cities, as well as the difference of means and its significance, if any. Finally, a column is provided to display where the green cities have a higher (+) or lower (–) mean than the brown cities. In the case of non-significance—where difference cannot be determined given the data and unit of analysis—a question mark is used. The first point to note is that the average percent of multimodal commuters in the green half is 27 percent—over a quarter of all commuters. In brown cities MM is only 18 percent, or 1 in 6 commuters. This is not a difference of 9 percent, but rather 33 percent. In other words, divided as there are, there are a third more multimodal commuters in the green cities—a considerable difference.

Urban Character Theme by Median. There are no significant differences between cities on either side of the median with regard to geographic size or Sperling's climate score. Multimodal cities are neither smaller spatially, nor have better overall weather (as measured by Sperling's). These findings correspond well with the lack of difference in commute time across all categories of commuters (e.g. smaller cities should have shorter commutes, *ceteris paribus*) and in latitude (e.g. higher latitudes should have worse weather). Recall that the cities in this data set have considerably shorter commutes than the national average.

Not surprisingly, WalkScore points to more walkability in MM cities. This finding is also supported by the smaller percentage of single family, detached homes (SFDH) in these cities. Conversely, auto-dependent cities can be associated with significantly higher percentages of housing stock in the form of single family, detached homes. We can safely say there is a negative relationship between the percent of multimodal commuters and the percent of single family, detached homes. This conforms to expectations, as this is in line with theory and research in urban studies that have analyzed the relationship between housing density and the viability of mass transit. Also, there is a higher percent of rentals in the MM cities, which corresponds to the smaller number of SFDHs. There are fewer vacant rentals in the green cities, although it is unclear if this can be said of SFDH rental vacancies. Finally, new residents in green cities are significantly younger. This corresponds to the considerable body of theory and research suggesting that Millennials are migrating to the more multimodal central cities.

Economy Theme by Median—Costs. There appears to be less overspending by renters in MM cities, but more overspending by homeowners. There is also a smaller gap between renters and homeowners regarding what is spent on housing, indicating more parity in housing costs. Both home values and rents are higher in MM cities. Thus, there is more equity within green cities than in brown cities (less difference within), but less equity between green and brown cities (greater difference between). This matches the results of the t-test for Sperling's Cost of Living, and corresponds to the literature: Green cities are more expensive. This, of course, makes no assumption about what inhabitants actually get for the money in terms of quality of life or health outcomes, nor does this ignore the increased demand placed on green cities by the less-desirable brown cities.

Economy Theme by Median—Income. There is no significant difference between green and brown cities regarding employment. This is despite the significantly higher state minimum wages found in green cities: MM cities seem to be located in high minimum wage states. In addition, taxes are higher, although this is likely to impact the wealthy and the poor disproportionately. Jumping ahead to the control variable of income, note that there was no difference in household incomes between green and brown cities; there is no difference for African-American households, as well. There seems to be no employment benefit to automobile dependency at this stage of the analysis, nor any employment "cost" to multimodality.

Rents are, on average, significantly higher as a percent of income in green cities. This is interesting considering there is less overspending by renters, and larger proportions of poverty-level inhabitants in green cities. Consistent with the findings on unemployment and household income, central city multimodality does not seem to have a measurable impact on the larger regional economy as calculated by Sperling's Jobs and Economy score using this methodology.

Quality of Life Theme by Median. All eight of the indicators in this theme are measured at the geographic scale of MSA. While the economic benefits of central city MM are not detectable in the larger regional economy in this model (as measured by Sperling's MSA-level Jobs and Economy), quality of life certainly is: Three of the four Sperling's measures are significant; only the much more specific "Arts" variable is not. Three of the four Gallup/Healthways measures are significant as well; again, only the extremely narrow construct of "Work Environment" is insignificant.

Human and Environmental Health Theme by Median. All of the EPA emissions figures are gathered at the county level. It is perhaps unsurprising that this study cannot capture definitive benefits from MM with regard to airborne emissions. Aside from the important exception of a lower measure of per capita NO_x in green cities, none of the environmental indicators are significant. Every indicator of human health is significantly different between MM and AD cities.

Control Variables by Median. Latitude is not significant across groups: As shown by the Moran's I analysis, neither category of cities is sorted geographically. Population is also similar across groups, as is median household income. Green cities have significantly higher densities, fewer African American residents and more college-educated residents.

Bivariate Analysis: Differences in Multimodality by Exemplars

In the literature review, I presented the idea of thresholds as being important to exploring urban sustainability: Relationships among and between social and environmental systems are not necessarily linear. A certain amount of MM may need to be achieved before its benefits can begin to be realized. Thus, following the method used by urban sociologist Harvey Molotch, a series of t-tests is performed on those 50 cities that have the 25 highest and the 25 lowest rates of multimodality. This is done to discover whether any substantive differences exist in the dependent variables among the exemplars of the two different transportation paradigms. The key statistics are presented in Table 4.2. The level of MM between these two groups is quite different: Only 15 percent of commuters are MM in brown cities, while over a third of all commuters are MM in green cities. This is over a 100 percent difference.

Mapping the exemplars (see Map 4.2), we can see that, while the exemplars together as a group are randomly distributed (I = 0.132, z = 1.60), the brown cities are clustered (I = 0.292, z = 1.92), with less than a 10 percent likelihood that the clustering results from chance. Moran's I suggests that green cities are randomly distributed (I = -0.069, z = -.132). However, we can see that proximity to the coasts may play a role.

Urban Character Theme by Exemplars.

Geographic Size and WalkScore. Whereas there is no difference between green and brown cities by median, green exemplars are much smaller than are brown exemplars, having nearly half of the physical footprint as do brown cities. According to WalkScore, they are also more walkable. This is not surprising, as smaller cities are traversed more quickly, *ceteris paribus*. Furthermore, the ability to get across town quickly probably decreases the opportunity cost of utilizing mass transit and other modes of travel versus automobile travel. Although more walkable, to be fair, a WalkScore of 48 is considered average: The 141 American cities with a population over 200,000 for which WalkScore calculates a rate have an average score of 47. This score is considered by the creators of the measure to be "car-dependent."

Climate. We might think that poor weather encourages car use. However, the climate does not create enough difference to be measured across scale: The Climate score is still similar across groups. Consider that there is also no (discoverable) difference in latitude between green and brown exemplars.

Commute Times. Recall that the cities in the data set have shorter commutes than the national average. However, commute times are significantly higher in the green exemplars with more multimodal commuters, both overall and for automobile users. If the commute for car users is longer, this reduces the incentive to use a car. Unfortunately, the commute for MM commuters is much longer than it is for SOV commuters. On the other hand, transit commute times are similar in both green and brown exemplars. Consider that green exemplars are half the geographic size of their brown counterparts.

New Resident Age. Whatever the reason (or, more likely, whatever *combination* of reasons), this research shows that green exemplars attract significantly younger new residents, on average.

Economy Theme by Exemplar – Costs. There are clear differences between green and brown exemplars in each of the variables focused on housing. Green exemplars have lower vacancy rates for both owner-occupied properties and rentals. Despite having significantly higher percentages of rentals than brown exemplars, green cities' median rents are higher relative to both their median incomes, and absolutely. So, too, are home prices. These results conform to the literature on the costs of clean environments and ample services: Desirable living conditions are in demand, so costs will be higher and vacancies quickly occupied. Given this, it may be surprising that fewer residents in green exemplars spend over 30 percent of their income on rental housing. On the other hand, more homeowners spend over 30 percent of their income on housing in green exemplars: Homes are more expensive in green cities relative to income.

Economy Theme by Exemplar—Income. The result of this test provides evidence that long-term unemployment is significantly lower in the green exemplars. Furthermore, while the overall median household income is statistically the same in both groups, for African-Americans the difference is dramatic: Black households in green exemplars make considerably more money than those living in brown exemplars; 18 percent more on average, or $5,285 per year.

Another intuitive finding is that taxes are somewhat higher in green cities. The higher costs associated with transit might contribute to this 1 percent difference in the state and local tax burden. On the other hand, partially compensating for this is the fact that green cities tend to be located in states with higher state minimum wages. Green exemplars contain higher proportions of impoverished residents. While there seems to be an impact on the economy from multimodality at the *city* level (see variables measured at the place level), it does not reveal itself at the level of MSA, as measured by Sperling's Economy and Jobs score.

Quality of Life Theme by Exemplar. The bivariate analysis shows that reduction in car usage is associated with higher quality of life; Seven of the eight variables were statistically significant, including Sperling's Overall, Sperling's Leisure, Sperling's Quality of Life, Gallup Overall and Gallup Life Evaluation. The only variable not associated was Sperling's Arts measure. In this study, there is no identifiable difference between groups in Sperling's measurement of Arts. Whatever the different nature of green versus brown transportation cities, it is not reflected in the quality and amount of regional arts. Nevertheless, the green cities' MSAs show better scores in the categories of Overall, Leisure, and Quality of Life.

Health Theme by Exemplar—Environmental Health Variables. The emissions data provide curious results. The green exemplars did not maintain the advantage found among the 74 green cities regarding lower per capita NO_x levels; they instead have *higher* emissions, at least in total emissions and carbon monoxide.

Health Theme by Exemplar—Human Health Variables. Regardless of the findings on emission outputs above, there is evidence that the multimodal transportation paradigm has more of a positive impact on health than the emissions have a negative impact. The more health-focused Gallup/Healthways WBI favors green city MSAs in every measurement: All of the variables point towards better health, both mentally and physically, in the cities with a more diverse transportation paradigm. Furthermore, all of the county-level variables in the health theme support the results of the WBI: Green cities have less obesity, fewer years of potential life lost, and fewer residents reporting below-average health.

Control Variables by Exemplar. The three basic control variables of population, latitude and median household income continue to show no difference between green and brown exemplars. Green exemplars have more college-educated residents, and are twice as dense, on average. Just teetering on significance is the percent population African-American being higher in brown cities.

Multiple Regression Analysis

A simple decision rule is made for the presentation of regression analyses: If the regression is significant for multimodality, regardless of the t-test, the results are posted. If the regression is not significant, it is assumed that multimodality is not an adequate explanatory variable for that construct, given the data available. As a result, 27 significant regression results are presented. Still, it is useful to discuss the variables for which multimodality did not contribute significantly to the model. A simple 2x2 contingency table is provided to illustrate whether and where the key test variable showed a relationship to the dependent variables in the t-tests and regressions (see Table 4.3).

Interpreting the relative worth of a coefficient of determination statistic in regression analysis is context-dependent. In some statistical models in the social sciences, one should expect high levels of explanation (e.g. .60 and above), while in others models, r values in the low .20s might be considered important. In this research, cross-scale measurements contribute greatly to the context in which the results should be evaluated.

Where Multimodality was Insignificant. The t-test that suggested a relationship between multimodality and *higher* total emissions per square mile was shown to be inconclusive after accounting for the six control variables. In fact, the connections between multimodality and total emissions point toward *lower* emissions for MM cities.

The vacancy rate variables are also shown to be unrelated to multimodality, and unrelated to long-term unemployment. Interestingly, overall commute time is also shown to be unrelated to multimodality.

The MSA-level Gallup/Healthways variables that measure *physical* health are maintained through the regression, while those that try to capture *mental* health are inconclusive. The county-level survey response variable measuring "below-average health" was also controlled out of significance.

Regression Results

The regression tables are laid out in a traditional fashion, grouped according to the four themes of variables. Along the top horizontal axis, the dependent variables are listed. The constant is provided along the top vertical axis, followed by a consistent ordering of control variables, with the key test variable at bottom. The F statistic, r-squared and adjusted r-squared values are presented along the bottom horizontal axis, as well as the sample population size. Within the cells, the unstandardized beta is provided, with the standardized beta in brackets below. The level of significance, if any, is attached to the unstandardized beta and F statistic as a superscript.

Urban Character Theme. Four of the five models of this theme explain half of the variation in their dependent variables (see Table 4.4).

Percent Single Detached Homes (reflected). The model explains fully half of the variation in the number of single-family, detached homes (SFDH) among the cities studied, and multimodality has the largest standardized beta of the seven independent variables. A larger proportion of people with college educations also relate to a smaller percentage of SFDHs. Intuitively, higher density is related to fewer SFDHs. Less expected, perhaps—but also comporting to the increased auto-dependency of Black Americans in this study—is the percent of African-American residents: In these 148 cities, African-Americans are associated with increased percentages of SFDHs.

WalkScore. WalkScore uses density as a component of its calculation, so density is removed from the model to avoid endogeneity. However, the other main constituents of the WalkScore are of interest: the frequency of third-place destinations, the length of city blocks, etc. Multimodality and latitude are the only significant contributors to the model, which still explains well over a third of the variation.

Percent Rental Units. The percentage of rentals is not only an urban concern due to the type of housing that lends itself to rentals, but because the presence of owner-occupied homes has a diverse impact on the fabric of the community. This is another strong model, with about 60 percent of the variation in the proportion of housing stock committed to rentals explained. Higher incomes are strongly associated with fewer rentals, while more college education is associated with more rentals. Multimodality is again the strongest explanatory factor, explaining more than even median income. An increase in multimodality is associated with a larger percent of rental units.

Single Occupant Automobile Commute Time. Higher densities, incomes and populations are all associated with longer SOV commute times. Increased levels of multimodality are also associated with longer SOV commute times.

Median Age of New Residents. About a quarter of the variation is explained by the model. The strongest factor is median income, with increases in income associated with older residents. Nearly as strong, however, is multimodality, but in the opposite direction: Increased mobility is associated with younger residents. Increased density—the weakest of the significant factors—is associated with older new residents: Lower-density cities may provide better, less expensive starter homes for Millennials. Another interesting observation is that the percent of African-American residents has no significant impact on the age of new residents.

Economy Theme—Costs. The theme of Urban Character contains models where the dependent variables and the explanatory variables are all measured on the same scale: the municipal (i.e. "place" per the U.S. Census). The microeconomic theme also contains place-measured variables, with one exception: Sperling's Cost of Living. Latitude makes a much stronger appearance in this theme, with significance in four of the six models (see Table 4.5).

Sperling's Cost of Living (reflected). Sperling's gives a score of 1 to 100, with a higher score reflecting a more desirable result. Only two variables make a significant contribution after being controlled for by the other six: median household income, and multimodality. The model shows that the higher the median income in the central city, the worse the regional score for cost of living. The higher the proportion of multimodal commuters, the less affordable the region is in general. Still, the percentage of the variation in regional cost of living explained by the model is low, at only 15 percent. Nevertheless, that the central city's transportation structure can be identified across scale amongst the economic noise is remarkable.

Renter overspending. The federal government has set the guideline for the percent of income that should be spent on housing at 30 percent. Renter overspending refers to the percent of renters who spend more than 30 percent of their income on rent. Only two variables are significant, although the model as a whole explains about a third of the variation. Income is the strongest factor. The results show that the higher the median income, the larger the proportion of renters who overspend. On the contrary, the more multimodality commuting there is, the smaller the proportion of rental overspending.

Owner overspending. The federal guideline of 30 percent is applied to homeowners as well. While multimodality is still an important contributor to the model, a different set of variables informs the variation among cities for owner overspending. Unlike for renters, where a higher median income is associated with more overspending, income does not inform owner overspending, one way or the other. Instead, the level of college education is the factor most associated with owner overspending: The more educated the public, the fewer who are overspending. This model explains slightly less than the model for renter overspending, at just under a third of the variation. Multimodality flips direction from what was found among renter overspending: The more MM commuters in the city, the larger percentage of owners who are overspending on their homes.

Tenure Gap. Tenure gap is the difference in overspending on housing by tenure. A city that has few owners overspending and many renters overspending will have a high tenure gap. Again, just under one-third of the variation is explained by the model. Higher incomes and levels of college education are associated with wider tenure gaps. As the level of MM goes up, the tenure gap narrows. Whereas income is the central factor in rental overspending, and education is most central to owner overspending, interestingly, multimodality is the strongest explanatory factor for the gap between the two.

Median Home Value. Fully six of the seven independent variables contribute to the explanation of variation in median home values. The model explains a large amount of the variation—as much as 70 percent. Notably, density is the only variable that does not contribute to the model. Higher latitude, population and percent population African-American are all associated with lower home values, while education, income and multimodality are associated with higher values, with income and education also being the strongest factors.

Median Rent. As with overspending, fewer variables contribute to the median rent model than the home value model. While strong contributions are again made by only two of the variables, well over half of the variation in rent is explained by the model. Median income is again the central driver, while multimodality also makes a strong contribution.

Economy Theme—Income. This research recognizes the relationship between cities and their states. Cities attempt to shape the particular state-level policies under which they live, and from which they benefit (Peterson, 1981). It is known that the governance of cities differs by state: States enable cities to exist, and provide a set of policies for the production of urban space and the urban political economy. Therefore, the macroeconomic portion of this theme includes the additional scale of the state in two important matters that go beyond the scope of the city: the state minimum wage, and the state and local tax burden. We can look to these results to find evidence of marginal differences between state-level policies and the types of cities that these states contain. See Table 4.6.

State Minimum Wage. Slightly over a quarter of the variation in the state minimum wage score is explained by the model. Still, the different geographic scales of measurements and issues of causality are problematic. Therefore, perhaps more than any other model, this needs to be interpreted conservatively. This model asks, “What kinds of cities typify high minimum wage states?” The most explanatory factor in this model is MM: States that contain cities with diverse modalities also tend to have a higher minimum wage than the federal guideline. This is followed by college education, which points in the other direction: States containing cities with higher levels of college-educated residents tend toward lower minimum wages. Higher latitude Northern states tend toward a higher minimum wage; Northern states tend toward progressive policies. The weakest factor is income, with higher incomes associated with higher minimum wages.

State and Local Tax Burden. The strongest factor in this model is density, with increased density associated with higher taxes. Density has particular infrastructural demands, which cost money.

Northern cities tend towards higher tax burdens, and the multimodality variable is associated with increased taxes. On the other hand, the findings show that higher populations are negatively associated with tax burden. Percent population African-American is weakly associated with higher taxes, while higher education is weakly associated with a lower tax burden. Interestingly, income is not a significant factor.

Median Black Household Income. At a respectable 45 percent, the model explains a considerable amount of the variation across cities. The strongest explanatory variable is median income. Not surprisingly, as overall household incomes increase, so do Black household incomes. Next, increased latitude is associated with lower Black household incomes. Following this is percent of the population that is African-American; larger percentages of Blacks are associated with lower incomes. Multimodality, on the other hand, is the only variable after median income that is *positively* related to higher Black incomes. Neither density nor population explains Black income in these cities.

Median Rent as a Percent of Income. While this model explains over a third of the variation in median rent as a percent of income, only two variables make a significant contribution. As we might expect, the first is income, with higher median incomes relating to rents taking a smaller proportion of income. Multimodality works the other way, with higher rates of MM commuters associated with a higher ratio of rents to income.

Percent Population in Poverty. This last model in the economic theme is the strongest of all, with the seven variables explaining 37 percent of the variation in rates of poverty across cities. Again, like the WalkScore model, median household income is removed in order to avoid endogeneity. Multimodality and, curiously, higher rates of college education are associated with higher levels of poverty.

Quality of Life Theme. Multimodality is the most consistent predictor of urban quality of life, with a central role in all five of the indicators that were statistically significant. Another powerful indicator of quality of life is, not surprisingly, college education. Still, multimodality provides the highest beta weight for Sperling's Leisure and Gallup's Life Evaluation, and is virtually tied with college education in explaining Sperling's Quality of Life indicator. What is surprising among the control variables is median household income's relative lack of importance for explaining quality of life. The amount of explained variation ranges from roughly a fourth to a half across the five models. Quality of Life, again due to the lack of data gathered at the municipal level, is comprised of dependent variables that are measured at the level of MSA. See Table 4.7.

Sperling's Overall. Recall that to rank cities in the construct, Sperling's examines a wide range of diverse subsections, such as the economy and quality of life. The model explains just under a third of this diverse measure. In this model, the central city's level of multimodality is shown to have a significant relationship to Sperling's assessment of the overall quality of an MSA: A higher percentage of MM commuters is related to a higher-scoring MSA. While the strongest explanatory factor is education, by observing the standardized betas, we can see that multimodality has an impact on a scale similar to such fundamental sociological concerns as population and racial composition.

Sperling's Leisure. Multimodality is again the variable that makes the most noticeable contribution to the model, followed by population. Income is also significant, as entertainment is at least somewhat enabled by income. Neither density nor percent population Black reflects a lower leisure score. Finally, latitude makes its only appearance in this theme. What might be surprising is its direction: With an increase in latitude, we find an increase in the Leisure score. The model explains about 40 percent of Leisure's variation.

Sperling's Quality of Life. In this model, education and multimodality are both strong contributors, with latitude also explaining some variation in Sperling's calculation. As the percent of college graduates rises, so too does the quality of life. Similarly, as the percentage of people using alternative means to get to work increases, so improves the quality of life. To a lesser degree, as one heads North in the United States, the better the calculated quality of life, according to Sperling's.

Gallup Overall. This dependent variable is Gallup/Healthways' broadest measure of quality of life, incorporating health issues, work and life satisfaction, and other factors. Population, income, and percent Black are not significant, while higher densities, more college-educated citizens, and more multimodality are independently associated with lower, better scores. Education makes the greatest contribution, followed by density and multimodality, respectively. Over two-fifths of the variation is accounted for by the model.

Gallup Life Evaluation. Multimodality and education again are central contributors to the model, with MM taking the top spot. Controlling for the other six variables, a higher proportion of the population being African-American is also associated with a better score. Nearly a quarter of the variation is captured by the model.

Health Theme—Human Health. Due to the current process of gathering health statistics, data is typically aggregated at the MSA and county levels. All of the dependent variables in this theme are measured at a higher scale than the independent variables, which are all measured at the level of the municipality. Nevertheless, the results show that multimodality in the central city is significant in four dependent indicators measuring human health at the regional or county level: Gallup/Healthways' Health and Healthy Behavior, Years of Potential Life Lost, and percent population obese. The most consistent indicator of urban health of all six independent variables was a lower rate of SOV commuters. Auto-dependency is also the most powerful indicator of unhealthy behaviors. Education level was the second best explanatory factor, while percent black and density contributed to three of the models. Latitude, median income and population were each significant in only one health measure. The amount of explained variation is good for this kind of model, ranging from roughly one-third to nearly two-thirds of the variation. See Table 4.8.

Gallup/Healthways' Overall Health. Multimodality is a significant factor in explaining the regional variations in the responses to Gallup/Healthways' survey on health. The model shows that an increase in multimodality is related to a decrease in the MSA's rank: More multimodality means better overall health. The model explains a modest proportion of the overall health in the MSA in which the city is located. What is remarkable is that the impact of the multimodality rate in the central city is still identifiable at the MSA-level. The two other contributing factors provide interesting results. Conforming to intuition, an increase in the percent of the population with college degrees is associated with better health. Not conforming to intuitions is that more density is also associated with better health.

Gallup/Healthways' Healthy Behaviors. As expected, multimodality is a strong explanatory factor for healthy behaviors, which include walking and biking. What is even more interesting is that it is the *only* significant factor: None of the other city-level measurements explains variation in the larger MSA around it. This is evidence that the urban form of the city is not only important, it is central. The healthy behaviors model is less explanatory overall than the health model. In any case, again, what is remarkable is finding a statistically significant impact on a regional outcome from a municipal measurement.

Years of Potential Life Lost. When a county has higher Years of Potential Life Lost (YPLL), this means that residents of the county are less likely to achieve the national average life expectancy. Therefore, a low YPLL is desirable. The model shows that an increase in the central city's rate of multimodality is significantly related to lower levels of YPLL. Overall, this model explains half of the variation in counties' Years of Potential Life Lost. Other factors that contribute to lower YPLL include higher income, higher education levels and again, perhaps surprisingly, increased density. Even controlling for income, education and density, an increase in the percent of population African-American is related to a higher YPLL. Latitude makes a strong contribution, suggesting that cities in the northern part of the United States have lower YPLLs. The standardized beta scores in the model show that multimodality has a level of importance comparable to that of income.

Percent Population Obese. This model is the strongest of the five in the theme of health, explaining well over half of the variation in obesity among the counties. Multimodality is second only to the percent of the population that is African-American in terms of relative impact. Higher rates of multimodality mean lower rates of obesity, and the relationship is noticeable across scale. In an interesting departure from the other health models, as neither density nor population has an impact when controlling for other factors.

Health Theme—Environmental Health. One of the stronger models in the health theme, over half of the variation in airborne emissions among the 148 cities is explained by this model.

Total Emissions, per square mile. A higher level of multimodality is associated with lower emissions, per square mile. Interestingly, total emissions per square mile—which was not statistically significant in the bivariate analysis—emerged as statistically significant when controlling for other variables, most notably density and population. Importantly, multimodality is the only factor in the model that contributes to lower emissions: Density and population are both also positively related with per square mile emissions. Furthermore, both higher education and larger percentage of Black residents are also related to higher emissions, although certainly for different reasons.

Summary

The findings have been discussed in terms of *explanations,* and not *predictions*. (Pedhazur, 1997, pp. 195-198). As stated earlier, this research examines a *population* of cities: It includes *all* cities in the United States which are both above 50,000 in population and which are not within 20 miles of another city of the same size. The idea is that the impacts of many intrinsic urban processes are more observable when the noise of ubiquitous interactions between cities' processes is not overlapping. As this is a population of cities, and not a sample, the results are not generalizable to those cities that are embedded in large conurbations, where the interactions between their individual processes create new impacts. In other words, the analysis is geared towards explaining outcomes (e.g. health) in these cities, and not predicting outcomes in other cities. This, of course, does not mean that future policies for these other cities cannot be *informed* by this research (*cf.* Bryman, 2015), which is the focus of the next chapter. The health theme shows unambiguously that different levels of multimodality in the central city have an important impact on the level of health not only for the city, but for the county and region as well.

CHAPTER FIVE: CONCLUSION

This dissertation asks the question, “How are green, multimodal cities different from brown, automobile-dependent cities?” As the data from the previous chapter clearly demonstrate, the differences are dramatic. The 25 green exemplars could hardly be more different from the 25 brown exemplars. The statistical analysis of all 148 cities clearly shows that an increase in multimodality holds vast promise for brown cities. Multimodality also explains a great deal of why some cities are more desirable to live in than others.

In this chapter I will provide an interpretation of the empirical findings of the previous chapter. Following this, I will describe multimodality’s importance as a sustainability indicator, as well as a variable in sociological research. I will then briefly discuss some of the limitations of this research and outline how to address these shortcomings in future research. Finally, I will discuss the urban policy implications of this research, with recommendations for how planners and policymakers should utilize this work.

Empirical Findings

The central goal of this research is to illuminate some fundamental differences between multimodal cities and automobile-dependent cities. The “three E’s” framework has been determined insufficient for investigating issues of sustainable urban development. Thus, this research is driven by four hypotheses:

a) “Different levels of automobile dependency have a measureable relationship to differences in cities’ human and environmental health.”

b) “Different levels of automobile dependency have a measureable relationship to differences in cities’ qualities of life.”

c) “Different levels of automobile dependency have a measureable relationship to differences in cities’ economic conditions.”

d) “Different levels of automobile dependency have a measureable relationship to differences in cities’ urban characters.”

In the next section I will discuss how these four hypotheses are borne out by the data. The results of all three testing methods are combined in Table 5.1. This table shows the results for each variable for the means testing by median and by exemplar, as well as the results of the regression analysis.

Health Theme. While there are stark differences in each of the four themes between these green and brown cities, the most important difference may be in the health theme. Despite the vast number of ways one can be unhealthy, multimodality’s influence is demonstrated even in broad measures such as Gallup/Healthways’ Well-Being Index Overall Health score. This shows the incredible reach that our transportation systems exert over our collective well-being. On the much narrower measurement of Healthy Behaviors, multimodality is not only powerful, it is the only explanatory variable in the model. Neither race, income, education nor density explain variation in the healthy behaviors of urban residents in these 148 cities. Increased transportation options for work imply increased transportation options for recreation and other travel needs. If there is a bike infrastructure suitable and safe enough for daily commuting, then there is also a bike infrastructure in place for other purposes.

Obesity has been definitively associated with the built environment, and rightfully so. Humans are built not only to walk, but to run. Removing the option to walk by forcing people to use a car to earn a living has impacted our very morphology. Multimodality explains more variation than any other variable in the model, besides the percent of African-Americans in the population. This is intuitively correct: Black neighborhoods suffer from a dearth of access to wholesome food, massive infrastructural disinvestment, racist hiring practices and segregation. That multimodality has a similar level of impact on obesity as does the Black American experience (albeit in the opposite direction) goes to show the power of multimodality.

Furthermore, the model shows that despite volumes of research to the contrary, it is not density that is the determining factor in obesity, but rather multimodality. Density was not a significant factor in the obesity model. Thus, we might be skeptical about research that considers density to be a determining factor in obesity. Unless controlling for multimodality, it is quite possible that density and obesity are merely correlated: The underlying factor may be multimodality. Finally, it appears that density—when controlling for multimodality and other variables—may have a positive effect on health outcomes, contrary to the conventional wisdom. This is likely related in no small way to access: Residents of dense cities may be, on average, marginally closer to emergency medical treatment, and experience a higher probability that someone is close enough to provide assistance to an injured person.

Premature death is possibly one of the most debilitating social strains on modern life. The impact on a family from such a loss cannot be calculated. The amount of loss that we endure as a society as a result of the automobile can hardly be expressed.

Happily, we have the ability to dramatically reduce this loss. Multimodality plays a mitigating role in the prevention of premature death to a much greater extent than even income. It is, in fact, rivaled only by higher education and urban density. The difference in the Years of Potential Life Lost between green and brown cities is about 13 percent, on average; between green and brown exemplars it is a difference of over 23 percent. This figure alone would seem to be a sufficient argument for increasing the multimodality of any city.

Airborne pollution has complex sources. While the 74 green cities did show lower NO_x emissions than the brown cities, the green exemplars did not show an improvement over their brown counterparts. In fact, the green exemplars were shown to have higher total emissions and carbon monoxide emissions. After controlling for the six control variables, multimodality was ultimately found to decrease total emissions per square mile—a major reason why regression analysis is so valued among social scientists. Nevertheless, there were no measureable benefits to MM for either NO_x or carbon monoxide emissions. Although this research shows that multimodality does decrease the concentration of pollution, there are many confounds. For example, green exemplars may be located in more industrial counties, or they may have highly-polluting energy sources such as coal, or some combination of the two. Additionally, what is not clear is whether the green cities have adopted a more multimodal transportation paradigm as a result of higher pollution levels, or if being "green" in the transportation sector has "enabled" browner processes in other emission-related sectors, such as manufacturing.

This research comports to findings on mental health and automobile dependency: There does not seem to be any benefit to multimodality after controlling for the six control variables. Similar in many respects to the idea of "average health," there are countless ways to be mentally and emotionally healthy or unhealthy. It is not surprising to find AD unassociated with mental and emotional health. Indeed, it may be that driving has many positive emotional effects: "getting away," "taking a ride," "getting out of Dodge" are all opportunities to take a much-needed break from the stress of everyday life, family and work.

The final point of interest from this theme is that the percentage of Black residents is also related to higher emissions. Toxic and high-emission industries are known to be located in proximity to African-American neighborhoods. With this finding, this research provides strong support for the field of environmental justice.

Health Theme Summary. Green cities have less obesity, fewer years of potential life lost and more options for healthy physical activity. Comparing their means to the dataset as a whole, it seems not that green exemplars are so much better than average, but that brown exemplars are so much worse. This research provides ample evidence that "Different levels of automobile dependency have a measureable relationship to differences in cities' human and environmental health."

Economy Theme. One of the most commonly heard tropes about sustainable development is that it is expensive. At first blush, this research seems to bear this out: In the green cities homes are more expensive, and homeowners pay a larger share of their income to buy them. Rents are significantly higher, and they consume more of their residents' income. The taxes are higher, as is the cost of living. All of this occurs with no measurable benefit to either employment levels or the regional economy in general.

What all of this seems to ignore is that this increased cost is largely a function of demand: People want to live in these cities. If we take a cue from some variables in the *urban character* theme, we start to develop a picture of this demand. First, the rental vacancy rates are 17 percent lower in green cities, despite having a larger percentage of rental properties. Cities such as San Francisco and Portland are frequently accused of not building enough housing units to keep up with demand. Secondly, green cities are attracting significantly younger—and more mobile—new residents. While much has been made of the "return to the city" by Millennials, it does not seem to be just any city, but rather the green ones.

So what role does an undesirable brown city like Fresno play in the cost of living of a relatively close, desirable green city such as San Francisco? Consider the outliers in the variable of average rental costs: On one hand you have the struggling post-industrial cities of Youngstown, Ohio and Flint, Michigan. On the other hand you have Honolulu, Hawaii and Santa Barbara, California. Are the first two cities doing a better job of keeping costs low, and providing ample housing? When viewed from this lens, it is clear that the claim that green cities are expensive is facile. A more informed view is that the brown cities are simply undesirable.

When cities such as Flint, Michigan take themselves off the market for consumers wishing to buy into environmentally clean and multimodal cities, it increases the scarcity of green cities. This drives up prices. So, instead of twisting the market further with state interventions in green cities, perhaps it is time for brown cities to go green and take some of the pressure off of our green cities' economies.

Looking closer at average rents, we find that they are significantly higher as a percent of income in green cities. This is interesting, considering there is less overspending by renters. One explanation is that the renters are paid more. While average incomes are not different between the two groups of cities, this tells us nothing of the distribution of that average: The lower-paid workers in green cities may be paid more than the lower-paid workers in brown cities. This is corroborated somewhat by the higher minimum wages found in states with green cities. Still, this is an empirical question, and one not answered by this dissertation.

When we compare the green and brown exemplars, this question of economic well-being and multimodality becomes even more compelling: The median Black household income is over 15 percent higher in the green exemplars. Recall that there is no difference in household income between green and brown cities: Both hover around $30,000 a year. How is this possible? This relationship holds even when controlling for race, education and income in the regression tests.

One explanation is that this measure is for *household income*, not *individual wages*. African-Americans have larger and more intergenerational households than whites. With more transportation options available, more jobs are within reach by more members of the family. Another complimentary explanation is access: When more working-class people can access a greater proportion of the local job market, this puts pressure on firms to pay more. African-Americans likely benefit from this pressure more than do whites, on average.

There was no measurable difference in unemployment between brown and green cities when divided along the median of multimodality. There is an indication that green exemplars perform better than do brown exemplars. On the other hand, after introducing the six control variables in the regression, the relationship between MM and employment becomes insignificant.

Why is this the case? It could very well be that there is a nonlinear relationship at work: It may be that a certain threshold of multimodality needs to be achieved before the full range of employment opportunities across the city can be accessed. If this is true, then further research using more advanced methods would be needed to find it: The type of regression tests used in this research are unsuitable for analyzing nonlinear relationships.

With regard to the state minimum wages and state and local tax burden being higher in multimodal cities, we can only make informed speculations. We know that cities are the major source of population and power in nearly every U.S. state: The simplest explanation is that green cities are in green states. This is, of course, another empirical question, which cannot be confidently asserted from this research. Nevertheless, it is unlikely to be a fluke.

Multimodality is associated with increased taxes: More choices cost more money, and mass transit is the most widely utilized component of multimodality. While federal transportation funding is critical, it is assumed that most cities and states contribute significant resources to transportation provision—this implies taxes.

Another source of increased taxes are the social services required by cities with larger proportions of impoverished citizens. While there is no statistical difference between green and brown cities, the green exemplars contain significantly higher proportions of impoverished residents; this holds through the regression. Multimodal cities are more attractive to poor people, especially considering the higher minimum wages and, possibly, a greater public commitment to social services. Economist Ed Glaeser and colleagues have described poverty as a *negative externality* of transit (Glaeser, Kahn, & Rappaport, 2008). This seems to be a category mistake: An externality is a cost of production which is not paid for by the producer, but is instead paid for collectively by others. The product of transportation is mobility and access. Poverty is not a by-product of this production; it exists prior to and independently of the provision of mobility. It seems more accurate to think about poverty as a negative externality of the current distribution of means and resources in society.

For whatever reasons, the regional economic variable provided by Sperling's is not significantly associated with multimodality. It is very likely that the scale mismatch between this MSA-level measurement of the economy and the city-level measurements of multimodality is too divergent to be measurably associated. That said, there are other MSA-level measurements in this study that are measurably connected to MM. It is more likely due to the nature of indices: The component elements of regional constructs like "the economy" should be put together carefully so that the various components within them do not wash each other out.

Economy Theme Summary. When making the "green cities are expensive" argument, many seem to conveniently ignore the other half of the "supply and demand" trope: The lack of desirability of brown cities means that green city living will be more expensive. The question is what will happen if brown cities go green. If there is more competition for healthy, connected, equitable urban living, then the prices should drop in even the most desirable cities. The onus has been put on green cities to reduce their costs of living, but this is wrong-headed, especially considering the collective burden that brown city living places on society through poor health of the citizenry and other problems. Again, there is enough evidence to conclude, “Different levels of automobile dependency have a measureable relationship to differences in cities’ economic conditions.”

Quality of Life. Arguably, the clearest differences between multimodal cities and auto-dependent cities are found in the theme of quality of life. When comparing green versus brown cities, six of the eight variables favor multimodal cities. Seven of the eight significantly favor the green exemplars. Five of the measures hold through the regression, showing a positive relationship between QoL and MM. Again, we must ask, “What is the process at work?” Why are multimodal cities higher in QoL? Importantly, there are two types of measures: Those that aggregate amenities representing QoL (Sperling’s), and survey responses where people’s opinions about their regional QoL are collected.

What are some reasons why a person might feel their city has a high quality of life? There are many, to be sure, but chief among them would be better health outcomes for their neighbors and relatives. Living in a city where more people had access to the local economy might be another. Perhaps it is the more connected social environment. The brilliant thing about multimodality is that you do not have to make use of it in order to feel its impact.

Still, the simplest answer would be that you and the people in your circle have more access to leisure. Recall that the Sperling’s Leisure variable is has the highest amount of its variation explained of any model in the QoL theme. In addition, multimodality is again the variable that makes the most noticeable contribution to the

Leisure model, followed by population. The level of multimodality in a city is in no small way also a measurement of the availability of multimodal infrastructure, such as bike paths and lanes, walkable streets, etc. Thus, while leisure may initially seem to have a tenuous connection to automobile dependency, those cities in which walking and biking are easy to use for commuting also accommodate walking and bicycling for leisure. Places with higher numbers of people who enjoy biking and walking to work also have more opportunities to bike and walk for recreation, although it may not be clear which is causal of the other.

Interestingly, density plays no determinate role in Sperling's measurements of QoL. In fact, contrary to the conventional wisdom which suggests big cities are full of miserable people, increased density supports a higher quality of life in both the Sperling's and the Gallup/Healthways' measurements, including Life Evaluation. Multimodality plays a leading role in these differences. The upshot is that too much has been attributed to density, when it is clear that it is *how that density is deployed* that matters. A clear example of this is in the provision of urban leisure amenities.

Quality of Life Theme Summary. Quality of Life (QoL) is a relatively new concern in the sustainability of cities. As illustrated by the research discussed in the literature review, connecting QoL to indices of sustainability—many of which contain factors that are difficult to connect to QoL—has been shown to be less than conclusive. The more direct measurement of multimodality is extremely robust by comparison.

Furthermore, the negative correlation between density and "happiness" has been shown to be spurious: Density can be multimodal or automobile dependent. Similar to the role of density in determining obesity, studies on QoL that do not incorporate multimodality are likely to be confounded by its absence. When considered alongside measures of health, the green cities simply seem like better places to live. Clearly, “Different levels of automobile dependency have a measureable relationship to differences in cities’ qualities of life.”

Urban Character Theme. The sustainability of a city is not simply a matter of having better health outcomes, a higher quality of life or a better economy. All of those things matter to a city’s ability to attract talent and investment. Still, there are other subjective and aesthetic aspects to a city’s desirability that have not been explored much in urban sustainability literature. When this aspect of urban living does make its way into the public discussion, it is often in terms of “the 30 most vibrant cities” or “the cities with the best nightlife.” These perspectives make a great deal of assumptions about what is important, and to whom.

As many New Urbanists have declared, the built environment not only informs *where* you are, but also *who* you are. It shapes the possibilities of various activities, such as leisure: If there are no parks, you cannot go to the park. Even more, the built environment is *pedagogic*: It teaches you about your relationship to the people, places and institutions around you.

This theme attempts to inspect a few variables that are more objective in their relation to the aesthetic experience imbued by different cities. So how are green cities different from brown cities with regards to the theme of urban character?

The physical size of a city, while often understated, clearly matters. The experience of living in a physically large city is qualitatively different from living in a small city. The spatial proximity between people and places is greater in large cities, and this has implications for city life and the relationships between residents. Smaller cities are traversed more easily, and thus, more residents can access a greater proportion of shops, services and amenities. This puts more different types people in contact with each other; this increase in contact has real implications.

While there is no difference in size between brown and green cities when divided along the median of multimodality, green exemplars are significantly smaller than are brown exemplars. It is likely that small physical footprint supports compaction, which supports multimodality. However, the reverse is probably also true: If MM cities are compact, then they have less pressure to expand in the first place.

Outliers on the large end include massive Anchorage, Alaska and Jacksonville, Florida. Looking only at the data, neither of these cities is necessarily more automobile-dependent as a result of its size: Both include vast empty spaces. With a comparatively compact city center, Anchorage has a respectable 25 percent MM. Even sprawling Jacksonville is close to the mean at 19 percent. A measure of compaction might be more useful than either density or size.

There was no measurable difference between multimodal and auto-dependent cities in either bivariate test, nor did the regression show any hint of an association between MM and climate. There does not seem to be any bearing on modal choice regarding the climate. Cold-weather cities like Minneapolis might have invested more in making transit comfortable, with heated bus stops and train stations. Nevertheless, the idea that multimodal transportation is a non-starter in the United States due to some imagined characteristic of Americans as being intimidated by the weather can probably be laid to rest.

While scoring better than the brown cities, the mean walkability for both green cities and green exemplars is still low: Even the green exemplars' average score of 48 is considered by the creators of the measure to be "car-dependent." Still, sustainability is a matter of degrees: Even if the green exemplars are not perfect examples of walkability, they are significantly more walkable than their brown counterparts. Controlling for the six variables in the regression analysis shows that the relationship still holds: Multimodal cities are more walkable.

Walkability is best thought of as a contributing factor towards MM, and not the other way around. In other words, it is unlikely that high levels of MM cause walkability, but the reverse is probably true. On the other hand, a high desire for multimodality may cause cities to develop in such a way as to increase walkability (e.g. residents may support infill development). This variable has one outlier. Lake Havasu City, Arizona has a remarkably low walkability score. This is not surprising given both the retirement community focus and Sunbelt sprawl of the southwestern United States.

One limitation of walkability as a descriptive component of urban character is that nearly every municipality is likely to have a wide range of walkability among its neighborhoods. This level of aggregation (i.e. municipalities, or "places") washes out the impact of a few highly walkable neighborhoods. Thus, one area of future research would be to identify the level of impact that the presence of a highly walkable district has on the overall municipal MM, as well as the four themes.

Much has been speculated about the return of Millennials to urban life, and so the median age of new residents is included here. Young new residents and multimodality were found to be associated in both the means tests and the regression analysis. This is supported by recent findings that show that young people may be spearheading a new migration out of the suburbs and into the city: Cities with built environments that resemble and perform like the suburbs might not be attractive.

How long this migration will last is another question. Young people like novelty, and each new generation is somewhat different from its predecessor. If most Millennials were raised in the suburbs, they might view downtown living as a temporary excursion. Housing options for urban families may preclude this migration back to the suburbs, if they can be built before many of them start families. The next generation, raised in the city, might idealize the suburbs!

Some cities have long average commute times—up to 45 minutes or more—while other city commutes are as low as 15 minutes. The social impact of the commute time is subtle, but substantive: The time commitment required for the average work commute dictates how much discretionary time is available to residents for other activities, such as leisure.

Increased levels of multimodality are associated with longer SOV commute times. It is probably not the case that getting more people out of cars increases the commute time, but rather that long commute times can help get people out of cars. Outlier Pittsburgh, with the longest SOV commute time, is also the highest in MM. Long SOV commute times may indeed make a somewhat longer transit commute time marginally more attractive. Still, having a diversity of modalities sharing the same physical space (the street) may tend to slow down the automobile commuter.

Another interesting finding is that, by far, the strongest predictor of mean commute time is the percent of African-American residents. It seems uncontroversial to suggest that cities with large black populations have been historically under-supported with infrastructure. Such cities may have been underinvested by the state, and as a result suffer from inefficient transportation networks. Recall that the percent African American was negatively correlated to multimodality. Thus, it is important to keep in mind that having a car does not mean you are maximizing the benefit of living in an automobile-dependent city.

Furthermore, there is no measurable benefit to transit users in multimodal cities versus automobile-dependent cities: Multimodal cities do not have lower transit commute times. Buses and trains are beholden to their design: The need to stop and pick up customers at frequent intervals is the same in both types of cities. On the other hand there are cities such as Curitiba, Brazil that have designed their buses and bus stops to minimize the loading time at each bus stop. So, while it is often remarked that high SOV commute times may make transit more attractive, the reverse is probably also true: Low MM commute times may make SOV commuting less attractive.

Housing is another critical aspect of a city's character. It was expected that multimodal cities would have more housing diversity, measured in a lower percentage of single-family detached homes (SFDH). The relationship between housing diversity and MM holds throughout the bivariate and multivariate analysis. Multimodality has been shown to be associated with more diverse housing choices. This finding is seen as supporting the model and the validity of the automobile dependency measurement used in this research.

Not surprisingly, multimodal cities have more rental properties. Intuitively, higher incomes are strongly associated with a lower proportion of rental units. Less intuitively, more college education is associated with more rentals. This finding, in light of the fact that income and education are traditionally tightly related, is curious. The incorporation of a control variable for college-town status would help to disambiguate the influence of colleges and universities on the provision of rental units. Still, the association between education and percentage of rentals is not necessarily due to college students. Undergraduate students are not counted in the education variable: They have not yet acquired a bachelor's degree, and many move after they graduate. Furthermore, graduate students are comparatively few, and some own homes. On the other hand, colleges employ more college-educated workers, including faculty and staff.

Percentage of rentals has one of the strongest associations with MM of any variable. It is possible that a more mobile workforce facilitates more rental units: When people have wider access to more jobs, property owners have more opportunities to rent. It would also be useful to know the proportion of single-family detached rental homes versus apartments. It may very well be that multimodality needs to be supported by an adequate distribution of rental properties.

Green cities have lower vacancy rates for rentals, but not homes. Meanwhile, green exemplars have lower vacancy rates for both SFDHs and rentals. However, this variable does not hold through the regression. As a measurement of demand, lower vacancy rates indicate an efficient property market. A city with diverse housing options and ample rentals will have a qualitatively different aesthetic than a city dominated by SFDHs, such as Tom's River, New Jersey.

Urban Character Theme Summary. If urban character matters, then cities would do well to increase the mobility of their workers. Multimodal cities attract young residents, and have fewer housing vacancies. Increasing a city's multimodality may also help minorities suffer less from American cities' legacy of disinvestment and automobile-centered infrastructure.

Smaller cities are greener cities because they facilitate MM: Those cities which can deliver the essentials for a modern urban life in a smaller spatial footprint are helping to fight climate change, as well as offering more just city living through increasing the access of people with differing mobility. While remembering that compaction alone is not a sufficient condition for an equitable city, this finding supports the use of growth-management strategies. However, it also seems reasonable to suggest that MM cities have less need to expand spatially. Finally, the local climate has no measurable impact on rates of MM. Planners and others should stop using the local climate as an excuse to limit multimodal development.

Multimodality as an Urban Indicator and Research Control

Multimodality was explored for its value as an indicator of urban sustainability, as well as for its usefulness in urban research more generally. It has been shown to have broad and important relationships across a wide range of urban and sustainability-related concerns in all four themes.

In comparison to the other control variables, multimodality seems to be at least as important a consideration as income, education, density, population and even race. Of the 27 models where MM was significant in the regression, only the percentage of college-educated people came close to a similar level of relevancy, with 20 significant relationships. Of the 47 dependent variables used, 26 were significant in both the bivariate and multivariate tests used. Ten variables were significant in the bivariate analysis, but controlled out of significance in the multivariate tests.

However, MM does not explain everything. An additional 10 variables were significant in neither analysis, and over half of those were airborne emissions variables measured at the larger scale of the county. For these it is assumed that the impact of multimodality at the municipality level is unable to be discerned at the average county level of various airborne emissions, such as carbon monoxide. On the other hand, a relationship between multimodality and total emissions per square mile—while insignificant at the bivariate level—can be observed *after* controlling for six common control variables. In any event, it is clear that the utility of this measure of car dependency in urban research merits additional theory and analysis.

There are many urban systems and practices that can be more or less sustainable. Thus, there is a need for a wide range of sustainability indicators, which can help planners and other assess progress towards various goals. However, not all systems and practices are equally important. This research shows that high levels of automobile dependency have wide-ranging impacts across seemingly unconnected social outcomes. Therefore, robust measures of automobile dependency should be prioritized among indicators.

This research shows how more accurate constructs for research in urban sustainability can improve our understanding of the phenomena under study. Multimodality—and the percentage of people who commute by SOV—is a determining factor in many social outcomes. Its use as a dependent variable has been valuable, but represents a severe underutilization of this data.

Policy Recommendations

This research supports a shift away from the problematic focus on sprawl and toward addressing those characteristics of sprawl that are unsustainable, such as automobile dependency. A great deal of our public policy is focused on increasing the density of a city. This research suggests that, instead of policy focusing on infill development for density's sake, planners and others should develop urban environments that foster connectivity, mobility, redundancy, diversity, access and equity.

There are important lessons in this research for automobile-dependent cities. In existing low-density cities, we might avoid narrow policies that are preoccupied with infill development. As the data bears out, increasing density alone is insufficient to attain the positive differences that green cities enjoy. What is equally important is increasing the means to access those developments. Instead of a reductionist approach with singular means intended to achieve singular goals, planners and others should consider the *relationship* between infill and healthier modalities.

This is particularly true if costs are an issue: Bike lanes and sidewalks are much less expensive than increasing the density of the built environment. Such investment in mobility may spur additional infill development between existing destinations: People can stop and park their bicycles much more easily than parking a car. Frequent and reliable bus and rail transit makes stopping in the middle of a trip less burdensome.

For high-density, automobile-dependent cities, it is somewhat more complex, as there is less space to accommodate multiple modalities. Here, more radical thinking may be required. Restricting automobiles from certain high-density shopping areas would not only encourage more foot traffic due to improved pedestrian safety, it would decrease the level of emissions in those open air spaces as well. This would create a more inviting, human-centered space. The central corridor in downtown Minneapolis, Nicollet Mall, is one such area. The street there is limited to buses and bicycles; the shops and restaurants that line the corridor are usually bustling. As the city is likely to receive many benefits from this approach, policymakers could afford to offer tax credits as an incentive for developers to invest in their city. A longer view is needed.

In short, urban policy should require developers not just to increase density, but to have a sense of aesthetics, as well. Instead of increasing and diversifying access alone, development should be prioritized in the interest of connectivity. For example, cities demonstrate a great deal of variation in density within their borders. The placement of a new residential development in the lowest density neighborhood of the city would certainly increase density. If that is the goal, then the development will be a success.

However, a development in this area, removed from third-place destinations, is likely to encourage automobile use. This automobile use will impress its negative impacts on areas that are multimodal, degrading the benefits of the more multimodal areas of town. The upshot is that cities need to be developed as wholes, a departure from the oxymoronic incremental comprehensive planning paradigm.

Limitations and Future Research

Like all research, this work has some limitations. Research in the social sciences, or any science for that matter, is a conversation among experts and their published studies. A study should be situated in that discussion. However, the unit of analysis used here—the isolated, mid-size U.S. city—is rarely used in urban research; therefore comparing the outcomes of this work with research that uses measurements taken at the

MSA-level is problematic. Nevertheless, U.S. Census “places” are considerably less arbitrary than MSAs in their make-up; it is assumed that these results are more accurate measurements of the relationship between the many facets of urban life and MM.

This work could also be criticized for reliance on bivariate analyses. Furthermore, as useful as multiple regressions can be, OLS is not suitable for exploring nonlinear relationships. Still, statistical analysis begins with simple procedures such as the interpretation of descriptive variables, and only afterwards increases in complexity. In other words, research in the social sciences is best approached using a step-wise process, where the inspection of data proceeds along with increasing complexity and more nuanced tests. I believe this level of analysis is a good place to stop and reflect on the findings.

Theory is one half of the research coin. Unfortunately, this field offers very little in the way of robust theory. The literature is both limited and diverse. For example, I have drawn on literature that contains some measure of automobile dependency. Unfortunately, in nearly every case the measurements of AD found in that literature capture fundamentally different aspects of automobile use. In addition, the literature around sustainable development is even more diverse; not only do they inspect different aspects of SD, they often use different conceptions of what SD actually is. Thus, the conceptual framework for this research is of the broadest sort. This encourages the survey aspects of the work, but at the cost of focus.

Related to this issue of extant theory is the urban character theme’s theoretically undefined nature. However, there are enormous possibilities for this construct. Some additional variables might include a tolerance index, or a segregation score. While it is difficult to conceptualize such a construct, if we are striving to see cities as more than economic machines, we need to look for alternatives.

It is assumed that the central city in these isolated metros is the strongest factor in determining these many social outcomes, but this may not always be true. Knowing this difference would go far to explain the relationship between the central city and the larger MSA around it, as found in this study. Even so, the use of the municipal level of analysis such as can be found in this research can equip urban planners, citizens and policymakers with compelling evidence in support of multimodal transportation policy.

One major assumption of this research is that MM is a useful and substantive factor that is often hidden in sprawl research. However, the opposite may also be true: The influence of sprawl may be undergirding many of the outcomes found here. Thus, the next step for this line of inquiry is to more accurately assess the unique contribution of sprawl and automobile dependency. This can be done by treating each as latent variables in an exploratory factor analysis. Three latent variables is assumed to be a minimum, so at least one additional factor (e.g. housing typology) will also need to be included.

Other limitations include the choice of control variables. For example, population was one of the weakest predictors of outcomes. Therefore, in future research the population variable will be swapped out for physical size in square miles. While latitude has been useful, it is possible that the dependent variable of climate as measured by Sperling's would be a more accurate control variable; future work will explore this possibility.

The segregation of African-Americans seems to be another variable that would help us to better understand the relationship between MM and social outcomes. It would be interesting to swap out the percent of the population that is African-American for the level of segregation of that community.

Another important concern might be the disposition of the employment sector: Are there a few large employers who are scattered throughout the metro, or are there many smaller firms concentrated in a few neighborhoods? This would be helpful for understanding the source of higher African-American incomes in MM cities, as well as the overall economy.

In some ways the cases are divided arbitrarily. For example, there is no rational basis for comparing the top 25 cities with the bottom 25: The number could just as easily be 20 or 30. There are statistical methods that could be used to more accurately categorize these cities, such as cluster analysis. However, it is assumed that minor changes in this area will not overturn the findings here. Likewise, green and brown could be divided along the mean. However, using the median is more conservative: Using the mean of MM as the first basis for a t-test would almost certainly make the differences between green and brown cities even more stark.

Next steps in this research would include comparing the difference between the 148 cities of the dataset with the other 600+ cities that are not isolated. This will help answer the question of how different “Molotch and Appelbaum cities” are from U.S. cities in general. Additional research using this methodology would also help us to revisit the larger discussion around the relationship between the central city and the suburb, which has received little attention lately. Despite these limitations, this work contributes to our overall knowledge about the impact of multimodality on urban life.

Dissertation Summary

American dependency on the automobile as the primary means of urban transportation has deep influences on the lives of city residents. The privileging of automobile infrastructure has resulted in many subtle but powerful impacts across the social landscape. We have traded in broad swathes of our individual and civic well-being for an increase in individual access. Not only does this have health and economic effects, but quality of life effects as well. The city as a whole is strongly impacted and even shaped by this fundamental feature of urban life, as is the surrounding region. Multimodality heralds the opening of a new front in the war for social equity. What is remarkable is that it is a war that we can easily win.

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APPENDIX A – FIGURES

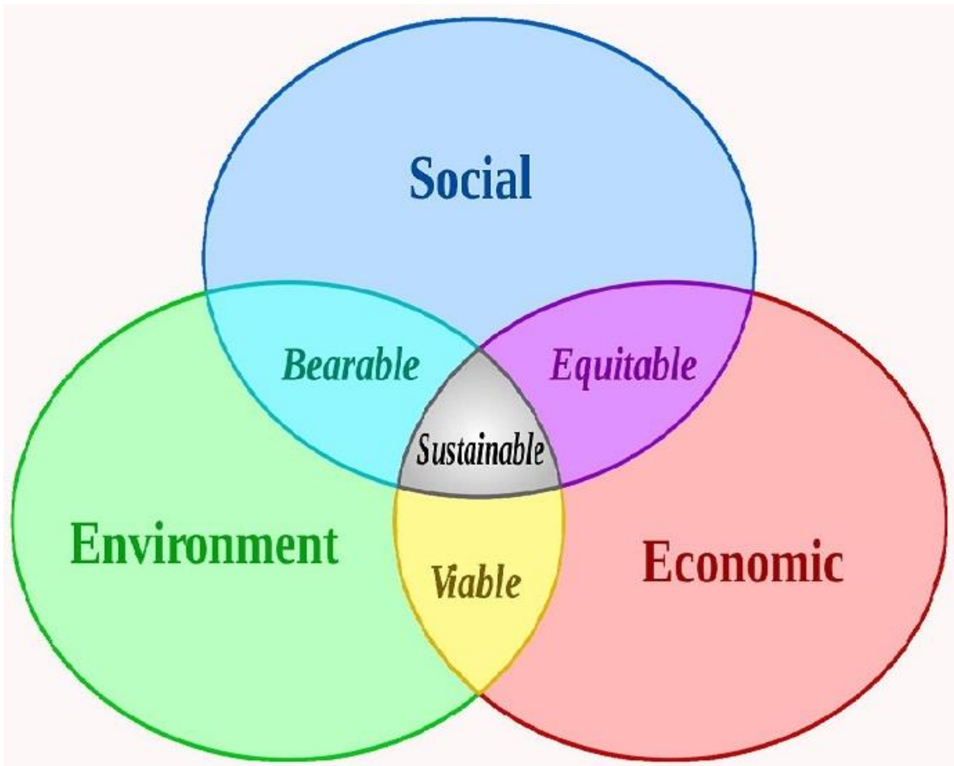


Figure 1.1 The 'Three Es' Venn-type Diagram. (source unknown) retrieved on April 22, 2016 from: https://en.wikipedia.org/wiki/File:Sustainable_development.svg

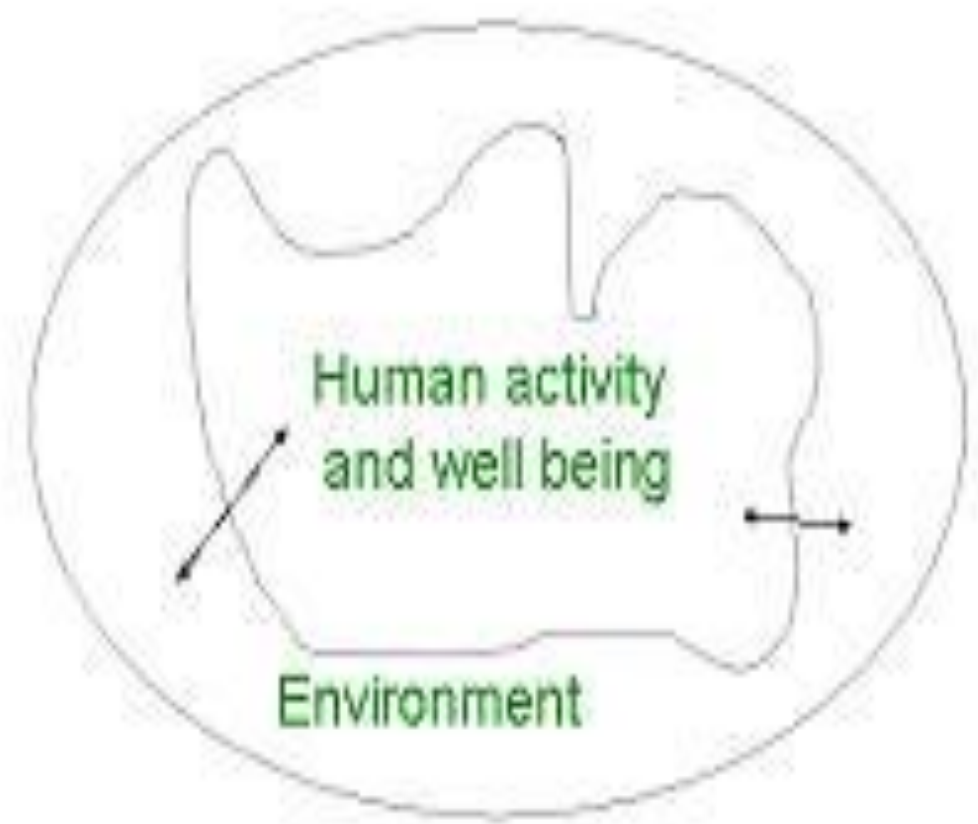


Figure 1.2 An Alternative Conception of Sustainable Development (From Giddings, B., Hopwood, B., & O'Brien, G. (2002).

APPENDIX B – TABLES

Table 2.1 Research Constructs: Sustainable Development and Automobile-use

Construct	Measurement	Citation
Airborne Emissions	Automobile Use	–
	Automobile Use;	Litman, 2002b;
Premature Death	Walkability	Gilderbloom et. al, 2015
	Sprawl;	Ewing et. al, 2008;
Health Quality	Urban Design	Frank, 2006;
		Ewing & Cervero, 2010;
	Sprawl;	Newman & Kenworthy,
	Density;	1989
Obesity	Fuel Prices	Courtemanche, 2011
Emotional Health	Sprawl	Sturm & Cohen, 2004
Overspend Housing	Sprawl	Hamidi & Ewing, 2015
		Litman, 2002a;
Median Home Value	Sprawl	Hamidi & Ewing, 2015
Med. Rent as % Inc.	Sprawl	Hamidi & Ewing, 2015
	Sustainable Development	Solow, 1991;
Sperling's CoL	(*i.e.* regulation)	Taylor, 2002
		Litman & Laube, 2002;
Unemployment	Automobile Use	Litman, 1999
		Litman & Laube, 2002;
Income and Wages	Automobile Use	Haas, et. al, 2013
		Solow, 1991;
State/Local Tax	Regulation	Taylor, 2002
		Giuliano, 2003;
Black Household Income	Transportation Access	Covington, in progress
% Pop. in Poverty	Transit	Glaeser & Kahn, 2014
		Litman & Laube, 2002;
		Litman, 1999;
		Vasconcellos, 1998;
	Automobile Use;	Litman, 2014;
	Automobile Dependency;	Williams, Burton, & Jenks,
Sperling's Econ/Jobs	Compactness	2000
		Cloutier, Jambeck, & Scott,
		2014;
		Cloutier, Larson, &
	"Sustainable	Jambeck, 2014;
	Development";	Bieri, 2013;
QofL	Density	Glaeser, 2014
		Cevero, 2005; Litman,
		2015;
Access	Compactness	Williams, et. al, 2000

Table 2.1 Research Constructs: Sustainable Development and Automobile-use, con't.

Geographic Size	Automobile Use	Haas, et. al, 2013
Sperling's Climate	Multimodality	Stinson & Bhat, 2004
WalkScore	Walkability	Gilderbloom, 2015
New Resident Age	Multimodality; Recession	Chapple, 2014; Deal, Altman, & Rogelberg, 2010
Mean Commute Time	Compact Development; Sustainability Policy	Gordon & Richardson, 1989; Pitt, 2010
Owner Vacancy Rate	Walkability; Aging Population	Dong & Hansz, 2016; Gilderbloom, Riggs, & Meares, 2015; Pitkin & Myers, 2008
Rental Vacancy Rate	TOD	Renne & Wells, 2003
Civic Assn's/10k	Sprawl	Putnam, 2000

Table 3.1 Multimodality in 148 U.S. Cities

City	% MM	City	% MM
Pittsburgh, Pennsylvania	44.3	Asheville, North Carolina	24.0
Reading, Pennsylvania	44.1	Athens, Georgia	23.7
Ann Arbor, Michigan	42.6	Columbia, Missouri	23.7
Honolulu, Hawaii	42.5	Lansing, Michigan	23.7
Bloomington, Indiana	39.5	Lynchburg, Virginia	23.6
Madison, Wisconsin	36.5	Wilmington, North Carolina	23.6
Champaign, Illinois	36.2	Savannah, Georgia	23.5
Jacksonville, North Carolina	36.1	Saginaw, Michigan	23.2
Gainesville, Florida	35.7	Yuba City, California	23.2
Syracuse, New York	35.4	Lafayette, Indiana	23.0
Columbia, South Carolina	34.8	Pocatello, Idaho	23.0
Flagstaff, Arizona	34.7	Columbus, Georgia	22.8
Santa Barbara, California	34.5	Charleston, West Virginia	22.5
Bellingham, Washington	33.8	Eau Claire, Wisconsin	22.4
Portland, Maine	33.8	Yakima, Washington	22.3
Santa Maria, California	32.8	San Angelo, Texas	22.2
Ames, Iowa	32.4	St. Cloud, Minnesota	22.2
Lancaster, Pennsylvania	31.9	Bowling Green, Kentucky	22.1
Frederick, Maryland	31.5	Yuma, Arizona	22.1
Rochester, New York	30.9	Auburn, Alabama	22.0
Missoula, Montana	30.8	Wichita Falls, Texas	22.0
Salinas, California	30.5	Medford, Oregon	21.9
Richmond, Virginia	29.9	Billings, Montana	21.5
Lawton, Oklahoma	28.6	Lake Havasu City, Arizona	21.5
Santa Fe, New Mexico	28.5	Pueblo, Colorado	21.4
Chico, California	28.2	Baton Rouge, Louisiana	21.3
Delano, California	27.9	Victoria, Texas	21.3
Scranton, Pennsylvania	27.6	Pensacola, Florida	21.2
Manhattan, Kansas	26.5	Youngstown, Ohio	21.2
Duluth, Minnesota	26.3	Grand Junction, Colorado	21.1
Utica, New York	26.1	St. George, Utah	21.1
La Crosse, Wisconsin	26.0	Canton, Ohio	20.8
Anchorage, Alaska	25.6	Corpus Christi, Texas	20.8
Rochester, Minnesota	25.4	El Paso, Texas	20.8
Harrisonburg, Virginia	25.3	Lexington, Kentucky	20.8
Erie, Pennsylvania	25.1	Amarillo, Texas	20.7
Bend, Oregon	24.9	Green Bay, Wisconsin	20.7
Albany, Georgia	24.8	Flint, Michigan	20.6
Salem, Oregon	24.5	Bakersfield, California	20.5

Table 3.1 Multimodality in 148 U.S. Cities, con't.

City	% MM	City	% MM
Colorado Springs, Colorado	20.5	Terre Haute, Indiana	17.8
Laredo, Texas	20.5	St. Joseph, Missouri	17.7
Dubuque, Iowa	20.4	Cheyenne, Wyoming	17.6
Valdosta, Georgia	20.2	Rockford, Illinois	17.6
Bismarck, North Dakota	20.1	Grand Island, Nebraska	17.4
Columbus, Ohio	19.9	Lake Charles, Louisiana	17.2
Springfield, Illinois	19.9	Lubbock, Texas	17.1
Abilene, Texas	19.8	Decatur, Illinois	17.0
Idaho Falls, Idaho	19.7	Sioux City, Iowa	16.7
Jacksonville, Florida	19.7	Conway, Arkansas	16.6
Roanoke, Virginia	19.6	Jackson, Mississippi	16.6
Manchester, New Hampshire	19.4	Janesville, Wisconsin	16.6
Redding, California	19.3	Knoxville, Tennessee	16.5
Tuscaloosa, Alabama	19.3	Rocky Mount, N. Carolina	16.5
Fargo, North Dakota	19.2	Joplin, Missouri	16.3
Chattanooga, Tennessee	19.1	Clarksville, Tennessee	16.0
Greenville, South Carolina	19.1	Jonesboro, Arkansas	16.0
Grand Forks, North Dakota	19.0	Kokomo, Indiana	15.9
Lincoln, Nebraska	18.9	Longview, Texas	15.9
Lafayette, Louisiana	18.8	Waterloo, Iowa	15.9
Toledo, Ohio	18.8	Fort Wayne, Indiana	15.5
Peoria, Illinois	18.7	Sioux Falls, South Dakota	15.5
Rapid City, South Dakota	18.6	Vineland, New Jersey	15.5
Tallahassee, Florida	18.6	Shreveport, Louisiana	15.4
Casper, Wyoming	18.5	Owensboro, Kentucky	15.2
Great Falls, Montana	18.5	Wichita, Kansas	15.2
Fayetteville, North Carolina	18.3	Mobile, Alabama	15.1
Gulfport, Mississippi	18.2	Toms River, New Jersey	14.7
Waco, Texas	18.2	Davenport, Iowa	14.6
Greenville, North Carolina	18.0	Montgomery, Alabama	13.9
Springfield, Missouri	18.0	Jackson, Tennessee	13.3
Tyler, Texas	18.0	Dothan, Alabama	10.6
Augusta, Georgia	17.9		
Las Cruces, New Mexico	17.9		
Louisville, Kentucky	17.9		
Akron, Ohio	17.8		
Evansville, Indiana	17.8		
Fort Smith, Arkansas	17.8		

Table 3.2 Variable Descriptions

Theme	Years	Values	Source	Scale
Urban Character				
Geographic Size	2010	Sq. Miles	US Census	City
Sperling's Climate	2007	Score	Sperling's	MSA
WalkScore	2014	Score	WalkScore	City
Median Age, New Residents	2013	Years	US Census	City
Mean Commute	2013	Minutes	US Census	City
Mean Car Commute	2013	Minutes	US Census	City
Mean Transit Commute	2013	Minutes	US Census	City
Percent Single Detached Homes	2013	Percent	US Census	City
Percent Rentals	2013	Percent	US Census	City
Owner Vacancy Rate	2013	Percent	US Census	City
Rental Vacancy Rate	2013	Percent	US Census	City
Civic Associations p/10k Pop.	2013	Number	CBP	County
Economics – Costs				
Percent Overspending, Rent	2013	Percent	US Census	City
Percent Overspending, Own	2013	Percent	US Census	City
Tenure Gap	2013	Percent	US Census	City
Median Home Value	2013	Dollars	US Census	City
Median Rent	2013	Dollars	US Census	City
Median Rent as % of Income	2013	Percent	US Census	City
Sperling's Cost of Living	2007	Score	Sperling's	MSA
Economics – Income				
15yr. Median Unemployment	1990-2005	Percent	BLS	County
State Minimum Wage Score	2005-2014	Z-Score*	BLS	State
State and Local Tax Burden	2011	Percent	Tax Found.	State
Median Black HH Income	2013	Dollars	US Census	City
Percent Population in Poverty	2013	Percent	US Census	City
Sperling's Economy/Jobs	2007	Score	Sperling's	MSA

* the sum of several z-scores

Table 3.2 Variable Descriptions, con't.

Theme	Years	Values	Source	Scale
Quality of Life				
Sperling's Overall	2007	Score	Sperling's	MSA
Sperling's Leisure	2007	Score	Sperling's	MSA
Sperling's Quality of Life	2007	Score	Sperling's	MSA
Sperling's Arts	2007	Score	Sperling's	MSA
G/H Overall	2014	Rank	Gallup	MSA
G/H Life Evaluation	2014	Rank	Gallup	MSA
G/H Work Environment	2014	Rank	Gallup	MSA
G/H Basic Access	2014	Rank	Gallup	MSA
Health – Environmental				
Total Emissions	2011	Tons	EPA	County
Total Emissions, p/cap.	2011	Tons	EPA	County
Total Emissions, p/m^2	2011	Tons	EPA	County
Total NO_X	2011	Tons	EPA	County
NO_X, p/cap.	2011	Tons	EPA	County
NO_X, p/m^2	2011	Tons	EPA	County
Total CO	2011	Tons	EPA	County
CO, p/cap.	2011	Tons	EPA	County
CO, p/m^2	2011	Tons	EPA	County
Health – Human				
YPPL, p/100k	2010-2012	Years	NCHS	County
Percent Below Average Health	2006-2012	Percent	CDC	County
Percent Obese	2011	Percent	CDC	County
G/H Emotional Health	2014	Rank	Gallup	MSA
G/H Physical Health	2014	Rank	Gallup	MSA
G/H Healthy Behaviors	2014	Rank	Gallup	MSA
Control Variables				
Latitude	2010	Degrees	US Census	City
Density	2013	Count	US Census	City
Population	2013	Count	US Census	City
Median Household Income	2013	Dollars	US Census	City
Percent Population Black	2013	Percent	US Census	City
Percent Pop. College Educated	2013	Percent	US Census	City
Multimodality	2013	Percent	US Census	City

Table 3.3 Descriptive Statistics

Theme	N	Min.	Max.	Mean	SD	Scale
Urban Character						
Geographic Size*	148	7.23	325.25	64.53	55.76	City
Sperling's Climate	143	0	100	46	29	MSA
WalkScore	148	15.0	80.0	36.35	10.26	City
Median Age, New Res.	148	22.9	53.1	33.69	4.55	City
% Single Detached Homes	148	11.0	79.5	58.42	12.25	City
Mean Commute	144	15.3	31.7	21.13	2.93	City
Mean Car Commute	144	15.2	30.9	20.77	2.97	City
Mean Transit Commute	144	13.4	69.3	36.29	10.58	City
Percent Rentals	148	20.2	67.1	47.14	8.25	City
Owner Vacancy Rate	148	0.6	8.8	2.46	1.20	City
Rental Vacancy Rate	148	0.9	15.7	6.87	2.90	City
Civic Assoc. p/10k Pop.	148	3.1	19.8	11.3	3.2	County
Economics – Costs						
% Overspending, Rent	148	29.0	62.9	45.75	5.98	City
% Overspending, Own	148	16.6	49.7	30.79	7.13	City
Tenure Gap	148	-52.07	73.13	30.52	22.45	City
Median Home Value	148	34,200	800,100	151,030	81,138	City
Median Rent	148	590	1487	781.35	140.59	City
Median Rent as % of Inc.	148	23.2	46.4	32.66	3.69	City
Sperling's Cost of Living	143	0	99	57.78	25.58	MSA
Economics – Income						
15yr. Med. Unemployment	148	2.20	18.55	4.94	1.93	County
State Min. Wage Score	148	-.701	2.935	-0.21	0.84	State
State/Local Tax Burden	148	6.9	12.6	9.32	1.25	State
Median Black HH Income	137	2,499	99,795	29,916	12,225	City
% Pop. in Poverty	148	5.4	40.6	21.9	6.76	City
Sperling's Economy/Jobs	143	2	100	51.06	26.88	MSA

* excluding extreme outliers Anchorage, Alaska (1,704 sq. miles) and Jacksonville, Florida (747 sq. miles).

Sources: US Census, 2013; WalkScore.com, 2015, NTD, 2013

Table 3.3 Descriptive Statistics, con't.

Quality of Life	N	Min.	Max.	Mean	SD	Scale
Sperling's Overall	143	11	100	58.555	17.74	MSA
Sperling's Leisure	143	0	95	39.00	23.63	MSA
Sperling's Quality of Life	143	0	98	39.80	29.94	MSA
Sperling's Arts	143	0	96	43.46	23.62	MSA
G/H Overall	68	4	188	103.68	55.97	MSA
G/H Life Evaluation	68	1	246	101.28	63.19	MSA
G/H Work Environment	68	2	189	98.96	54.02	MSA
G/H Basic Access	68	2	188	101.28	59.09	MSA
Health – Environmental						
Total Emissions	148	11,170	484,631	126,969	82,439	County
Total Emissions, p/cap.	148	0.18	3.61	0.62	0.44	County
Total Emissions, p/mi^2	148	26.03	771.57	162.68	127.11	County
Total NO_X	148	1,166	46,852	11,286	8,648	County
NO_X, p/cap.	148	0.014	0.18	0.05	0.03	County
NO_X, p/mi^2	148	0.931	115.84	16.57	17.57	County
Total CO	148	5,076	201,223	52,104	35,556	County
CO, p/cap.	148	0.102	1.18	0.23	0.15	County
CO, p/mi^2	148	6.985	435.39	72.76	69.59	County
Health – Human						
Years Life Lost, p/100k	148	3,945	10,897	7,232	1,487	County
% Below Average Health	147	5.8	26.0	15.75	4.24	County
Percent Obese	148	14.2	38.6	28.91	4.15	County
G/H Emotional Health	68	1	188	94.16	59.11	MSA
G/H Physical Health	68	5	188	106.96	59.73	MSA
G/H Healthy Behaviors	68	8	313	122.41	67.48	MSA
Control Variables						
Latitude	148	21.33	61.18	38.16	5.43	City
Density	148	175	8,902	2,348	1,328	City
Population	148	50,002	836,087	134,529	126,317	City
Median Household Income	148	24,012	76,159	41,785	8,272	City
Percent Population Black	148	0.20	80.70	17.11	17.48	City
% College Educated	148	7.6	70.4	28.47	11.07	City
Multimodality	148	10.6	44.3	22.47	6.68	City

Sources: Sperlings, 2007; Gallup/Healthways, 2013; EPA, 2011; CHRR, 2015

Table 3.4 Variable Transformations

Theme	Transformation	Shapiro-Wilks
Urban Character		
Percent Single Detached Homes	Box Cox, λ=0.4	.108
WalkScore	Box Cox, λ=0.5	.008
Percent Rentals	–	.180
Mean Single Occ. Car Commute	–	.175
Median Age, New Residents	Box Cox, λ=0.9	.006
Civic Associations/10k Pop.	–	.724
Economic – Costs		
G/H Cost of Living	Box Cox, λ=0.8	.009
Renter Overspending	–	.936
Owner Overspending	–	.058
Tenure Gap	Box Cox, λ=0.5	.838
Median Home Value	Box Cox, λ=0.3	.000
Median Rent	Box Cox, λ=0.3	.027
Economic – Income		
State Minimum Wage	Inverse	.000
State/Local Tax Burden	Box Cox, λ=0.7	.007
Median Black HH Income	Box Cox, λ=0.4	.000
Median Rent as % of Income	Box Cox, λ=0.5	.023
Percent Population in Poverty	Box Cox, λ=0.7	.095
Quality of Life		
Sperling's Overall	–	.248
Sperling's Leisure	Box Cox, λ=0.8	.012
Sperling's Quality of Life	–	.000
G/H Overall	–	.000
G/H Life Evaluation	Box Cox, λ=0.8	.028
Health		
G/H Physical Health	–	.000
G/H Healthy Behaviors	Box Cox, λ=0.7	.031
YPLL[1]	–	.179
Obesity	–	.231
EPA Emissions, m^2	Natural Log	.000
Controls		
Latitude	–	.008
Density	Log 10	.001
Population	Log 10	.000
Median Household Income	Log 10	.023
Percent Population Black	Natural Log	.000
Percent College Educated	Natural Log	.563
Multimodality	Natural Log	.000

– = Box Cox Transformation did not improve the skew; original data retained for model.

Table 3.5 Control Variable Correlations[1]

	Latitude	Density	Population	Med. HH Inc.	% Pop. Black	% Pop. College	Multimodality
Latitude	1						
Density	.183*	1					
	.026						
Population	-.174*	.058	1				
	.035	.484					
Med. HH Inc.	.175*	-.119	.151	1			
	.033	.150	.067				
% Pop. Black	-.393**	-.142	.124	-.446**	1		
	.000	.086	.135	.000			
% Pop. College	.065	-.068	.020	.299**	-.125	1	
	.433	.412	.810	.000	.129		
MM	.098	.571**	-.038	.026	-.171*	.379**	1
	.236	.000	.643	.755	.038	.000	

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). 1. Listwise N=148

Table 3.6 Winsorized Univariate Outliers and Cases

Dependent Variable	Cases	Z-score Value
Emissions P/SM	Flagstaff, Az.	-4.189
Median Home Values	Flint, Mi.	-5.274
	Honolulu, Hi.	3.438
	Santa Barbara, Ca.	4.481
Median Rent	Youngstown, Oh.	-3.499
WalkScore	Lake Havasu, Az.	-3.346
SOV Time	Pittsburgh, Pa.	3.414
Med. Age, New Residents	Lake Havasu, Az.	4.013
Black Median HH Income	Eau Claire, Wi.	-5.563
	Laredo, Tx.	3.944
Med. Rent Percent Income	Bismarck, ND	-3.847

Table 4.1 Differences in Thematic Measures by Median Multimodality[1]

Theme		Means				
Urban Character	Scale	Green	Brown	Diff.*	Sig.	Direction
Geographic Size, m^2	City	75	85	10	.699	?
Sperling's Climate	MSA	47	45	2	.731	?
WalkScore	City	40	33	7	.000	+
Med. Age, New Residents	City	33	35	2	.014	–
% Single Detached Homes	City	54	63	8	.000	–
Mean Commute	City	21	21	0	.620	?
Car Commute Time	City	21	21	0	.479	?
Transit Commute Time	City	35	37	2	.283	?
Percent Rentals	City	50.07	44.21	5.86	.000	+
Owner Vacancy Rate	City	2.36	2.56	.2	.314	?
Rental Vacancy Rate	City	6.23	7.51	1.28	.007	–
Civic Associations/10k Pop.	County	10.76	11.85	1.09	.038	–
Economic – Costs						
% Overspending, Rent	City	44.24	47.26	3.03	.002	–
% Overspending, Home	City	32.32	29.26	3.06	.009	+
Tenure Gap[2]	City	25.26	35.78	10.52	.004	–
Median Home Value	City	171,384	130,677	40,707	.002	+
Median Rent	City	820	743	77	.001	+
Sperling's Cost of Living	MSA	50	65	15	.000	–
Economic – Income						
15yr. Med. Unemployment[3]	County	5.09	4.78	.31	.329	?
State Minimum Wage[4]	State	0.01	-0.44	.45	.001	+
State/Local Tax Burden[5]	State	9.64	9.0	.64	.002	+
Med. Black HH Income[6]	City	30,339	29,511	829	.693	?
Med. Rent as % of Income	City	33.49	31.83	1.66	.006	+
Percent Pop. in Poverty	City	23	21	3	.023	+
Sperling's Economy/Jobs	MSA	49	53	4	.326	?

*Note rounding errors; 1 N=50, unless stated; 2 Tenure Gap is ... ; 3 Median of data gathered at years 1990, 1995, 2000, and 2005; 4 Sum of Z-scores for percent State minimum wage above Federal minimum for years 2007-2014; 5 Percent of median income; 6 N= 67,70

Sources: US Census, 2013; WalkScore.com, 2015, NTD, 2013?

Table 4.1 Differences in Thematic Measures by Median Multimodality[1], con't.

Theme		Means				
Quality of Life	Scale	Green	Brown	Diff.*	Sig.	Direction
Sperling's Overall[6]	MSA	62	55	8	.007	+
Sperling's Leisure	MSA	47	31	16	.000	+
Sperling's Arts	MSA	45	42	4	.331	?
Sperling's Quality of Life	MSA	49	30	19	.000	+
G/H Overall†[7]	MSA	79	123	44	.001	–
G/H Life Evaluation	MSA	73	124	50	.001	–
G/H Work Environment	MSA	89	107	19	.154	?
G/H Basic Access	MSA	81	117	36	.014	–
Health – Environmental						
Total Emissions[8]	County	128,542	125,396	3,146	.817	?
Total Emissions, p/cap.	County	0.61	.63	.02	.786	?
Total Emissions, p/m^2	County	152	173	21	.327	?
Total NO_X	County	10,813	11,759	946	.508	?
NO_X, p/cap.	County	.04	.05	0.01	.040	–
NO_X, p/m^2	County	16	18	2	.491	?
Total CO	County	54,566	49,642	4,923	.401	?
CO, p/cap.	County	.25	.22	.03	.255	?
CO, p/m^2	County	71	74	3	.799	?
Health – Human						
Years Pot. Life Lost, p/100k	County	6,740	7,724	984	.000	–
% Below Average Health	County	15	16	1	.037	–
Percent Obese	County	27	31	3	.000	–
G/H Emotional Health	MSA	77	108	30	.034	–
G/H Physical Health	MSA	88	122	34	.020	–
G/H Healthy Behaviors	MSA	90	148	57	.000	–
Control Variables						
Latitude	City	39	38	1	.282	?
Density	City	2,741	1,954	787	.000	+
Population	City	116,485	152,574	36,090	.083	?
Median Household Income	City	41,754	41,816	62	.964	?
Percent Population Black	City	15	21	6	.028	–
Percent College Educated	City	31	26	5	.004	+
Multimodality	City	27	18	9	.000	+

*Rounding errors, †lower scores are more desirable. 6 N=49; 7 N=23, ranked 1 (best) to 300+ (worst); 8 Particulate matter (2.5 and 10 micron), SO_x, NO_x, and CO.

Sources: Sperling's, 2007; Gallup/Healthways, 2013; EPA, 2011; CHRR, 2015

Table 4.2 Differences in Thematic Measures by Exemplars of Multimodality

Theme		Means				
Urban Character	Scale	Green	Brown	Diff.*	Sig.	Direction
Geographic Size, m[2]	City	41	74	34	.001	–
Sperling's Climate	MSA	42	41	0	.969	?
WalkScore	City	48	29	19	.000	+
Med. Age, New Residents	City	31	36	5	.000	–
% Single Detached Homes	City	43	67	24	.000	–
Mean Commute	City	22.62	21.21	1.4	.019	+
Car Commute Time	City	22.47	20.93	1.53	.008	+
Transit Commute Time	City	34.09	33.37	0.72	.277	?
Percent Rentals	City	55.97	41.09	14.88	.000	+
Owner Vacancy Rate	City	2.05	2.72	0.68	.011	–
Rental Vacancy Rate	City	5.71	7.80	2.09	.029	–
Civic Associations/10k Pop.	County	10.56	12.53	1.97	.017	–
Economic – Costs						
Percent Overspending, Rent	City	42.18	46.71	4.54	.006	–
Percent Overspending, Own	City	34.43	28.34	6.09	.007	+
Tenure Gap[2]	City	17.12	36.85	19.73	.004	–
Median Home Value	City	218,456	124,684	93,772	.007	+
Median Rent	City	921	740	181	.000	+
Sperling's Cost of Living	MSA	37	69	31	.005	–
Economic – Income						
15yr. Med. Unemployment[3]	County	4.25	4.89	0.64	.054	–
State Minimum Wage[4]	State	0.10	-0.50	0.59	.005	+
State/Local Tax Burden[5]	State	10.03	9.17	0.86	.024	+
Med. Black HH Income	City	34,304	29,019	5,285	.000	+
Med. Rent as % of Income	City	34.64	31.97	2.68	.010	+
Percent Pop. in Poverty	City	24.46	19.45	5.01	.012	+
Sperling's Economy/Jobs	MSA	59	48	12	.285	?

*Note rounding errors; 1 N=50, unless stated; 2 Tenure Gap is ... ; 3 Median of data gathered at years 1990, 1995, 2000, and 2005; 4 Sum of Z-scores for percent State minimum wage above Federal minimum for years 2007-2014; 5 Percent of median income

Sources: US Census, 2013; WalkScore.com, 2015, NTD, 2013

Table 4.2 Differences in Thematic Measures by Exemplars of Multimodality, con't.

Theme		Means				
Quality of Life	Scale	Green	Brown	Diff.*	Sig.	Direction
Sperling's[6] Overall	MSA	73	55	19	.012	+
Sperling's Leisure	MSA	67	40	28	.001	+
Sperling's Arts	MSA	70	57	13	.156	?
Sperling's Quality of Life	MSA	80	28	52	.000	+
G/H†[7] Overall	MSA	41	127	86	.000	–
G/H Life Evaluation	MSA	45	103	58	.021	–
G/H Work Environment	MSA	75	129	54	.005	–
G/H Basic Access	MSA	36	105	69	.005	–
Health – Environmental						
Total Emissions[8]	County	147,249	100,652	46,597	.041	+
Total Emissions, p/cap.	County	.61	.55	.06	.682	?
Total Emissions, p/m^2	County	161.1	152.3	8.8	.791	?
Total NO_X	County	12,460	9,447	3,013	.160	?
NO_X, p/cap.	County	.04	.05	.01	.132	?
NO_X, p/m^2	County	17.8	14.1	3.7	.477	?
Total CO	County	64,715	40,627	24,088	.011	+
CO, p/cap.	County	.25	.20	.05	.367	?
CO, p/m^2	County	78.5	61.4	17.1	.368	?
Health – Human						
YPPL, p/100k	County	6,076	7,964	1,888	.000	–
% Below Average Health	County	14	17	3	.008	–
Percent Obese	County	25	32	7	.000	–
G/H Emotional Health	MSA	51	115	64	.025	–
G/H Physical Health	MSA	38	120	82	.002	–
G/H Healthy Behaviors	MSA	58	145	86	.000	–
Control Variables						
Latitude	City	38.45	37.31	1.14	.417	?
Density	City	3,840	1,672	2,168	.000	+
Population	City	125,385	120,482	4,902	.830	?
Median Household Income	City	42,831	42,230	601	.817	?
Percent Population Black	City	14.25	24.4	10.15	.058	?
Percent College Educated	City	36.96	24.77	12.18	.000	+
Multimodality	City	34.89	15.48	19.41	.000	+

*Rounding errors, †lower scores are more desirable. 6 N=49; 7 N=23, ranked 1 (best) to 300+ (worst); 8 Particulate matter (2.5 and 10 micron), SO_x, NO_x, and CO.

Sources: Sperling’s, 2007; Gallup/Healthways, 2013; EPA, 2011; CHRR, 2015

Table 4.3 Significance in Means Tests and Regression Tests; Multimodality

	Regression significant	Regression nonsignificant
T-test significant	% Single Detached Homes	Owner Vacancy Rate
	WalkScore	Renter Vacancy Rate
	Percent Rentals	15yr Med. Unemployment
	Civic Assoc./10k Pop.	Mean Commute Time
	Med. Rent as % of Income[b]	G/H Emotional Health
	Renter Overspending	G/H Work Environment
	Owner Overspending[b]	G/H Basic Access
	Tenure Gap	Total Emissions
	Median Home Value[b]	Total CO
	Median Rent[b]	% Below Average Health
	State Minimum Wage	
	State/Local Tax Burden[b]	
	Black Median HH Income	
	Med. Age, New Residents	
	Percent Pop. in Poverty	
	Car Commute[b] Time	
	Sperling's Overall	
	Sperling's Cost of Living[b]	
	Sperling's Leisure	
	Sperling's Quality of Life	
	G/H Overall	
	G/H Life Evaluation	
	G/H Physical Health	
	G/H Healthy Behaviors	
	YPPL	
	Percent Obese	
T-test nonsignificant	Total Emissions p/m^2	Transit Commute Time
		Sperling's Economy/Jobs
		Sperling's Climate
		Sperling's Art
		Total Emissions, per cap.
		Total NO_x
		NO_x, p/m^2
		NO_x, per capita
		CO, per capita
		CO, p/m^2

b: results favor brown cities

Table 4.4 Multiple Regression, Urban Character

	% Single Detach. Homes^R	Walk Score	% Rentals	SOV Commute	Med. Age, New Residents	Civic Assoc.
(Constant)	-8.83	2.726	159.97***	-36.82**	-42.94*	19.84
Latitude	0.03	0.099**	-0.21*	-0.03	0.05	0.23***
	[0.089]	[0.25]	[-0.136]	[-0.062]	[0.082]	[0.397]
Density	1.32*	-	3.66	1.93*	2.12†	1.44
	[0.157]	-	[0.101]	[0.149]	[0.139]	[0.102]
Population	0.00	1.275*	-0.66	1.90**	-0.52	-3.09**
	[0]	[0.159]	[-0.021]	[0.174]	[-0.04]	[-0.259]
Med HH Inc	-1.67	-3.53†	-39.97***	6.54*	14.90***	-1.57
	[-0.074]	[-0.138]	[-0.407]	[0.188]	[0.362]	[-0.041]
% Black	0.21†	-0.149	1.20*	1.71***	0.09	1.26***
	[0.127]	[-0.08]	[0.166]	[0.672]	[0.029]	[0.453]
% College	2.06***	-0.769†	7.46***	0.20	-2.97***	2.10**
	[0.419]	[-0.139]	[0.351]	[0.027]	[-0.333]	[0.255]
MM	3.11***	4.37***	14.11***	2.64***	-4.45***	-3.03**
	[0.439]	[0.548]	[0.461]	[0.243]	[-0.347]	[-0.255]
F	22.14***	16.62***	31.52***	20.87***	8.60***	11.17***
R^2	0.53	0.41	0.61	0.52	0.30	0.36
Adj. R^2	0.50	0.39	0.59	0.49	0.27	0.33
N	148	148	148	144	148	148

† significant at the .1 level; * .05; ** .01; *** .001. R=reflected variable

Table 4.5 Multiple Regression, Economic – Costs

	Sperling's Cost of Living[R]	Renter Over spending	Owner Over spending	Tenure Gap[R]	Med. Home Value	Med. Rent
(Constant)	-204.61**	-102.51***	-9.96	37.62*	-338.28***	-122.36***
Latitude	0.10	0.09	-0.38***	-0.14**	-0.53***	-0.19***
	[0.042]	[0.079]	[-0.288]	[-0.22]	[-0.178]	[-0.301]
Density	6.64	-0.20	1.26	0.27	-2.92	-0.46
	[0.121]	[-0.008]	[0.04]	[0.018]	[-0.041]	[-0.03]
Population	2.59	1.01	1.66	0.53	-5.80†	0.44
	[0.056]	[0.045]	[0.062]	[0.042]	[-0.096]	[0.035]
Med. Inc.	30.14*	35.14***	8.22	-6.82†	91.46***	26.54***
	[0.205]	[0.494]	[0.097]	[-0.168]	[0.474]	[0.659]
% Black	1.15	-0.18	-0.14	0.04	-3.37***	0.34
	[0.106]	[-0.035]	[-0.022]	[0.012]	[-0.239]	[0.114]
% College	-1.35	-0.35	-8.12***	-2.81***	15.36***	-0.21
	[-0.042]	[-0.023]	[-0.442]	[-0.319]	[0.367]	[-0.024]
MM	16.76***	-6.52***	10.30***	5.03***	11.70***	5.95***
	[0.365]	[-0.294]	[0.389]	[0.396]	[0.194]	[0.473]
F	4.67***	11.51***	9.34***	9.46***	48.20***	29.89***
R^2	0.20	0.37	0.32	0.32	0.71	0.60
Adj. R^2	0.15	0.33	0.28	0.29	0.69	0.58
N	143	148	148	148	148	148

† significant at the .1 level; * .05; ** .01; *** .001. R=reflected variable

Table 4.6 Multiple Regression, Economic – Income

	State Min. Wage^R	State/Local Tax Burden	Med. Black HH Inc.	Med. Rent % Inc.	% Poverty
(Constant)	5.04***	-7.90†	-459.01***	34.96***	1.802
Latitude	-0.01***	0.04***	-1.29***	-0.01	-0.018
	[-0.253]	[0.266]	[-0.315]	[-0.057]	[-0.033]
Density	-0.11	1.19***	-8.82	-0.01	2.42*
	[-0.1]	[0.307]	[-0.09]	[-0.003]	[0.19]
Population	-0.06	-0.42†	7.61	-0.17	-1.861*
	[-0.07]	[-0.127]	[0.092]	[-0.042]	[-0.172]
Med HH Inc	-0.62*	1.02	142.43***	-7.27***	-
	[-0.22]	[0.098]	[0.541]	[-0.557]	-
% Black	0.01	0.12†	-5.12**	0.03	1.382***
	[0.068]	[0.163]	[-0.266]	[0.036]	[0.548]
% College	0.17***	-0.32†	-16.26***	0.28	-1.046*
	[0.275]	[-0.14]	[-0.285]	[0.099]	[-0.14]
Multimodality	-0.29***	0.76**	16.57**	1.08***	3.068***
	[-0.325]	[0.232]	[0.202]	[0.264]	[0.286]
F	8.99***	8.46***	17.09***	13.06***	15.21***
R^2	0.31	0.30	0.48	0.40	0.393
Adj. R^2	0.28	0.26	0.45	0.37	0.367
N	148	148	137	148	148

† significant at the .1 level; * .05; ** .01; *** .001. R=reflected variable

Table 4.7 Multiple Regression, Quality of Life

	Sperling's Overall	Sperling's Leisure	Sperling's QoL	Gallup Overall	Gallup Life Eval
(Constant)	-49.75	-249.86***	-419.91**	1099.80**	549.06**
Latitude	0.26	0.51***	0.87*	-1.51	-0.01
	[0.079]	[0.236]	[0.157]	[-0.147]	[-0.001]
Density	-1.82	4.61	-0.63	-71.23**	-7.89
	[-0.023]	[0.09]	[-0.005]	[-0.289]	[-0.069]
Population	15.51**	14.64***	6.58	15.25	-7.22
	[0.234]	[0.337]	[0.059]	[0.073]	[-0.075]
Med HH Inc	-14.12	24.16*	40.32	-89.29	-57.93
	[-0.067]	[0.175]	[0.113]	[-0.134]	[-0.188]
% Black	-3.24*	1.21	-3.41	-2.92	-6.60*
	[-0.21]	[0.12]	[-0.131]	[-0.06]	[-0.293]
% College	16.80***	-4.35†	29.00***	-60.84***	-16.27*
	[0.368]	[-0.145]	[0.376]	[-0.422]	[-0.244]
Multimodality	14.37**	20.70***	39.86***	-52.43*	-33.59**
	[0.218]	[0.48]	[0.359]	[-0.253]	[-0.349]
F	9.04***	14.09***	19.28***	8.43***	3.97**
R^2	0.32	0.42	0.50	0.50	0.32
Adj. R^2	0.28	0.39	0.47	0.44	0.24
N	143	143	143	68	68

† significant at the .1 level; * .05; ** .01; *** .001

Table 4.8 Multiple Regression, Human and Environmental Health

	Gallup Health	Gallup Healthy Beh.	YPLL	% Obese	Emissions/ mi^2
(Constant)	1147.503*	228.15†	32389.15***	84.07***	2.31
Latitude	0.076	0.28	-61.20***	0.04	-0.01
	[0.007]	[0.089]	[-0.223]	[0.059]	[-0.071]
Density	-87.92**	0.14	-1872.02***	-1.44	0.90**
	[-0.334]	[0.002]	[-0.286]	[-0.08]	[0.196]
Population	8.00	-5.24	234.96	-1.18	0.99***
	[0.036]	[-0.083]	[0.042]	[-0.078]	[0.254]
Med HH Inc	-93.71	-21.46	-2670.92*	-5.07	-1.47
	[-0.132]	[-0.107]	[-0.151]	[-0.105]	[-0.118]
% Black	-5.60	2.60	306.37**	1.50***	0.50***
	[-0.108]	[0.177]	[0.237]	[0.425]	[0.55]
% College	-63.79***	2.45	-913.72***	-3.00***	0.50**
	[-0.415]	[0.056]	[-0.239]	[-0.287]	[0.184]
Multimodality	-44.91†	-29.73***	-1041.13**	-5.34***	-0.42†
	[-0.203]	[-0.475]	[-0.189]	[-0.354]	[-0.107]
F	5.99***	3.39**	23.50***	28.41***	26.54***
R^2	0.41	0.28	0.54	0.59	0.57
Adj. R^2	0.34	0.20	0.52	0.57	0.55
N	68	68	148	148	148

† significant at the .1 level; * .05; ** .01; *** .001

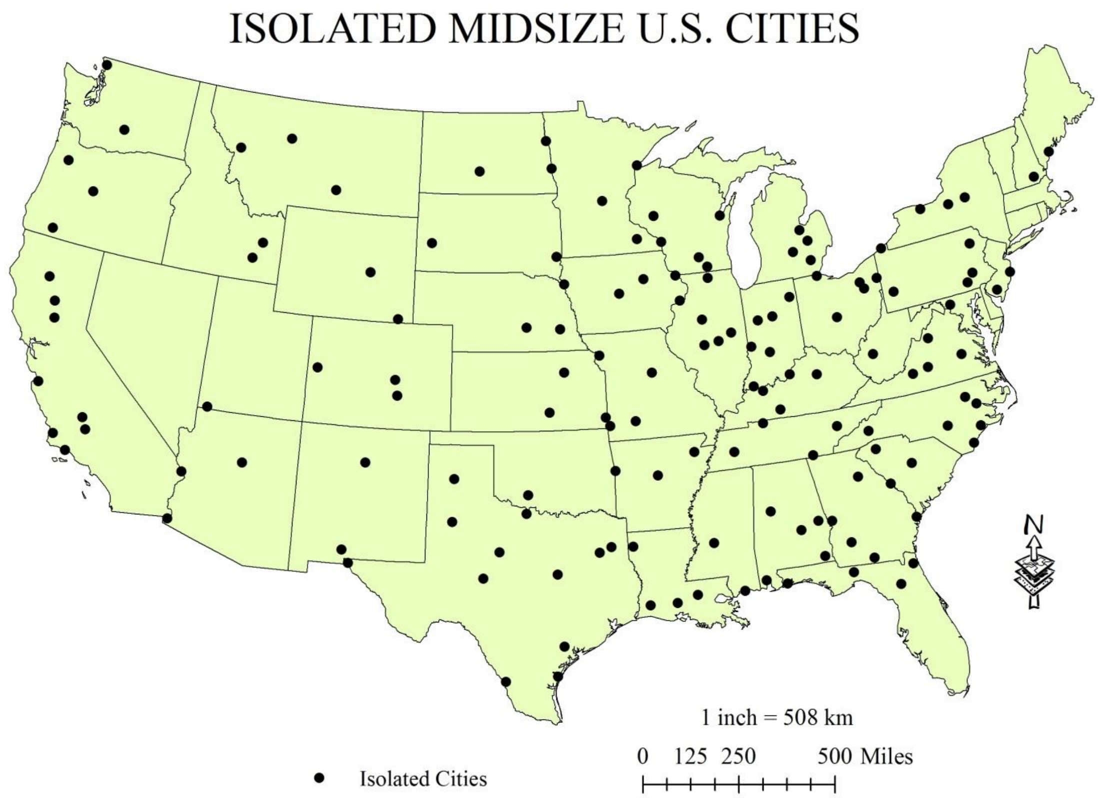
Table 5.1 Differences in Thematic Measures by Test

Theme	Median		Exemplars		Regression
Urban Character	Sig.	Direction	Sig.	Direction	
Geographic Size, m^2	.699	?	.001	–	
Sperling's Climate	.731	?	.969	?	?
WalkScore	.000	+	.000	+	+
Med. Age, New Res.	.014	–	.000	–	–
% SFD Homes	.000	–	.000	–	–
Mean Commute	.620	?	.019	+	?
Car Commute Time	.479	?	.008	+	+
Transit Commute Time	.283	?	.277	?	?
Percent Rentals	.000	+	.000	+	+
Owner Vacancy Rate	.314	?	.011	–	?
Rental Vacancy Rate	.007	–	.029	–	?
Civic Assoc./10k Pop.	.038	–	.017	–	–
Economic – Costs					
% Overspending, Rent	.002	–	.006	–	–
% Overspending, Home	.009	+	.007	+	+
Tenure Gap	.004	–	.004	–	–
Median Home Value	.002	+	.007	+	+
Median Rent	.001	+	.000	+	+
Sperling's Cost/Living*	.000	–	.005	–	–
Economic – Income					
15yr. Med. Unemploy.	.329	?	.054	–	?
State Minimum Wage	.001	+	.005	+	+
State/Local Tax Burden	.002	+	.024	+	+
Med. Black HH Income	.693	?	.000	+	+
Med. Rent % of Income	.006	+	.010	+	+
Percent Pop. in Poverty	.023	+	.012	+	+
Sperling's Econ/Jobs	.326	?	.285	?	?

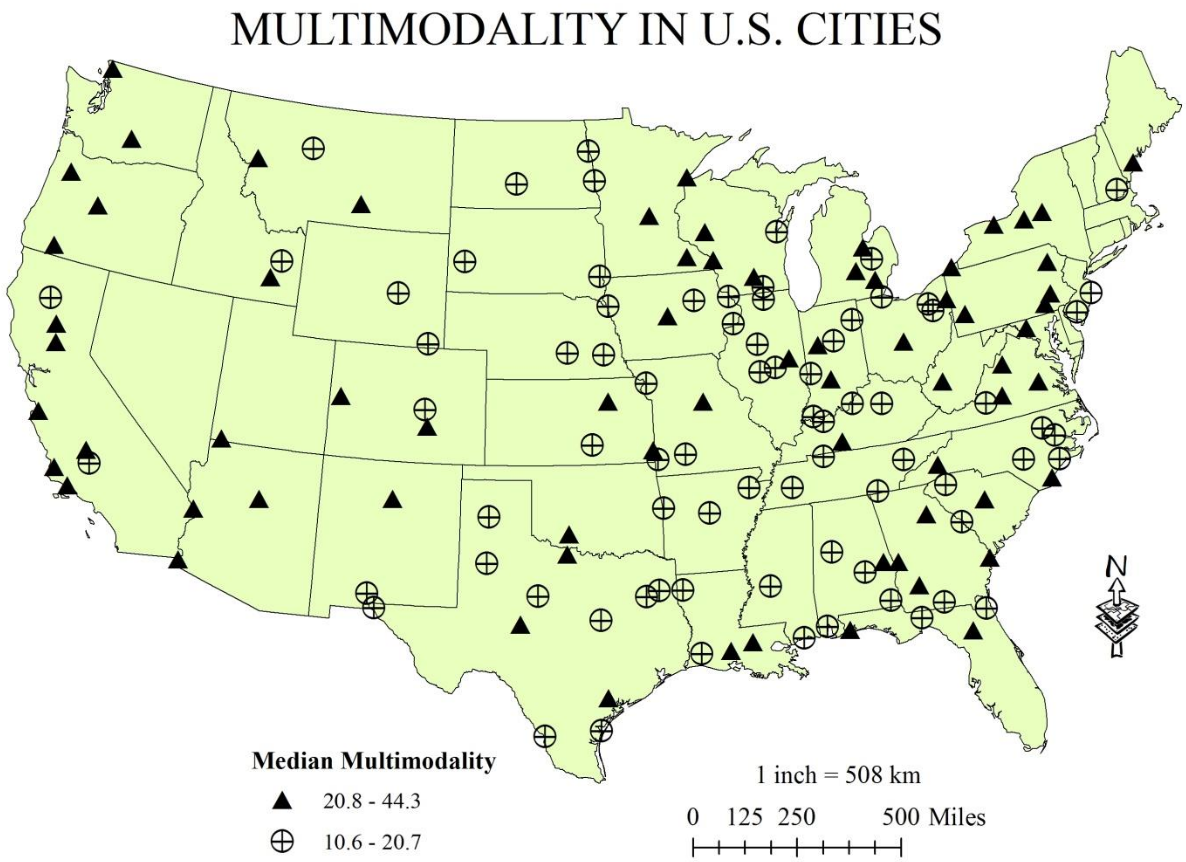
Table 5.1 Differences in Thematic Measures by Test, con't

Theme	Median		Exemplars		Regression
Quality of Life	Sig.	Direction	Sig.	Direction	
Sperling's Overall	.007	+	.012	+	+
Sperling's Leisure	.000	+	.001	+	+
Sperling's Arts	.331	?	.156	?	?
Sperling's QoL	.000	+	.000	+	+
G/H Overall	.001	–	.000	–	–
G/H Life Evaluation	.001	–	.021	–	–
G/H Work Environment	.154	?	.005	–	?
G/H Basic Access	.014	–	.005	–	?
Health – Environmental					
Total Emissions	.817	?	.041	+	?
Total Emissions, p/cap.	.786	?	.682	?	?
Total Emissions, p/m^2	.327	?	.791	?	–
Total NO_X	.508	?	.160	?	?
NO_X, p/cap.	.040	–	.132	?	?
NO_X, p/m^2	.491	?	.477	?	?
Total CO	.401	?	.011	+	?
CO, p/cap.	.255	?	.367	?	?
CO, p/m^2	.799	?	.368	?	?
Health – Human					
YPLL, p/100k	.000	–	.000	–	–
% Below Average Health	.037	–	.008	–	?
Percent Obese	.000	–	.000	–	–
G/H Emotional Health	.034	–	.025	–	?
G/H Physical Health	.020	–	.002	–	–
G/H Healthy Behaviors	.000	–	.000	–	–
Control Variables					
Latitude	.282	?	.417	?	
Density	.000	+	.000	+	
Population	.083	?	.830	?	
Median HH Income	.964	?	.817	?	
Percent Population Black	.028	–	.058	–	
Percent College Educated	.004	+	.000	+	
Multimodality	.000	+	.000	+	

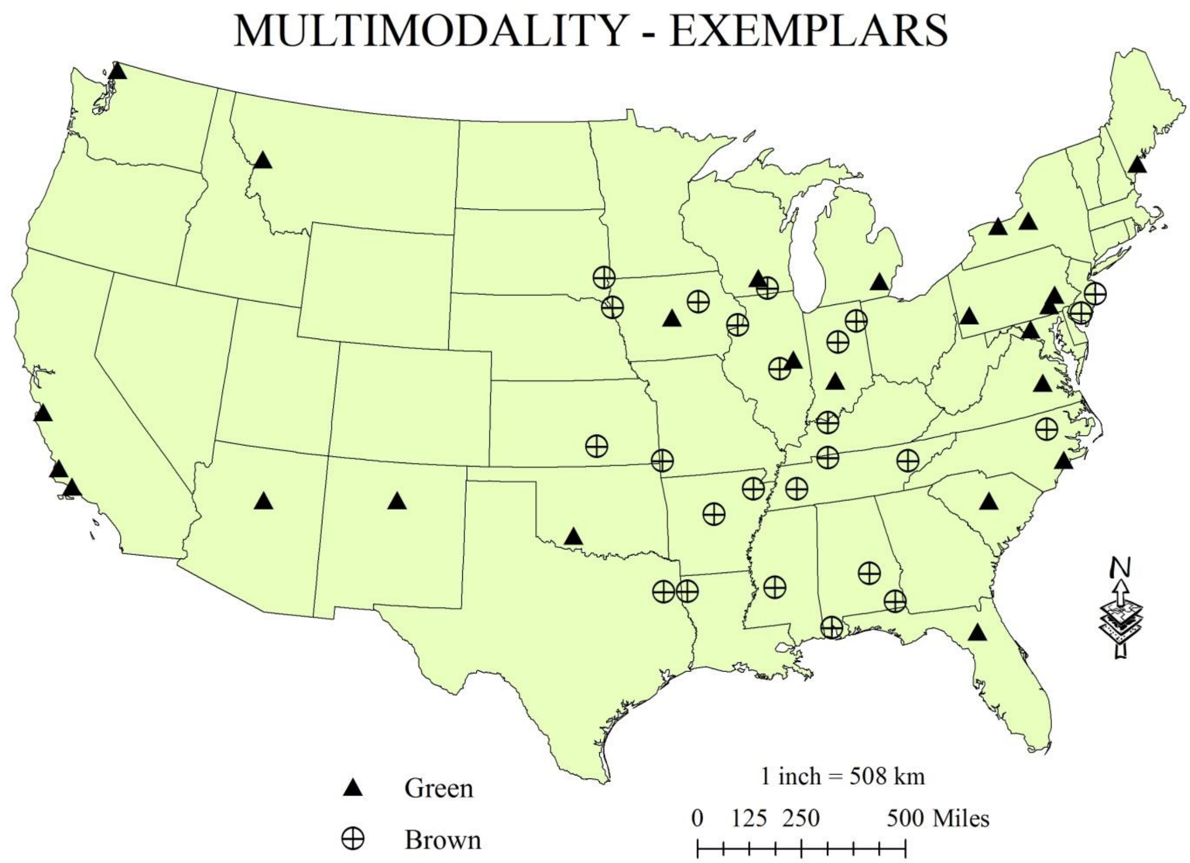
APPENDIX C – MAPS



Map 3.1 Isolated, Mid-size Cities in the Continental United States. Map created by Justin Hall and Chad Frederick, 2016.



Map 4.1 High and Low-Multimodality U.S. Cities. Map created by Justin Hall and Chad Frederick, 2016.



Map 4.2 Exemplars of High and Low Multimodality. Map created by Justin Hall and Chad Frederick, 2016.

CURRICULUM VITAE

NAME: Chad Paul Frederick

ADDRESS: 2414 Sherry Road, Louisville, Kentucky, 40217

DATE OF BIRTH: October 20, 1971

Education

PhD in Urban and Public Affairs – Urban Planning 2016
University of Louisville

Master of Urban and Environmental Planning – Sustainability Pedagogy 2012
Arizona State University

Bachelor of Arts in Individualized Studies –Sustainability 2010
Metropolitan State University

Research Interests

Equity, the Built Environment, and Sustainable Community Development
Education for Sustainable Development – Learning Outcomes, Pedagogy
Urban Governance – Citizenship, Identity, Place, and Participation

Teaching Interests

Sustainability; Sustainable Urban Development; Resilient Communities
Urban and Design Theory; Human-Environment Interactions; Urban Forestry
Statistics; Structural Equation Modeling; Survey Methodology; Participatory Research

Publications

Journal Articles:

Frederick, C., Pijawka, D. (2015). "The Critical Role of Student Interest: Education for Sustainable Development and Urban Planning Pedagogy." International Journal of Sustainability Education, January, 2015.

Frederick, C., Pijawka, D. (2015). "Constructing and Assessing an Introductory Urban Sustainability Course: Applying New Insights Using Survey Research." Journal of Sustainability Education. Winter, 2015.

Pijawka, D., Yabes, R., Frederick, C., White, P. (2013). "Integration of Sustainability in Planning and Design Programs in Higher Education: Evaluating Learning Outcomes." Journal of Urbanism.

Book Chapters:
Frederick, C., Pijawka, D. (2015). "Measuring Learning Outcomes in Education for Sustainable Development." in David Pijawka (ed.), Understanding Sustainable Cities: Concepts, Cases, and Solutions, 2nd ed. Kendall Hunt.

Works in Progress
Books:
Frederick, C. "Finding the Reach of Progress: How Sustainable Urban Development Shapes City Life." Praeger, proposal accepted.

Journal Articles:
Frederick, C., Gilderbloom, J., Riggs, B. "Are Green Cities Free?" Journal of Urban Affairs, in progress.

Frederick, C., Gilderbloom, J., Riggs, B. "Automobile Dependency and Urban Health Outcomes: a Multivariate Analysis of 148 Mid-Size Cities" Journal of Urban Affairs, submitted.

Frederick, C., "The Molotch and Appelbaum Method: A Quantitative Approach to Urban Research." Research Methods, in preparation.

Frederick, C. "Sustainable Development as a Control Variable in Urban and Built Environment Research." Journal of Planning Education and Research, in preparation.

Frederick, C. "Transportation Multimodality as an Indicator of Sustainable Urban Development." Journal of the American Planning Association, in preparation.

Frederick, C. "Diversity in Housing Typology as an Indicator of Sustainable Urban Development." Journal of the American Planning Association, in preparation.

Teaching Experience
Instructor:
Political Science 399, Social Change 304 - Sustainability 2016

Co-instructor:
Urban and Public Affairs 648, Urban Planning 680, Public Administration 626, 2015
Social Work 697 - Housing and Community Development

Teaching Assistant:
Urban Planning 190/Sustainability 111 – Sustainable Cities (Lead) 2011-12
Duties: Write syllabus, assignments, and exams; identify and order textbooks; develop online lectures; grade; lecture; coordinate two faculty, four assistants, 12 guest lecturers, and 400 students.

Urban Planning 190/Sustainability 111 – Sustainable Cities (Honors Rec.) 2011-12
Duties: Direct and instruct 24-seat recitation seminar for Barrett Honors College.

Urban Planning 190/Sustainability 111 – Sustainable Cities 2010

Conference Presentations

"Go Green for Better Health." Frederick, C., Riggs, B., Gilderbloom, J. 46th Conference of the Urban Affairs Association. San Diego, CA, 2016.

"The Real Economic Impacts of Automobile Dependency." Frederick, C., Gilderbloom, J., Riggs, B. 46th Conference of the Urban Affairs Association. San Diego, CA, 2016.

"Green Threads: Assessing Outcomes for Educators." Association for the Advancement of Sustainability in Higher Education Conference. Minneapolis, MN, 2015.

"A Basic Vocabulary for Sustainability Education." Association for the Advancement of Sustainability in Higher Education Conference. Minneapolis, MN, 2015.

"Investigating Interest in an Introductory Planning Course." Association for the Advancement of Sustainability in Higher Education Conference. Portland, OR, 2014.

"You Can't Measure That? Measuring (some) Affective Learning Outcomes in an Undergraduate Urban Sustainability Course." Association for the Advancement of Sustainability in Higher Education Conference. Nashville, TN, 2013.

Panels

"So You Think that's a Sustainability Course? Identifying Sustainability Courses in STARS 1.2." Association for the Advancement of Sustainability in Higher Education Conference. Nashville, TN, 2013.

Posters

"Fostering a Disposition for Interdisciplinary Problem-Solving in an Undergraduate Sustainability Course." Association for the Advancement of Sustainability in Higher Education Conference. Nashville, TN, 2013.

"Measuring Learning Outcomes in Education for Sustainable Development." University of Louisville Graduate Symposium. Louisville, KY, 2013.

Certificates

Graduate Teaching Assistant Academy, PLAN Program, School of Interdisciplinary and Graduate Studies, University of Louisville. 2015-16

Workshops

"The Writing Process: Preparing Manuscripts and Publishing in Peer-Review Journals (Part Two)." Dr. Deirdre Pfeiffer (Arizona State University, School of Geographic Sciences and Urban Planning). 2011

"The Writing Process: Preparing Manuscripts and Publishing in Peer-Review Journals (Part One)." Dr. Alan Murray (Arizona State University, School of Geographic Sciences and Urban Planning). 2011

"Using Video Tools in the Classroom." Blackboard Workshop Seminar, Arizona State University, University Technology Office. 2010

"Grade Center – Advanced Topics." Blackboard Workshop Seminar, Arizona State University, University Technology Office. 2010

"Grade Center One." Blackboard Workshop Seminar, Arizona State University, University Technology Office. 2010

"Assignments, Tests, and Discussions." Teaching Assistant Development Series, Arizona State University, Webinar and Lectures [hybrid]. 2010-11

Grants and Scholarships

Educational Grants:

University Fellowship, University of Louisville – $96,000 2012-16

Metropolitan State Foundation Award – $1,000 2008-09

Research Grants:

Graduate Research Award, University of Louisville – $500 2013

Program Grants:

Minnesota State University Student Association (MSUSA) – $8,000 2008

Metropolitan State University "Get Out The Vote Program."

Service and Committees

Reviewer:

International Journal of Sustainability in Higher Education

Journal of Sustainability Education

International Journal of Sustainability Education

Kendall-Hunt Publishers

University of Louisville:

Speaker Series – co-director 2015-16

Urban and Public Affairs PhD Student Association – president 2013-14

21st Century Initiative: Technology, Demographics and Engagement – graduate student representative 2013

University Sustainability Council, Education and Research Sub-Committee – graduate student representative 2012-13

Graduate Student Council – department representative 2012-13

Urban and Public Affairs Departmental Culture Initiative – chair 2013

Arizona State University:
School of Geographical Sciences and Urban Planning Colloquium Committee 2011-12

Metropolitan State University:
Student Senate – member 2008-10
SAFAC (Student Activity Fees Advisory Committee) – vice-chair 2010
ACUPCC (American College and University Presidents' Climate Commitment) – senate liaison 2010
OCT (Orientation Coordinating Team) – member 2009-10
AQUIP (Academic Quality Improvement Program) – member 2008
ARLT (Anti-Racism Leadership Taskforce) ¬– member 2007-08
CICT (Continuous Improvement Coordinating Team) – member 2007

Professional Memberships:
Planners Network – student member 2010-15
AzAPA (Arizona Chapter, American Planning Association) – student member 2010-12
ISA (International Society of Arboriculture) – member 2004-10

Academic Memberships:
GRASS (University of Louisville – Sustainability) 2014
ASPA (ASU Student Planning Association) 2010-12
GISER (ASU – Graduates in Integrative Society and Environment Research) 2011
GPSA (ASU – Graduate and Professional Student Association) 2010-12
MSUSA (Minnesota State University Student Association) 2008-10

- Diversity Representative
- Organizer, GOTV (Get out the Vote)

Other Work Experience

Arborist; Minneapolis, MN. 1998-2007

US Army Reserves and California National Guard:
144th Field Artillery Regiment, California National Guard; Hollywood, CA. 1992-96
288th Attack Helicopter Battalion, US Army Reserve; Minneapolis, MN. 1990-92

References

Dissertation Committee Chair, Center Director:
John I. Gilderbloom, Ph.D.
Urban and Public Affairs, Professor
Center for Sustainable Urban Neighborhoods
University of Louisville
Department of Urban and Public Affairs
426 West Bloom Street
Louisville, KY 40208
john.gilderbloom@louisville.edu
502-852-8557
Letter of Reference: send.Gilderbloom.A9B6271F8D@interfolio.com

Dissertation Committee Member, Department Chair:
David M. Simpson, Ph.D., AICP
Fifth Third Bank Professor of Community Development
Chair, University Sustainability Council
Chair, Department of Urban and Public Affairs
Director, Masters of Urban Planning Program
University of Louisville
Department of Urban and Public Affairs
426 West Bloom Street
Louisville, KY 40208
dave.simpson@louisville.edu
502-852-8019
Letter of Reference: send.Simpson.ADBCAFF170@interfolio.com

Master's Thesis Chair, Program Director, Co-Author:
K. David Pijawka, Ph.D.
Senior Sustainability Scientist, Julie Ann Wrigley Global Institute of Sustainability
Professor, School of Geographical Sciences and Urban Planning
Associate Director, School of Geographical Sciences and Urban Planning
Arizona State University
School of Geographical Sciences and Urban Planning
PO Box 875302
Tempe, AZ 85287-5302
pijawka@asu.edu
480-727-7319
Letter of Reference: send.Pijawka.E7FDB329A6@interfolio.com

Dissertation Committee Member:
Dr. Steven Koven, Ph.D.
Professor of Public Sector Ethics
University of Louisville
Department of Urban and Public Affairs
426 West Bloom Street
Louisville, KY 40208
steven.koven@louisville.edu
(502) 852-8257

Former instructor:
Allen S. Bellas, Ph.D.
Professor of Environmental Economics
Metropolitan State University
College of Management
Management Education Center, 2024
Minneapolis, MN 55403
allen.bellas@metrostate.edu
(612) 659-7272