Evaluating Transportation and Built Density of LEED Gold Certified Municipal Buildings

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Abstract

Evaluating transportation and built density of LEED Gold certified municipal buildings

This study focuses on transportation and Leadership in Energy and Environmental Design (LEED) certified buildings. Four custom metrics, reflecting environmentally progressive concepts in transportation were developed to provide a method of analyzing transportation and density-related credits awarded by the LEED program. Specifically, custom metrics were designed to measure transportation density, built density, and public transportation usage. Two transportation density metrics were generated using line density within a GIS and were calculated using TomTom/Tele Atlas roads data. The local transportation density metric used line density surfaces that incorporated roads within close proximity of each building in the study. The global transportation density metric used a single line density surface for the entire United States. The built density metric was calculated using landcover data that was analyzed within a GIS and reflected the total built up area around each LEED building in this study. The public transportation metric was calculated using Census 2000 data regarding commuting habits. Statistical analysis was completed on all of the custom metrics to include comparisons between custom metrics and the corresponding transportation and density related LEED credits. Key findings of the study were that there was no correlation between the LEED transportation credits and the custom metrics from the study. There was a weak correlation between the public transportation metric and a metric that combined all five transportation and density related LEED credits into one aggregate metric. A strong correlation was observed between the built density custom metric and the global and local transportation density metrics. The final finding was that most of the sampled buildings attained some or all of the transportation or density related LEED credits with only one building failing to receive any. The study provides a starting point for greater analysis of transportation related LEED credits.

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Chapter 1: Introduction and Literature Review

Introduction

What is LEED?

The Leadership in Energy and Environmental Design (LEED) program is a program administered by the United States Green Building Council (USGBC). The program is considered one of the premiere programs for environmental building design.

The USGBC developed the LEED program in March 2000 to provide "building owners and operators with a framework for identifying and implementing practical and measureable green building design, construction, operations, and maintenance solutions." (USGBC, 2013). The system employs a series of rating systems that certify buildings based on a number of metrics that translate to credits. Credits are organized into five credit categories which are Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Environmental Quality. The number of credits a building attains at construction or renovation determines the level of certification. There are four levels of certification for the LEED program which are in order of increasing credit certified, silver, gold, and platinum.

Who is the USGBC

The USGBC is a membership-based non-profit organization that consists of stakeholders in the building industry (USGBC, 2013). The membership includes 77 chapters with 13,000 member organizations and 181,000 LEED professionals (USGBC, 2013). The difference between LEED professionals that administer the LEED program, members that certify their building projects, and industry leaders is primarily in the role each stakeholder plays in the program. LEED professionals are individuals employed by builders or contractors and are certified through examination to organize a LEED building project. These individuals are usually involved in construction or renovation projects and have LEED qualification in addition to their regular skillset. Members that certify their building projects are in a way customers of the USGBC. These members pay an annual fee in addition to their building effort to retain their LEED certification. Fees range between $900 to more than $20,000 based on the type of certification and the square footage of the building (USGBC, 2013).

The various levels of certification afford these members services from the USGBC that range from online information at a very basic level to complete public relations support at the platinum level. The building industry stakeholders of the USGBC however are what classify the organization as a trade organization however the USGBC still “represents a wide range of actors- architects, engineers, product manufacturers, academics, and public institutions- who concluded that the construction industry must change course to be sustainable” (Kibert, 2001, p. 384).

The Success of LEED

Since the establishment of the LEED program it has “become the accepted benchmark for designating ‘green buildings’ in the USA and many other countries” (Cidell, 2009, p. 621). The LEED program has provided a flexible credit based infrastructure for buildings to identify areas of sustainability. This flexibility has made the program an ideal decision support tool for both private and public sector building projects (Keysar, 2007). In the public sector this has led to several federal, state, and municipal level actors to adopt green building practices and more specifically the LEED program and has resulted in unchallenged mandates across the United States for buildings to attain LEED certification (Fox, 2009). These governmental policies provide incentives for green building initiatives as well as mandates for the use of LEED in public building projects (King, 2005). In an American Architects of America study 138 cities with a population greater than 50,000 persons had green building programs to include both mandates for the use of LEED as well as customized green building programs (Rainmaker, 2009).

What concerns exist

Several concerns exist regarding the LEED program. The first is highlighted by the fact that several key stakeholders within the USGBC are building industry leaders. As a trade organization the USGBC has a responsibility to these stakeholders that could potentially supersede environmental goals. There is incentive for the organization to pursue policies and practices that improve the wellbeing or sales of its industry stakeholders (Fox, 2010). This is further exacerbated by the fact that the LEED program is designed to incentivize products and services of its stakeholders and is then packaged into a saleable framework that is sold to customers (Fox, 2010). The customer base is comprised of groups that are trying to make their buildings more environmentally friendly. However these buildings could be led to attain particular LEED credits that may or may not provide the most environmental advantage for a particular building (Bray, 2006).

Much of the concern regarding the most advantageous environmental benefit for a building stems from the one size fits all approach afforded by LEED. While a credit may indicate an environmental benefit in one particular geographic location it may not actually have a benefit in another area (Bray, 2006). Alternatively, proponents of the LEED program assert that the multi-tiered credit system provides flexibility for building projects to better attain sustainability (Cidell, 2009).

Statement of Purpose and Research Questions

Within the LEED framework there is an emphasis on access to public transportation, development density, and community connectivity. However, this emphasis is not based upon actual measures of the efficiency or commuter usage of a given public transportation system, the built area of the surrounding environment, or the density of the transportation network. Optimizing the built density and commutes to include both access to public transportation and transportation efficiency for a building project are essential factors for sustainability (CNT 2010). Both built density and transportation density are important aspects of the environmental area of a building as both are directly related to commuting efficiency (CNT 2010). However, within the LEED framework there is no measure for the efficiency of a commute or the minimization of commute times.

This study will aim to explore those gaps through the use of custom metrics. Custom metrics were developed to explore transportation network density, built density, and public transportation usage and compared to the LEED credits as reported by the USGBC. Building selection was completed using a stratified sample (100 buildings) of publicly owned LEED Gold buildings that fell into 8 particular climatic zones and a 9th other zone (Arid Mountain, Florida Type III, Great Lakes, Inland Desert, LA/San Diego, Mid Atlantic, Pacific Northwest, Southeast, and Other).Using USGBC data about individual LEED building credit attainment, this study examines regional differences and correlations between measured built density, transportation density, and public transportation usage and a building's attainment of transportation specific within LEED New Construction 2.1 and 2.2 Sustainable Site credits (See Table 1.1).

Table 1.1: LEED NC 2.1 and 2.2 Transportation Related Credits

	Credit Description
LEED Credit 2	Development Density and Community Connectivity
LEED Credit 4.1	Alternative Transportation: Public Transportation Access
LEED Credit 4.2	Alternative Transportation: Bicycle Storage, and Changing Rooms
LEED Credit 4.3	Alternative Transportation: Low Emitting and Fuel Efficient Vehicles
LEED Credit 4.4	Alternative Transportation: Parking Capacity

Using transportation access and density measures could potentially provide a customized metric that accounts for geographic variability as well as a metric that can be compared across large areas (Bolstad, 2008). This is possible as a density surface provides local averages of incredibly granular information and also normalizes the information across a large geographic area (Silverman, 1986). Additionally the use of zonal statistics allow for a way to group the local averages from a density surface as well as the continuous information found in land cover data to create comparisons (Bolstad, 2008).

This study relied primarily on quantitative techniques to include significant GIS analysis, spatial statistical analysis, and traditional statistical analysis. Spatial statistical analysis was used to calculate two transportation density metrics. Traditional statistics were used to provide basic descriptive statistics and establish central tendencies for the LEED data and the custom metrics generated for the study. Additionally traditional statistics were used to explore correlations between LEED credits and custom metrics.

Literature Review

Environmental literature on Transportation and Built Density

The current reality of transportation in the United States is far from the eventual goal of a majority ride sharing or public transportation commuting scenario. According to the 2009 American Community Survey Report "Commuting in the United States: 2009" (US Census, 2009) 76% of commuters drove alone. The remaining 24% included all other means as well as 4.3% of workers that worked from home. When non commuting trips are taken into consideration the results are even more stark. According to the "2001 National Household Travel Survey" (US Department of Transportation, 2003) 87% of daily trips were in personal vehicles with about 38% of all trips taking place with a single occupant.

The literature reviewed for this study included environmentally specific transportation literature that focused on the optimization of commutes and access to public transportation rather than a larger study of transportation density. The literature focused on the optimization of commutes emphasized the importance of incentivizing the use of public transportation, the reduction of commuters using or a reduction in time commuters spent in private vehicles, and the optimization of pedestrian commutes. There was general agreement that in order to increase the effectiveness of a building prioritizing access to public transportation and walkability are important. Studies of commuting and housing costs in the greater Chicago and greater Washington DC metropolitan areas concluded that the costs associated with commuting by private car are increased tremendously with the length of a commute (ULI, 2009 & CNT, 2010). Geographic considerations become imperative to both increase the accessibility to public transportation as well as to an efficiently connected transportation network. These case studies highlight the need to minimize transportation costs (CNT, 2010 & ULI, 2009). Both studies emphasize the importance of access to public transportation and walkability to minimize the large number of commuters using privately operated vehicles. The CNT (2010) study of Chicago determined that no more than 15% of household income should be consumed by transportation costs. The CNT (2010) study also determined that lower property costs in outlying areas hid transportation cost tradeoffs when compared to more dense and convenient downtown areas.

In regards to commuting and walkability it was generally accepted that commuters were willing to walk between a quarter to a half mile for transit or from their homes to their final destination (Guerra, 2011 & Zhao, 2003) While walkability was cited as a primary factor in optimizing the environmental benefits of a building there was also a discussion of minimizing commuting costs.

Litman’s (1999) study examines multi modal commutes that involve personal automobiles, walking, and public transportation. The study argues that commuters will choose the most efficient and cost effective method to reach their destination. Litman’s main argument is that it is necessary to incentivize use of public transportation and ride sharing. Additionally Litman emphasizes the importance of a suitable road network to support an economical driving commute. This will serve both to minimize the cost of the individual driver but also will strengthen bus service and ease burdens for ride share users. Maximizing transportation efficiency is incorporated as a metric within a life cycle assessment (LCA) and identified in Horst’s (2003) article “Integrating LCA Tools in LEED: First Steps”. Horst argues that it is imperative that a building project be located in a place that allows for easy delivery of building materials. This efficiency will be translated into lower commuting costs and lower costs to supply the building throughout the building’s life cycle.

The literature regarding environmental transportation needs and deficiencies highlight most broadly a lack of metrics that account for the diversity of a large geographic space. Not all locations across the United States have developed consistently and uniform LEED metrics may not reflect the uneven development of both the transportation network and the public transportation infrastructure (ULI, 2009).

LEED Program

There is a significant amount of literature critiquing the USGBC and the LEED program. In exploring the varying opinions on the LEED program there were four categories of literature reviewed. The first category included both scientific and qualitative studies of the effectiveness of green building programs, the second category discussed issues related to generalized guidelines, the third category provided a discussion of LEED methodologies and implementations, and the final category provided analysis of Green Building Policies.

Scientific and Qualitative Studies

The scientific and qualitative studies reviewed varied greatly in scope however there was limited agreement that green building standards did not always result in environmental gains over conventional building techniques (Newsham, 2009, Bray, 2006, Kiebert, 2004 & Kaatz, 2006).

Kibert (2004) completed an analysis of green building techniques both within the United States and internationally. The study relied heavily on USGBC data regarding all LEED certified buildings and USGBC membership as of 2003. Kiebert’s (2004) piece claimed that the low environmental gains by green buildings as compared to conventional buildings are isolated. However, the overwhelming majority of green building projects are an improvement over their conventional counterparts. Kiebert also states that green buildings make both ethical and economic sense and address some human health concerns associated with conventional buildings.

This view is in stark contrast with Bray (2006) who attributes a number of unintended negative consequences to LEED highlights how applications of LEED can fail to benefit the environment. The most striking example was in regards to the indoor environmental credit that required the introduction of outdoor air to be vented into a building when the CO_2 levels within the building reached a certain level. This requirement is based on the assumption that the outdoor air would have a lower CO_2 content than the indoor air. However, this is not a safe assumption in certain site specific locations. This generalized requirement, as a result, neglected the specific geographic limitations of the building site. Lesser negative consequences were cited at buildings implementing alternative transportation credits in areas that were not conducive to bicycle access. In these areas, credits were attained but these facilities were for the most part unused.

Newsham (2009) further highlighted some of the non-intuitive energy consumption rates of LEED certified buildings as compared to conventional ones. Even though the study highlighted an 18-39% percent reduction in energy per floor area than conventional buildings there was still a startling statistic that 28-35% of LEED buildings used more energy than conventional buildings. Newsham concludes that there is potentially an overstatement of the energy benefits of a LEED certified building however since the majority of buildings performed better than conventional buildings the credits do promote sustainable practices for society. However the shortfall among the 28%-35% of underperforming buildings pose a problem for the owner of the buildings that do not achieve the performance that is expected with their particular credit attainment. This conclusion highlights the need for more adequate mechanisms to advance the environmental impact of a green building project.

Problems with Generalized Guidelines

This commitment to green building programs has constituted, according Cidell (2009), a drive to create built environments. Cidell claims that from a political ecology perspective the built environment produced by green building projects is a combination of the human practices as well as the materials and features included in the building. The built environment according to Cidell does not necessarily translate into a positive environment however careful planning and analysis of the interplay between human activities and the green building features can result in a much more positive result in the construction of the built environments. The overarching discussion of positive and negative impacts of green buildings in the area of scientific and qualitative studies highlights the potential problems with using a generalized approach to green building rating.

Bray’s paper highlighted another trend within the literature with regards to the problems with generalized guidelines. These problems were also explored in Wedding’s research (2006). In his study he cited the variation in energy sources across the country. The variation in fuel mixes and the temporal aspects of energy use all come into play. His assessment was that based on a building’s source of energy, which is dependent on its location within the electricity grid, its actual offset measures for emissions and energy consumption may be miscalculated. One of the key conclusions from this study was an indication that the LEED program was better suited for and probably “intended to be an instrument for market change, not a scientific tool for assessing the environmental impacts of buildings (Wedding, 2006, p. 166).”

Reijnders’ (1999) piece addresses the importance of such tools and advocates an approach that incorporates life cycle analysis as well as environmental indicators. This article predates the official establishment of the LEED program however it still provides pertinent points of consideration regarding the development of green building rating systems. By correctly using tools, Reijnders claims that green building projects can more effectively apply environmental improvements and avoid incorporating unnecessary features. This approach however assumes a more tailored approach to developing green buildings.

The use of a more tailored approach to planning green building projects while not completely antithetical to LEED certification is still a slight departure from the traditional approach of LEED professionals. Kaatz (2006) advocates for sustainability planning and particularly sustainability assessments to be included into the green building planning process. In Kaatz’s study, theories such as Environmental Assessment and the Process Protocol are used. Environmental Assessment is used to determine sustainability on a project level and Process Protocol is used to optimize the effect of each green feature in a building. Since the publication of this study the USGBC has introduced Regional Priority Credits that incentivize credits for a local area (USGBC, 2013). The effectiveness of the Regional Priority Credits have not been the subject of any peer reviewed studies to date.

The studies by Reijnders (1999) and Kaatz (2006) indicate that a generalized approach does not in fact constitute the best practice for green building rating. Bray (2006) and Kiebert (2004) both emphasize the problems that are inherent in a generalized model however the majority of their research still indicated that for the most part the generalized method did not yield any major concerns.

LEED Methodologies and Implementation

The second category of literature reviewed outlined methodological approaches to green building projects and served to provide both critiques of current general building policies as well as tailored building approaches. The guidelines for planners and engineers for green building projects whether the building is a LEED building or any other system require a systematic implementation of each green building feature. The determination of which features will be included and the order in which they will be incorporated are determined in several ways and each piece of literature dealing with methodology outlines various techniques for planning green building projects.

Cupido (2006) establishes a framework aimed at providing guidance for senior facility professionals. The study evaluated green building projects at universities and used interviews and surveys to determine what policies and guidelines influenced each project and how that would provide a better framework to approach a green building project for higher education facilities as well as other institutional buildings. Cupido (2006) recommends that professionals responsible for a building project to form a clear strategy and revisit the various pieces of the process as necessary. The goal is to ensure uniform application of all policies and to maintain green building costs to a minimum while maximizing green building effects.

The minimization of cost is an important factor for LEED practitioners in developing strategies to implement a building plan. This is of concern because each green feature incorporated into a building could potentially increase the cost of the building. The "Cost of Green Revisited" instructional paper prepared by the construction firm Davis Langdon (2007) outlines the most cost effective LEED credits that a planner can implement in their LEED building. This reinforces the theme found in Weddings (2006) piece that market factors and economic concerns drive LEED design. The resulting LEED plan focused more on cost savings rather than environmental impact runs the risk of incorporating features that may be unnecessary but are incorporated in an attempt to gain a LEED rating at a discount.

Keysar's (2007) endeavors to develop a series of decision making tools that go further than the Davis Langdon (2007) cost saving cheat sheet and focus on methods for both cost saving and environmental sustainability for a particular region. This framework aims to customize the generalized credit system of the LEED standard to accomplish a more tailored project. The driving factors in Keysar's model are applicability and cost of a project. The applicability portion is perhaps the most important in that it identifies what features are in fact necessary for a truly sustainable green building project based on its geographic location. This model is aimed at public sector projects however guidelines such as these are not incentivized to the private sector in the same way as cost savings and maximum LEED credit levels.

Mackley (2001) addresses this gap between the incentives behind a green building project and the actual green building features that are most important for a particular location. In her study she focuses on how the gap in knowledge transfer of sustainable feature analysis and planners in the Green Building Challenge served to limit the effectiveness of the green building initiatives at the micro and macro level of the projects. This gap is indicative of both the problems with methodologies that focus too much on costs and not enough on geographically appropriate credits and the policies that do not incentivize the holistic planning that would account for the geographical applicability of a credit.

Several building assessment systems have been developed to address this gap. While some commercial interests could be indifferent to issues beyond cost minimization, planners more concerned in meeting sustainability goals are left with a myriad of systems to choose from. Retzlaff (2008) aims to develop a framework to help decide on the most appropriate building assessment system for their particular building and explores several different green building models in addition to LEED. In the study she identifies scale as an incredibly important factor in determining an appropriate assessment system. Additionally the particular local concerns of a project are important to consider. This reinforces the indication that a generalized approach to green building projects may not be as effective a tailored solution however this framework indicates that it may be more possible to tailor the particular green building rating system to local needs. The need for a framework for environmental assessment is reinforced by Cole's (1998) survey of various environmental assessment methods. In his conclusion Cole indicates that a generalized approach may in fact allow for a more easily adapted green building project because it is not tied to any particular location. However Cole's study predates the LEED program and the further ubiquity of green buildings.

Green Building Policy

The importance of a generalized LEED certification process as a means to customize a building is not a priority within the green building policy and legal literature. The policies regarding green building are myriad and have increased dramatically in the last decade. The American Association of Architects reports that between the 2007 and 2009 survey of municipalities there was a 50% increase in the number of cities with green building program with 24 of 25 of the most populated regions in the United States being built around cities with a green building policy (Rainmaker, 2009). However the particular policies in place are difficult to compare due either the limited availability of policy details or the inherent specificity of a particular policy. The policies are occasionally reactionary of their neighbors and may or may not complement bordering policies and laws.

The US Department of Defense's mandate to pursue LEED certification for all future building projects reiterates the federal government's commitment to green building projects and specifically to LEED certified building projects (Keysar, 2007). Local commitment to green buildings is clarified in Sammy Zahran's (2008) study. Zahran's quantitative analysis of environmental vulnerability and demographic trends saw a high correlation between localities that would experience catastrophes because of climate change and a willingness to commit to climate change related programs such as green building programs.

Fredriksson (2002) outlines the “asymmetric” manner in which state governments implement incentives for green building projects. His conclusion is that stringent requirements by one state will influence a neighboring state to increase regulations however a rise in regulations in an otherwise lax regulatory environment will not have any effect on its neighbors. This indicates that while there is both competition and interaction between states in determining green building policy it is also indicative of potential regulatory practices that incorporate geographic location into the regulatory framework. However the amount of logistical effort and planning required for a statewide green building regulation detracts from this theory since in some cases responding to a neighbor may just be more expedient than investing time and money into research and policy development that has already been completed in a similar community.

In DuBose’s (2006) “Analysis of State-Wide Green Building Policies” she outlines the obstacles and intricacies involved in developing a state wide green building policy. Using the case study of nine states DuBose is able to highlight the organizational policies that are being used to inform state level policy. The study highlights the evolution of green building programs within bureaucracies and the interplay between the public, private, and non-governmental sectors in influencing policy. There is discussion of opposition to LEED in the form of both cost concerns and resistance to change. Dubose also highlights enablers in the form of champions and stakeholders. She does not elaborate on commercial interests and or potential conflicts of interest. Evaluation of particular needs within a state is also identified as a key step in the assessment process and intends to drive any statewide policy towards a result that will drive toward more tailored green building projects that are specific to the state in which they are built.

While state level polices are important in determining the trends of green building programs municipalities are generally responsible for most building codes and LEED certification customization will probably be more indicative of local needs than state or federal policies. King’s (2005) paper advocates for municipalities to enact incentives to promote green building projects. She also mentions the importance of a tiered approach to incentives that incorporate federal, state, and local policies that promote particular green building features as well as overall incentives such as large property tax breaks for qualifying buildings. However a delicate balance is necessary with individual feature incentives because these could result in the same problems as the cost saving motivations from the Davis Langdon (2007) paper. However, a well-researched and well-implemented incentive program can offset any cost saving imbalances in green building plans (King 2005).

Schindler (2010) addressees uneven green building development as it relates to feature incentives and the threat of cost saving measures by project planners. Her study advocates green building policy that is divorced from biased stakeholders such as private industry and the non-profits like the USGBC that are primarily serving industry interests. An alternative plan that is developed by “public governmental bodies” is seen as the alternative. Schindler states that LEED standards were designed for a voluntary framework and are not conducive to legislative mandates.

The consensus of the legal and policy related literature was that legal efforts should be focused on fostering coordination and on promoting green building features and initiatives that are unpopular but necessary for a particular area. Nilsson (2009) emphasized the importance of coordination based policy through the waste management case study. Retzlaff (2009) in addition to incentive policies addresses governmental requirements as well as private instructional requirements.

While analysis of legislation and policy development to mold green building initiatives is very prevalent there is limited insight into the legality of LEED standards in and of themselves. Fox (2010) begins to address these issues and specifically cites a lack of challenge to LEED. Since LEED is a product of the USGBC, a product of private industry, Fox claims that there are potential preemption, delegation, and antitrust issues with the policy. Additionally the impacts of legislated LEED standards have on personal property rights have yet to be established. It is clear however that green building mandates are aimed mainly at government buildings while tax incentives are aimed at private sector building projects.

Chapter 2: Methodology

Overview

This chapter first examines the methodology used to analyze the large amount of data received from the USGBC. The details of the dataset are examined. The study was completed by using a sample of municipal LEED buildings. These buildings were sampled based on climatic criteria which were determined by compiling precipitation and temperature data with locational information for each LEED building. Four custom metrics were calculated based on land cover data, roads data, and census data. This discussion is followed by the sampling techniques used to determine the final study area. Once the sampling techniques are described the creation of each metric is explained in detail. To conclude, the statistical analysis of the metrics is described. The first metric was an aggregation of LEED credits regarding transportation. The second and third metrics were a local and global calculation of the density of the road network in the vicinity of each building. The fourth metric was a calculation of the built up area in the vicinity of each building. The fifth metric measured the percentage of commuters that used public transportation within a building's census tract These custom metrics were all then compared to an aggregate metric that was calculated by combining each building's transportation related credit attainment.

The study incorporated traditional statistical analysis as well as GIS based analysis. The initial sample of LEED Gold municipal buildings were selected using a stratified sample based on various climatic zones. The climatic zones were determined by average rainfall as well as geographic location. Each site in the study was compared using five custom generated metrics and the two most comparable LEED credits.

Public Gold LEED project

This project exploring transportation and built density in LEED is part of a larger ongoing project “Public Gold” (personal communication, Melissa Keeley, June 2012). Through this study, building credit achievement data was acquired for 100 municipally owned and operated buildings which had achieved LEED Gold 2.1 or 2.2 New Construction certification as of June 2011. The 100 building sample was selected utilizing a stratified sampling methodology designed to explore regional differences in credit achievement relative to storm water management, yet which still allows us to ignore the loss of randomness in the sample (Pearson's Chi-square statistic in the goodness of fit test= 2.556 with 8 degrees of freedom). The Pacific Northwest zone contained 9 buildings, the Great Lakes zone contained 13, the Midatlantic zone contained 11, the Southeast zone contained 8, the Type 3 zone contained 7, the Arid Mountain zone contained 9, the Inland desert zone contained 7, and the LA/San Diego Zone contained 16 (See Figure 2.1).

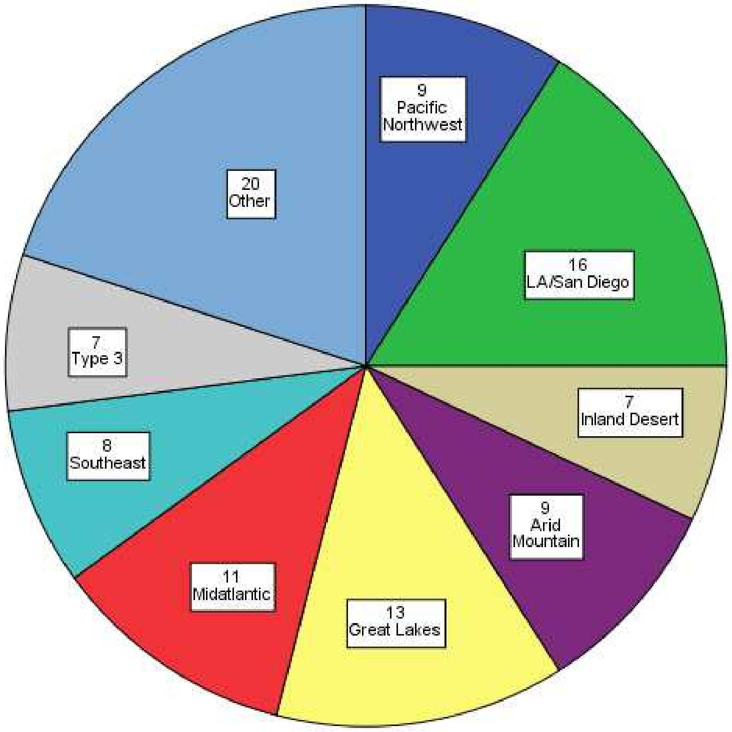

Figure 2.1: Breakdown of buildings by region

The sample covered 28 states with California containing the most buildings with a total of 25 and with Florida and Illinois both containing the second most with 9 buildings each (See Appendix 1 for all state totals).

LEED Aggregate Metric

The USGBC within the LEED 2.1 and 2.2 framework defined five different categories of credits. These were sustainable sites, water efficiency, energy and atmosphere, materials and resources, and environmental quality. This study focused on credits that were included in the sustainable sites credit category. In addition to the particular LEED credits that custom metrics were generated for comparison a metric was determined by aggregating the total credit achievement of each building for 5 specific credits related to these issues: credit 2 Development Density and Community Connectivity, credit 4.1 Alternative Transportation: Public Transportation Access, credit 4.2 Alternative Transportation: Bicycle Storage and Changing Rooms, credit 4.3 Alternative Transportation: Low Emitting & Fuel Efficient Vehicles, and credit 4.4 Alternative Transportation: Parking Capacity (See Appendix 2 for a full list of LEED credits). "Innovation in Design" credits, sometimes achieved by buildings accomplishing exemplary performance related to an existing credit were also included in this aggregated total when they were associated with one of the above credits. As a result buildings could potentially receive extra credit for a particularly innovative method of attaining a credit.

Custom Metrics

Four custom metrics were generated to describe different phenomena. The first two metrics were based on transportation density and are referred to as the Global Transportation Density metric and the Local Transportation Density metric. The third metric was based on built density around each building and is called the Built Density Metric. The fourth metric was based on usage of public transit and is referred to as the Public Transportation Metric. The four custom metrics were compared to the individual LEED credits as well as a LEED aggregate metric that combined five transportation related credits together. Each custom metric was designed to provide greater insight into the phenomena that particular LEED credits were describing (See Table 2.1).

Table 2.1: Custom metrics and Corresponding LEED Credits

Custom Metric	Corresponding LEED Credit
Global Transportation Metric	Credit 2: Development Density and Community Connectivity
Local Transportation Metric	Credit 2: Development Density and Community Connectivity
Built Density Metric	Credit 2: Development Density and Community Connectivity
Public Transportation Metric	Credit 4.1 Alternative Transportation: Public Transportation Access

Global and Local Transportation Density Metrics

Once built density was analyzed from the NLCD both transportation network density metrics were calculated. The road network was a TomTom developed dataset that included sixteen classes of roads (TomTom/TeleAtlas, 2011). The roads dataset was then manipulated in several ways to run a model that would generate a line density surface. For the local transportation density metric the model first took the incredibly detailed and large TomTom roads dataset that encompassed the entire contiguous United States and clipped the dataset based on a fifteen mile buffer around the 100 different buildings. The fifteen mile buffer was used to prevent artificial clipping occurring at the boundary of the buffer within the twelve and a half mile study area for the purposes of density analysis. The clipped dataset was then projected into an Albers Equal Area Conical projection. This was done to accurately make measurements between features in the road dataset (Silverman, 1986).

Local Transportation Density

Once the dataset was clipped, a line density surface was calculated for each building. The density was calculated using a mask made up of a dissolved buffer of fifteen miles around each building. While only data within the study area was used for the metric it was necessary to calculate the density beyond that boundary so the density would not be clipped at the borders. This served to establish the study area and to normalize the variation between the various buildings. Additionally, a quarter mile radius was chosen to represent the smallest walking-shed distance (Guerra 2011). The resulting 100 density surfaces had a grid size of 30 meters which was consistent with the landcover surface used to calculate the built density metric. Zonal statistics were then run against each density surface. The metric consisted of the average pixel value in square kilometers within the twelve and half mile buffer.

Global Transportation Density

The global transportation density metric was completed using only one density surface rather than 100 different ones. For the global metric one density surface was created for the entire study area and encompassed all of the buildings. This was an incredibly difficult GIS task as that required several days of processing time. Once the 30 meter density surface of the entire study area was calculated, zonal statistics were calculated within the twelve and a half mile buffer of each building and like the local metric it too consisted of the average pixel value in square kilometers within that buffer.

Built Density Metric

The metric for built density was calculated using the USDA's national land cover map, derived from satellite imagery called the National Land Cover Database (NLCD) (MRLC, 2001). The 2001 NLCD provides a rough means of measuring 29 land use types, spanning a range of geological, hydrological, vegetation, and urban features. The NLCD raster dataset was derived by reclassifying 30 by 30 meter aerial imagery into discrete land cover classes (MRLC, 2001). For the purposes of this study, areas impacted by human significant development were isolated. Four classes were identified from the NLCD to indicate built density: Developed open space, Developed low intensity, Medium intensity development, and High intensity development. Developed open space (NLCD Class 21) most consists of areas with 20 percent or less impervious surfaces and large amounts of planted vegetation. "These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes." (MRLC, 2001). Developed low intensity (NLCD Class22) includes 20-49 percent impervious surfaces and is usually single-family housing. Medium intensity development (NLCD Class 23) includes 50-79 percent impervious surfaces and is also most commonly inclusive of single family homes. High intensity development (NLCD Class 24) is indicative of highly urbanized areas with 80 to 100 percent impervious surfaces.

In order to process the NLCD, it was necessary to extract these classes from the rest of the dataset. To complete these tasks four rasters were created from the original NLCD. A conditional statement was written to process this incredibly large dataset. This task required 72 hours of processing within ERDAS Imagine. A distance of twelve and a half miles (Zhao, 2003) was used to represent driving or average commute distance and was the buffer distance used to calculate zonal statistics from each of the four rasters. The developed area around each building was then aggregated and each building was ranked according to the amount of built density surrounding the building.

Public Transportation Metric

The final metric was based on commuting data from the 2000 Census summary file 3 (US Census 2000) at the census tract level. Verified addresses were used to identify the census tract of each building. The data was downloaded from the P30 detailed table for means of transportation to work for workers over the age of 16. This data was then presented as a percentage of the total number of commuters within the census tract. The commuting values represent the number of commuters that originate their commute from the given census tract. The use of 2000 Census data was necessary for this metric as the 2010 Census did not capture data at this level of granularity.

Statistical Analysis

Analysis of Descriptive Statistics and Central Tendencies

Once each metric was calculated and tabulated in a spreadsheet, statistical analysis was completed. Each metric was analyzed to calculate the mean, median, mode, skewness, and kurtosis. These statistics, the Kolmogorov-Smirnov (K-S) test, and visual inspection of metric histograms were used to determine central tendencies (Fields, 2009). The normalcy of a metric was based primarily on the z-scores of the skewness and kurtosis values. The K-S test provided further insight if the skewness and kurtosis test were inconclusive and the visual inspection of the histogram was given the least relevance.

Once the central tendency of each metric was determined, a comparison was completed by climatic zone. In order to compare the metrics the average value for each metric was used to generate a bar chart. Basic trends were noted as well as significant differences between the zones.

Analysis of Correlations

After analyzing the differences between the credits by climatic zone, each custom metric was compared to the LEED Aggregate metric and to the LEED credit that the custom metric was intended to represent. To best compare each metric, correlation tests were run to determine whether there was a significant relationship either positive or negative between the custom metrics and the LEED credits.

Since the LEED Aggregate metric and the individual LEED credit values contained only a couple variations in the data scatterplots were difficult to because visually the LEED Aggregate metric resembled ordinal data. Each custom metric was analyzed using the appropriate test for the metric. A Pearson correlation was run for all normally distributed custom metrics and LEED credits (LEED Aggregate, LEED Public Transportation Credit 4.1, Built Density Metric, Global Transportation Density Metric, and Local Transportation Density Metric) and a Kendall-tau correlation was run for all non-normally distributed custom metrics and LEED credits (Public Transportation Credit and LEED Development Density Credit 2).

Once correlation tests between the custom metrics and the LEED metrics were completed correlations between the built density and the global and local transportation density metrics were explored. Since the three metrics were normally distributed, a Pearson correlation was calculated between each metric.

Building Rankings

In addition to statistical analysis, building performance in each metric was ranked and compared. The top ten buildings and bottom ten buildings were then compared across each metric. The buildings that were in the top ten or bottom ten of multiple credits' rankings were noted. Additionally any buildings that were in the top ten of a particular credit's ranking and in the bottom ten of another was also noted.

Chapter 3: Results and Discussion

Statistical Analysis of Metrics

Descriptive statistics of each metric

Analysis of LEED Public Transportation and Development Density Credits

Analysis of individual credit achievement revealed that most buildings within the study achieved most or all of the LEED transportation and density related credits (See Table 3.1). Only one building within the sample failing to receive any transportation related credits and only 18 buildings received less than three transportation related credits. Bicycle Storage (LEED SS Credit 4.4) was attained by the most buildings followed by Low Emitting and Fuel efficient vehicles (LEED SS Credit 4.3), Parking Capacity (LEED SS Credit 4.4), Public transportation access (LEED SS Credit 4.1), and Development Density and Community Connectivity (LEED SS Credit 2).

Table 3.1: LEED Transportation and Density Credit Attainment

	Credit Description	Attainment Percentage
LEED Credit 2	Development Density and Community Connectivity	57%
LEED Credit 4.1	Alternative Transportation: Public Transportation Access	58%
LEED Credit 4.2	Alternative Transportation: Bicycle Storage, and Changing Rooms	81%
LEED Credit 4.3	Alternative Transportation: Low Emitting and Fuel Efficient Vehicles	78%
LEED Credit 4.4	Alternative Transportation: Parking Capacity	73%

Analysis of LEED Aggregate Metric

Analysis of the LEED Aggregate metric reveals that on average the buildings in the study attained around 3.52 credits for transportation. This value was indicative of the entire distribution of the LEED Aggregate metric as it is close to the median value of 3 credits. Additionally buildings most frequently attained a score of 3.

The LEED aggregate metric was determined to be normally distributed. While the histogram (see figure 3.1) seems slightly leptokuric it is still normal considering that the height of the chart is emphasizing the median and mean values of the metric. Furthermore, analysis of the kurtosis and skewness also determined that the metric was normal (z-score skewness = $|-0.4315| < |1.96|$; z-score kurtosis = $|-0.4059| < |1.96|$). The only deviating normality test was the Kolmogorov-Smirnov (K-S) test ($D(100)=0.200$, $p<0.05$). With three of four measures of normalcy confirming normalcy the metric was treated as normal data for this study.

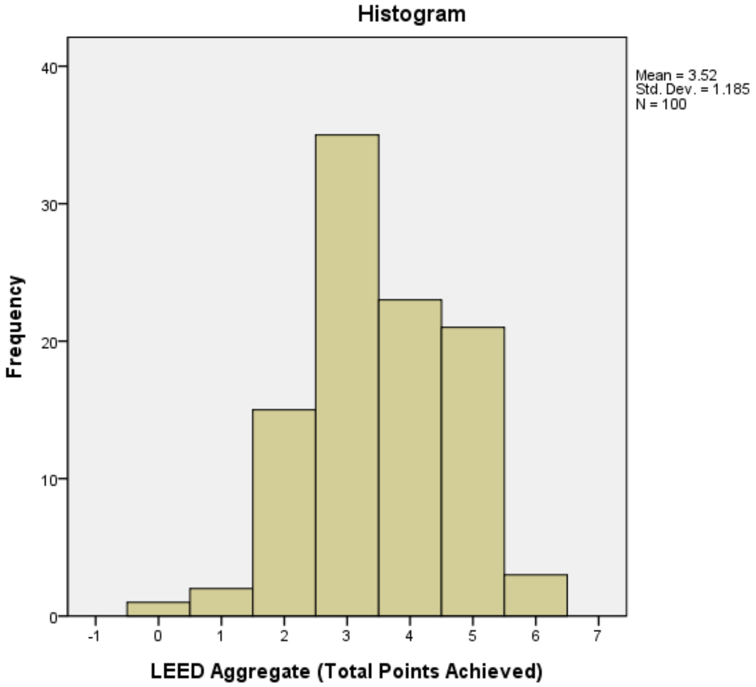

Figure 3.1: Histogram of the LEED Aggregate Metric

These results indicate that most of the buildings that are in the study sample did in fact attain most of the LEED credits related to transportation. Of the five LEED credits that comprise the LEED aggregate only one building (Building 1042) attained none of the five transportation related LEED credits. The Development Density Credit (LEED SS Credit 2) and the Public Transportation Credit (LEED SS Credit 4.1) had the most non-attaining buildings of the five metrics with 43 buildings failing to achieve credit 2 and 42 buildings failing to achieve credit 4.1. This deficiency in public transportation access is perhaps even further skewed by the fact that the threshold for this credit allows buildings to be located as far as a half mile from a public transportation station to qualify for this credit.

Global Transportation Density Metric

Analysis of the global transportation density metric reveals that the average density of road features within 12.5 miles of each building in the study was 4.570 miles per a square mile. The average was very close to the median value of 4.164 miles per a square mile.

Visual analysis of the global transportation density metric's histogram (See Figure 3.2) indicates that the metric is normally distributed. Additionally analysis of the kurtosis indicated that the metric was normally distributed while analysis of skewness indicated the metric was non-normal (z-score skewness = |3.212| < |1.96|; z-score kurtosis = 0.4247| < |1.96|). The K-S test also indicated a normal distribution (D(100)=0.080, *p*>.05). With three of four measures confirming normalcy the metric was treated as normal data for this study.

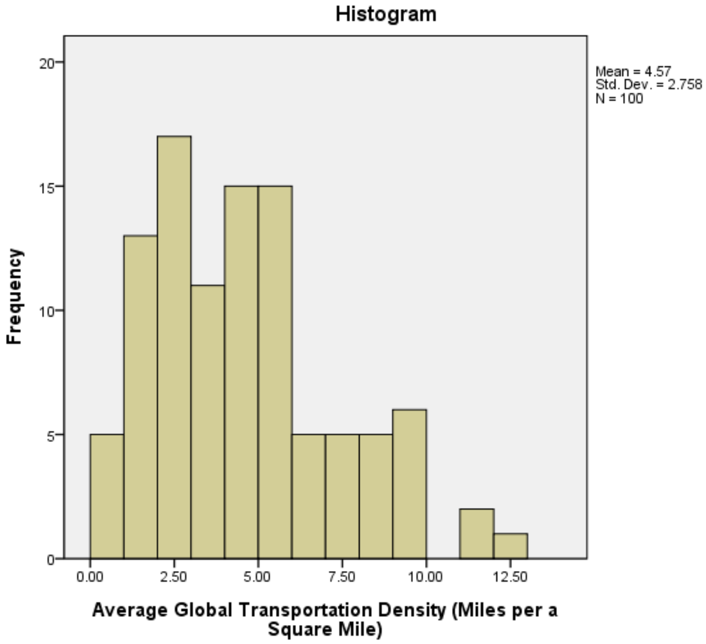

Figure 3.2: Histogram of the Global Transportation Density metric

Local Transportation Density Metric

Analysis of the local transportation density metric reveals that the average road feature density of each building within 12.5 miles of each building in the study was 8.724 miles per a square mile. The average was very close to the median value of 8.603 miles per a square mile.

Visual analysis of the local transportation density metric's histogram (See Figure 3.3) indicates that the metric is normally distributed. Additionally analysis of the kurtosis indicated that the metric was normally distributed while analysis of skewness indicated the metric was non-normal (z-score skewness = |2.037| < |1.96|; z-score kurtosis = |-0.433| < |1.96|). The K-S test also indicated a normal distribution (D(100)=0.056, *p*>.05). With three of four measures of normalcy confirming normalcy the metric was treated as normal data for this study.

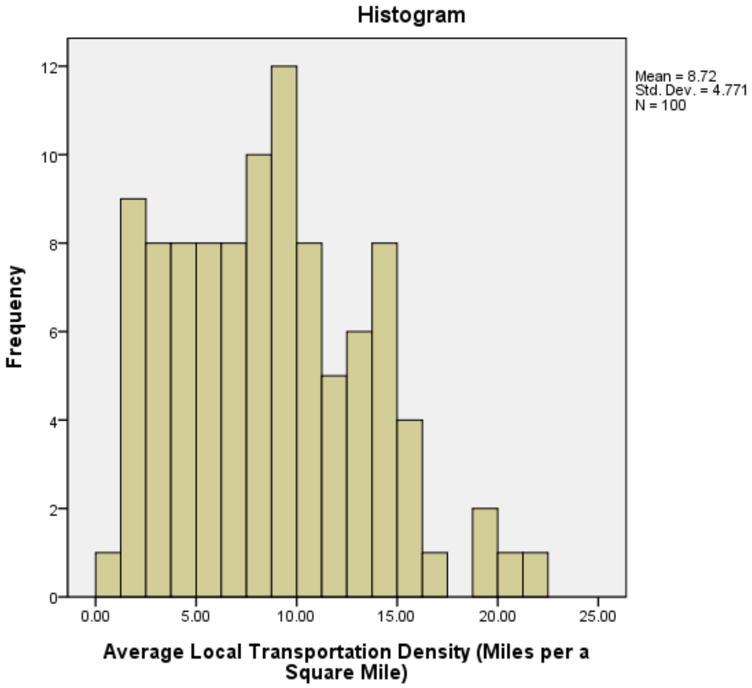

Figure 3.3: Histogram of the Local Transportation Density metric

Built Density Metric

Analysis of the built density metric reveals that on average the buildings in the study contained 40.368% total developed space within 12.5 miles of each building. The average was very close to the median value of 39.25%. Most frequently buildings contained 59.82% of developed space within the 12.5 mile commuting radius.

Visual analysis of the built density metric's histogram (See Figure 3.4) indicates that the metric is normally distributed. Additionally, analysis of the kurtosis and skewness also determined that the metric was normal (z-score skewness = |0.8506| < |1.96|; z-score kurtosis = |-1.713| < |1.96|). The K-S test also indicated a normal distribution

(D(100)=0.074, *p*>.05). With all four measures confirming normalcy, the metric was treated as normal data for this study.

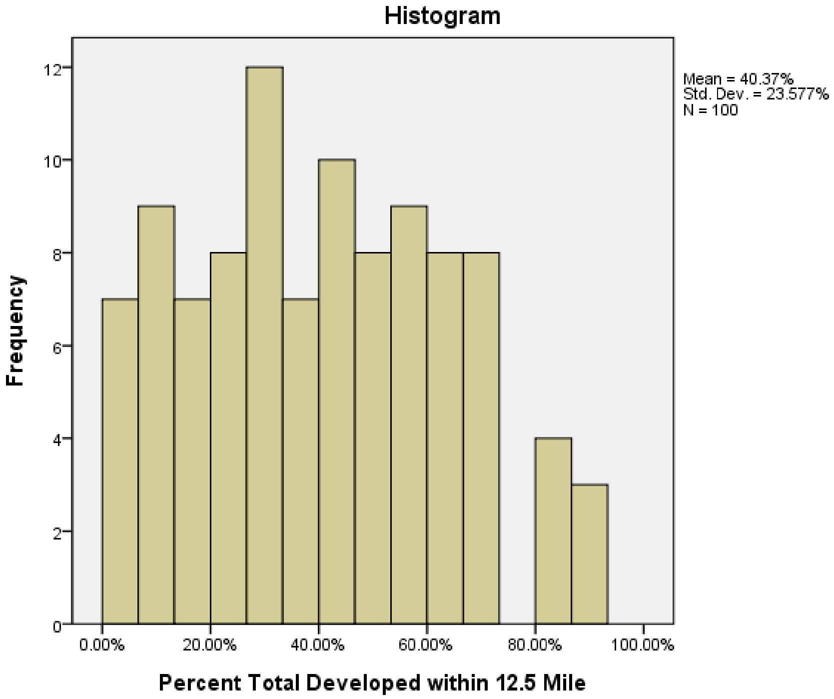

Figure 3.4: Histogram of the built density metric

Public Transportation Metric

Analysis of the custom public transportation metric reveals that on average the buildings in the study were located in census tracts in which 5.746% of commuters used public transportation. However this metric is very negatively skewed which is evident from both visual analysis of the histogram as well as the large difference between the mean and median (Mean = 5.746%; Median = 1.099%) (See Figure 3.5). Additionally most frequently buildings were located in census tracts in which 0% of commuters used public transportation.

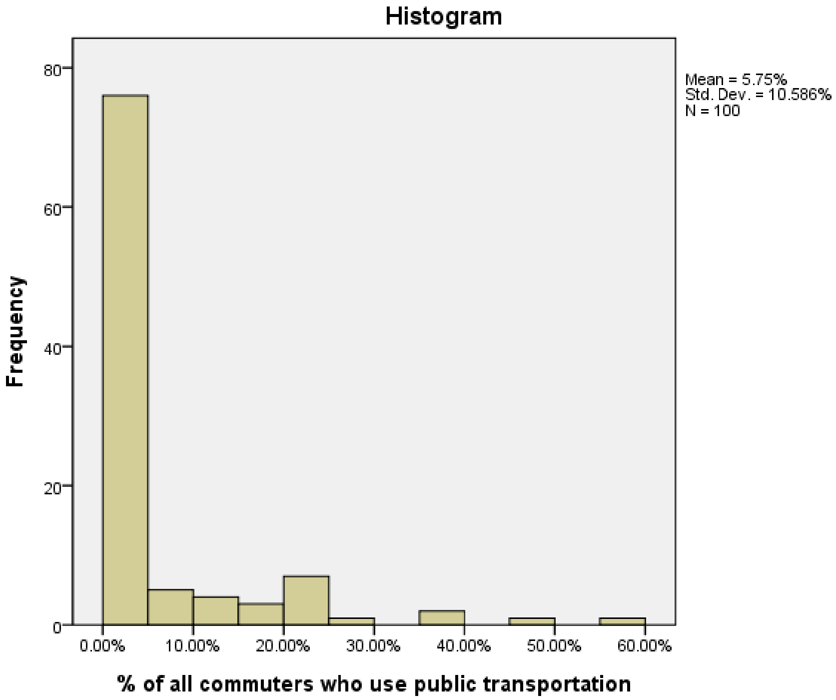

Figure 3.5: Histogram of the public transportation metric

Visual analysis of the public transportation metric's histogram indicates that the metric is not normally distributed. The chart highlights a very noticeable positive skew. Additionally analysis of the kurtosis and skewness also determined that the metric was non-normal (z-score skewness = |11.058| < |1.96|; z-score kurtosis = |16.515| < |1.96|). The Kolmogorov-Smirnov (K-S) test also indicated a non-normal distribution (D(100)=0.302, *p*<.05). With all four measures of normalcy confirming a non-normal the metric was treated as non-normal data for this study.

Correlations

Exploring correlations

Public Gold metrics and LEED Credits

There were no significant correlations (See Table 3.2) between the custom metrics and related LEED credits. Each of the custom metrics were designed to roughly reflect a theme that various components of the LEED aggregate metric were ostensibly designed to measure. The development density credit (LEED SS Credit 2) and the public transportation access credits (LEED SS Credit 4.1) were the most directly related to the four custom metrics. The fact that none of the custom metrics have any significant correlation with the LEED credits indicates that either the LEED credit or the custom metrics are poor indicators for one another.

Table 3.2: Correlations between LEED Credits and Custom Metrics

		LEED Public Transportation Credit 4.1
Public Transportation Metric	Pearson Correlation	.077
	Sig. (2-tailed)	.446
		LEED Development Density Credit 2
Average Global Transportation Density	Correlation Coefficient (Kendall's tau_b)	.042
	Sig. (2-tailed)	.609
Average Local Transportation Density	Correlation Coefficient (Kendall's tau_b)	-.016
	Sig. (2-tailed)	.845
Percent Total Developed within 12.5 Mile	Correlation Coefficient (Kendall's tau_b)	-.067
	Sig. (2-tailed)	.415

The composite nature of the development density and community connectivity credit seems to dilute the goal of increasing density and it seems to equate a set number of accessible services with community connectivity. A building can attain this credit by either developing the building to have a built density of 60,000 square feet per acre net within the development radius or a building can attain this credit by locating the building within a half mile of ten distinct services that can be accessed by pedestrians from the building (USGBC, 2013).

When basic comparisons are made between custom metrics and LEED credits for superior development density there is a fairly large disconnect between the built density and the transportation density of the surrounding areas. This indicates that many of the buildings probably rely on the community connectivity option which allows for achievement of this credit in a less dense area as long as at least 10 distinct services are made available within a half mile radius of the building (USGBC, 2013). This highlights the problems where certain areas may in fact have the necessary density but lack essential services or areas within economically disadvantaged communities that cannot achieve the necessary density due to a lack of development. Additionally the use of transportation density in regards to connectivity and development density could prove to be an important proxy for the progress of a particular neighborhood. Neighborhoods in question may be located in a service or public transportation dessert and the development of an environmentally friendly building could provide an important catalyst. If there is a robust and dense transportation system other services and higher density development are more easily established.

Analyzing correlations between Public Gold Metrics and LEED Aggregate

Since the LEED Aggregate metric consists of 6 different whole number values it is difficult to visualize any relationships in a scatterplot form because the plot begins to resemble a comparison of ordinal variables rather than a scale variable. However, using the non-parametric Kendall tau correlation coefficient was found to be significant ($0.002 < 0.05$) although $r = 0.238$ indicates a very weak correlation (See Table 3.3). The Pearson Correlations between the LEED Aggregate and each of the other custom metrics were found to be insignificant (Built Density $0.5 > 0.05$; Global Transportation Density $0.855 > 0.05$; Local Transportation Density $0.325 > 0.05$).

Table 3.3: Custom Metric Correlation Tests

Custom Metric	Statistic	As compared to LEED Aggregate
% of all commuters who use public transportation	Correlation Coefficient (Kendall's tau_b)	0.238
	Sig. (2-tailed)	0.002
Percent Total Developed within 12.5 Mile	Pearson Correlation	0.068
	Sig. (2-tailed)	0.5
Average Global Transportation Density	Pearson Correlation	-0.019
	Sig. (2-tailed)	0.855
Average Local Transportation Density	Pearson Correlation	0.099
	Sig. (2-tailed)	0.325

The lack of any significant correlations between three out of four custom metrics and the weak correlation between the public transportation metric and the LEED aggregate indicates that there may be inconsistencies between some of the physical realities of each building's geographic location and the LEED credit achievement of each building. The weak correlation between the custom public transportation metric and the LEED aggregate is expected as the 0-0.5 mile threshold (USGBC, 2011) for the public transportation credit (LEED SS Credit 4.1) results in a very low barrier for credit achievement for this credit. This is because the 0-0.5 mile threshold results in situations in which buildings that are directly connected or right next to high traffic central transit systems achieve the same credit as buildings that are up to 0.5 miles away from peripheral bus stops in a low traffic transit system. In contrast, measuring the actual usage of public transportation within the vicinity of a LEED building is much less permissive. Difficultly in public transportation access significantly reduces the number of commuters that use public transportation and while 0.5 miles of walking distance has been cited as an appropriate measure of a transit station's catchment area (Guerra, 2011) the LEED credit is awarded based on Euclidean distance (personal communication, Christopher Pyke of USGBC, March 2, 2012) which does not account for actual walking distance. Additionally, if buildings are located in communities that have been traditionally underserved by public transportation and are more often located very close to the upper limits of the half mile threshold it is less likely that the building will actually be adequately served by public transportation (ULI, 2009). Furthermore it is necessary to attempt to locate a building as best as possible within the appropriate context of the wider metropolitan area and within the most appropriate type of transit for the wider area (CNT, 2010).

While 58% of buildings received the LEED Public Transportation credit 4.1, when each building was analyzed in relation to the percentage of commuters that use public transportation within each buildings census tract only 19 buildings were in census tracts that had greater than 10% of commuters using public transportation and only 4 buildings had more than 35%. This finding does raise the question of whether the criteria used for determining the public transportation credit are sufficiently stringent to indicate transportation access that is convenient and usable for significant numbers of commuters. However, a significant limitation on finding is the fact that the census data from which commuter percentages is drawn is organized by commuter origin rather than destination. As a result, the data presented here represents the commuting preferences of those that live within the census tract in which the building is located rather than the commuting preferences of those for which this census tract is their destination.

Exploring correlations between built density and Global and Local transportation density custom metrics

Visual inspection of the scatterplots (See figure 3.6) between the two transportation density metrics and the built density metrics highlights a strong positive correlation between the metrics. The relationship between the average local transportation density metric and built density was slightly more tightly clustered than the global transportation density metric.

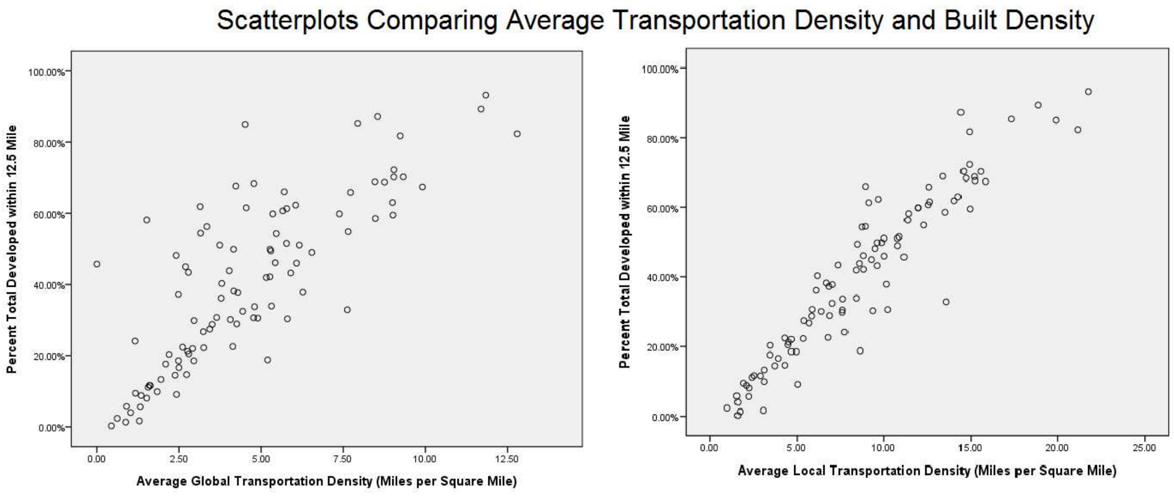
Scatterplots Comparing Average Transportation Density and Built Density

Figure 3.6: Scatterplot of Built Density and both Local and Global Transportation Density metrics

This particular trend is surprising since the calculation of the local transportation metric calculates density in regards to the density of the transportation network that is in the local area around each building whereas both the global transportation metric and the built density metric both calculated as compared to the intensity of either built area or transportation networks across the entire country rather than just within the 12.5 mile radius of the particular building.

The visual relationship was confirmed by the Pearson Correlation between each metric (See Table 3.4). The Global Transportation Density and Built Density metrics had a significant Pearson Correlation of r = 0.804. The Local Transportation Density and Built Density metrics had a significant Pearson Correlation of r = 0.939. Both of these values indicate very strong relationships.

Table 3.4: Correlations between Built Density and Transportation Density

Custom Metric	Statistic	As Compared to Built Density Metric
Average Global Transportation Density	Pearson Correlation	.804**
	Sig. (2-tailed)	0
Average Local Transportation Density	Pearson Correlation	.939**
	Sig. (2-tailed)	0

The strong relationship between these metrics was expected. The built density metric was calculated using a landcover dataset with a 30 meter resolution and required significant processing to calculate. The transportation density metrics were calculated using road network data which allows for much more control over the resolution of study. For this study the transportation density was calculated at the same 30 meter resolution for the purpose of comparison. The accessibility of landcover data is occasionally limited outside of the United States however transportation data is often easier to acquire. Since the LEED program is an international program using transportation density as a proxy for development density could provide an easy alternative.

Comparison of metrics

In addition to the Kendall-Tau test for correlation visual comparisons of each building ranked by the custom metrics was also completed. The visual comparison of the top ten buildings as ranked by each metric highlighted only 3 buildings in common in the top ten between the LEED aggregate metric and the public transportation metric (See Table 3.5). The comparisons between the other three metrics were even more disconnected with only one building falling in the top ten of both the LEED credit aggregate metric and each of the other calculated metrics.

Table 3.5: Buildings ranked (1-10) by LEED aggregate and each custom metric*

Rank	LEED Aggregate		Public Transportation		Built Density		Global Transportation Density		Local Transportation Density	
	ID	Building Use	ID	Building Use	ID	Building Use	ID	Building Use	ID	Building Use
1	1027	School	1027	School	1112	Public Safety	1074	Public Library	1112	Public Safety
2	1002	Public Library	1033	School	1008	Public Library	1112	Public Safety	1074	Public Library
3	1089	Public Library	1060	Public Safety	1015	Office Building	1008	Public Library	1025	Transit Station
4	1071	Public Library	1052	Sports Arena	1104	Office Building	1070	Community Center	1008	Public Library
5	1034	Office Building	1025	Transit Station	1025	Transit Station	1033	School	1104	Office Building
6	1105	Public Health Facility	1086	Office Building	1074	Public Library	1013	Manufacturing Facility	1070	Community Center
7	1052	Sports Arena	1006	Office Building	1013	Manufacturing Facility	1106	Office Building	1075	Community Center
8	1102	Community Center	1012	Public Safety	1106	Office Building	1075	Community Center	1027	School
9	1053	Manufacturing Facility	1074	Public Library	1033	School	1014	Public Safety	1076	School
10	1033	School	1075	Community Center	1075	Community Center	1101	Community Center	1014	Public Safety

*Colors highlight crossover between metric top ten ranks

A visual comparison of the bottom ten buildings (See Table 3.6) highlights some crossover between the built density metric and both transportation density metrics. Building 1002 is found to be in the top ten ranks for the LEED aggregate metric while it is found in the bottom ten rankings for the built density and both transportation density categories.

Table 3.6: Bottom Ten Buildings ranked (100-91) by LEED aggregate and each custom metric*

Rank	LEED Aggregate		Public Transportation		Built Density		Global Transportation Density		Local Transportation Density	
	ID	Building Use	ID	Building Use	ID	Building Use	ID	Building Use	ID	Building Use
100	1042	Community Center	1013	Manufacturing Facility	1085	Transit Station	1078	Public Health Facility	1046	School
99	1007	Community Center	1021	Public Safety	1001	Community Center	1085	Transit Station	1056	Public Safety
98	1045	School	1026	Office Building	1010	Public Safety	1046	School	1085	Transit Station
97	1076	School	1043	School	1046	School	1001	Community Center	1002	Public Library
96	1013	Manufacturing Facility	1044	Public Assembly	1002	Public Library	1056	Public Safety	1001	Community Center
95	1063	Manufacturing Facility	1081	Public Library	1047	Public Safety	1002	Public Library	1067	Manufacturing Facility
94	1019	Public Safety	1083	Office Building	1056	Public Safety	1036	Public Library	1011	University Building
93	1023	Public Safety	1082	Office Building	1081	Public Library	1067	Manufacturing Facility	1047	Public Safety
92	1021	Public Safety	1073	Public Safety	1011	University Building	1010	Public Safety	1081	Public Library
91	1031	Office Building	1113	School	1040	Public Library	1047	Public Safety	1028	School

* Colors highlight crossover between metric bottom ten ranks

The custom metrics that were calculated for the study were found to have much more crossover than with the LEED metrics. The most similarities between top and bottom ten ranks were found between the built density metric and the global and local transportation density metrics. This was expected as a subset of this study was to determine whether transportation density could be used as a proxy for built density. However certain locations in suburban and exurban locations potentially have higher transportation density than built density (Handy 2005). The built density metric had the most similarities with the global transportation density metric with seven buildings classified in the top ten rankings of either metric. This result was not completely surprising since both the global transportation density metric and the NLCD derived built density metric are calculated using global dataset comparisons. Since every cell in the source raster for these metrics is calculated based on national level data there is consistency throughout the dataset regardless of region. There is slightly less similarity between the built density metric and the local transportation density metric but there are still six buildings that are in both top ten rankings. There were four buildings that were found to be in the top ten of the public transportation metric and the built density metric, three between the public transportation metric and the global density metric and four with the local density metric.

Chapter 4: Conclusion

Key Findings

Four custom metrics were designed in an attempt to describe particular LEED credits of Development Density and Community Connectivity (LEED SS Credit 2) and Access to Public Transportation (LEED SS Credit 4.1). The first key finding of this study was that there was no relationship between the LEED Aggregate metric or related individual LEED credits evaluated and custom metrics of Global Transportation Density, Local Transportation Density, and Built Density. There was a very weak relationship between the LEED Aggregate and Public Transportation metric. The lack of strong relationships means that either the LEED credits or the custom metrics or neither of these characterizes the situation around each building adequately.

The lack of a relationship between the LEED credits and the custom density metrics can potentially be explained by the fact that the built density metric and the global and local transportation density metrics measured overall density around a building while the LEED Development Density and Community Connectivity credit measured several different aspects of a building. The lack of a relationship between the Public Transportation metric and the LEED Access to Public Transportation credit is more surprising, however, this also could be explained by the fact that the custom public transportation metric used Census data that reports commuting activity at a respondents origin rather than their destination which could have skewed the custom metric if no commuters originate their commutes within the census tract of the building used in the study.

The second key finding of this study was the strong relationship between the custom Built Density and Global and Local Transportation Density metrics. The built density metric was derived from remote sensed landcover data while the transportation density metrics were derived from road network data from TomTom/ Tele Atlas. Since both describe similar built environments this adds flexibility for a study that requires density information but lacks either road network data or landcover data. This finding is similar to the findings of Zhang's (2002) study which used road density to differentiate between rural non-built-up areas found using remote sensed data.

The final key finding was that only one building within the sample failed to receive any transportation related credits and only 18 buildings received less than three transportation related credits. When compared to the custom public transportation metric the transportation LEED credits might be too permissive. The permissive nature of this metric was even more apparent in regards to the Public Transportation Credit (LEED Credit 4.1). 23% of buildings that attained this credit had fewer than 1% of commuters using public transportation within the building's census tract however this particular finding may be skewed by the fact that Census data on commuting patterns is reported to a respondent's home census tract rather than where they are commuting. As a result if the majority of users of a building are commuting from outside of the building's census tract the information will not correctly reflect public transportation usage.

Policy Recommendations

Policy recommendations from this study are aimed both at the USGBC as well as LEED practitioners. The first recommendation is for the USGBC to design more specific transportation credits which do not combine multiple methods of credit achievement. Specifically, a reevaluation of the development density and community connectivity credit so as to separate the density of a building project from the accessibility of services would be beneficial. Also providing greater credit opportunities for buildings that have access to more useful and efficient transportation would incentivize efficient commutes in a meaningful manner. While the innovation in design credits provide an avenue to provide credit for designs that serve community needs specific credits in regard to this effort are important and could potentially be explored through the newly introduced Regional Priority Credits. While promoting public transportation is necessary if a locality does not yet have a robust public transit network incentivizing an efficient driving commute becomes much more important.

Finally, transportation research points to the vital importance of green building recertification. Building recertification should take into account actual use of transportation-related building amenities. For example, if a building received a public transportation credit, public transportation usage should meet a pre-determined threshold in order to retain that credit.

Further Research

This provides an introduction to transportation density, built density, and public transportation of green buildings. However, as a quantitative study of remotely gathered information, it is significantly limited by the lack of ground truth analysis of user behaviors. Ground truth would be required for each of the four custom metrics to determine whether the calculations based on remote sensed and survey data are in fact accurate and current. In the case of transportation density and built density it is necessary to determine whether driving and transit commutes are more efficient within higher density areas. Additionally it would be important to measure the walking distance between a building and the qualifying public transportation stop. Both of these ground truth activities require significant effort and resources to complete.

Finally, measurable ground truth should be supplemented by interviews of building inhabitants. This could include questions regarding commute costs, commuting convenience, and commute times, all which would directly inform the perceptions of the various building aspects that the custom metrics are designed to measure. This could be an important component of a recertification process that would assess the perspectives of building inhabitants on not only the factors that drive their commuting decisions but the building with which they are associated and the LEED program more generally.

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Appendices

Appendix 1: Number of Projects listed by State

State	Number of Projects
AR	1
AZ	6
CA	25
CO	7
CT	1
DC	2
FL	9
GA	2
IA	4
ID	2
IL	9
KS	1
MD	4
MI	1
MN	1
MO	1
NC	2
NM	1
NV	1
OH	1
OR	1
PA	2
TN	1
TX	2
UT	1
VA	3
WA	8
WY	1
Total	100

Appendix 2: Table of all LEED 2.1 & 2.2 New Construction Credits

Credit	Credit Category	No.	Value
Construction activity pollution prevention	Sustainable Sites	N/A	Pre-Requisite
Site selection	Sustainable Sites	1	1 point
Development density and community connectivity	Sustainable Sites	2	1 point
Brownfield redevelopment	Sustainable Sites	3	1 point
Alternative transportation - public transportation access	Sustainable Sites	4.1	1 point
Alternative transportation - bicycle storage and changing rooms	Sustainable Sites	4.2	1 point
Alternative transportation - low emitting and fuel efficient vehicles	Sustainable Sites	4.3	1 point
Alternative transportation - parking capacity	Sustainable Sites	4.4	1 point
Site development - protect or restore habitat	Sustainable Sites	5.1	1 point
Site development - maximize open space	Sustainable Sites	5.2	1 point
Stormwater design - quantity control	Sustainable Sites	6.1	1 point
Stormwater design - quality control	Sustainable Sites	6.2	1 point
Heat island effect - non-roof	Sustainable Sites	7.1	1 point
Heat island effect - roof	Sustainable Sites	7.2	1 point
Light pollution reduction	Sustainable Sites	8	1 point
Water efficient landscaping - reduce by 50%	Water Efficiency	1.1	1 point
Water efficient landscaping - no potable water use or no irrigation	Water Efficiency	1.2	1 point
Innovative wastewater technologies	Water Efficiency	2	1 point
Water use reduction - 20% reduction	Water Efficiency	3.1	1 point
Water use reduction - 30% reduction	Water Efficiency	3.2	1 point
Fundamental commissioning of the building energy systems	Energy and Atmosphere	1	Required
Minimum energy performance	Energy and Atmosphere	2	Required
Fundamental refrigerant management	Energy and Atmosphere	3	Required
Optimize energy performance	Energy and Atmosphere	1	Up to 10 points
On-site renewable energy	Energy and Atmosphere	2	Up to 3 points
Enhanced commissioning	Energy and Atmosphere	3	1 point
Enhanced refrigerant management	Energy and Atmosphere	4	1 point

Measurement and verification	Energy and Atmosphere	5	1 point
Green power	Energy and Atmosphere	6	1 point
Storage and collection of recyclables	Materials and Resources	1	Required
Building reuse - maintain 75% of existing walls, floors & roof	Materials and Resources	1.1	1 point
Building reuse - maintain 95% of existing walls, floors & roof	Materials and Resources	1.2	1 point
Building reuse - maintain 50% of interior non-structural elements	Materials and Resources	1.3	1 point
Construction waste management - divert 50% from disposal	Materials and Resources	2.1	1 point
Construction waste management - divert 75% from disposal	Materials and Resources	2.2	1 point
Materials reuse - 5%	Materials and Resources	3.1	1 point
Materials reuse - 10%	Materials and Resources	3.2	1 point
Recycled content - 10% (post-consumer + 1/2 pre-consumer)	Materials and Resources	4.1	1 point
Recycled content - 20% (post-consumer + 1/2 pre-consumer)	Materials and Resources	4.2	1 point
Regional materials - 10% extracted, processed and manufactured regionally	Materials and Resources	5.1	1 point
Regional materials - 20% extracted, processed and manufactured regionally	Materials and Resources	5.2	1 point
Rapidly renewable materials	Materials and Resources	6	1 point
Certified wood	Materials and Resources	7	1 point
Minimum IAQ performance	Indoor Environmental Quality	1	Required
Environmental Tobacco Smoke (ETS) control	Indoor Environmental Quality	2	Required
Outdoor air delivery monitoring	Indoor Environmental Quality	1	1 point
Increased ventilation	Indoor Environmental Quality	2	1 point

Construction IAQ management plan - during construction	Indoor Environmental Quality	3.1	1 point
Construction IAQ management plan - before occupancy	Indoor Environmental Quality	3.2	1 point
Low-emitting materials - adhesives and sealants	Indoor Environmental Quality	4.1	1 point
Low-emitting materials - paints and coatings	Indoor Environmental Quality	4.2	1 point
Low-emitting materials - carpet systems	Indoor Environmental Quality	4.3	1 point
Low-emitting materials - composite wood and agrifiber products	Indoor Environmental Quality	4.4	1 point
Indoor chemical and pollutant source control	Indoor Environmental Quality	5	1 point
Controllability of systems - lighting	Indoor Environmental Quality	6.1	1 point
Controllability of systems - thermal comfort	Indoor Environmental Quality	6.2	1 point
Thermal comfort - design	Indoor Environmental Quality	7.1	1 point
Thermal comfort - verification	Indoor Environmental Quality	7.2	1 point
Daylight and views - daylight 75% of spaces	Indoor Environmental Quality	8.1	1 point
Daylight and views - views for 90% of spaces	Indoor Environmental Quality	8.1	1 point
Innovation in design	Innovation and Design	1	Up to 4 points
LEED Accredited Professional	Innovation and Design	2	1 point
Introduction/Other	Introduction/Other	N/A	N/A

Appendix 3: Tables of all projects ranked by each metric

Appendix 3.1: Projects ranked by aggregate LEED transportation credit score

GW_ID	Region code	LEED Aggregate	% of all commuters who use public transportation	Percent Total Developed within 12.5 Mile	Average Global Transportation Density	Average Local Transportation Density
1027	Midatlantic	6	57.52%	67.63%	4.22989	15.2304
1002	Arid Mountain	6	0.78%	3.99%	1.02676	1.60131
1089	Pacific Northwest	6	11.06%	30.34%	5.80133	9.36126
1071	Other	5	0.06%	18.80%	5.19813	8.62462
1034	Other	5	3.38%	14.50%	2.38067	3.73646
1105	Type 3	5	0.44%	54.45%	3.15580	8.92801
1052	Southeast	5	35.51%	65.83%	7.72172	12.5809
1102	Southeast	5	0.03%	32.46%	4.43852	7.03273
1053	Southeast	5	20.11%	30.14%	4.06472	6.39739
1033	Midatlantic	5	47.74%	70.24%	9.32625	14.5823
1101	Midatlantic	5	1.16%	63.01%	8.99902	14.2662
1037	Midatlantic	5	3.12%	49.89%	4.16006	9.87952
1004	Arid Mountain	5	5.97%	37.73%	4.29190	7.04752
1085	Arid Mountain	5	0.15%	0.28%	0.44142	1.5934
1022	Inland Desert	5	0.03%	54.86%	7.64923	12.2775
1025	LA/ San Diego	5	27.68%	84.92%	4.51393	19.9104
1072	LA/ San Diego	5	8.94%	61.86%	3.14372	14.0504
1024	LA/ San Diego	5	1.37%	45.98%	6.07820	10.0176
1103	LA/ San Diego	5	0.03%	43.24%	5.90241	9.61374
1068	LA/ San Diego	5	1.04%	49.88%	5.26985	9.61374
1086	Pacific Northwest	5	24.98%	51.06%	3.73900	10.7869
1051	Pacific Northwest	5	3.65%	37.85%	6.26916	10.1529
1049	Pacific Northwest	5	12.39%	44.98%	2.69824	9.28232
1048	Pacific Northwest	5	4.51%	37.20%	2.48161	6.84694
1061	Other	4	0.49%	48.99%	6.54314	10.8017
1084	Other	4	0.20%	27.48%	3.43619	5.38088
1040	Other	4	0.07%	9.13%	2.42443	5.02406
1035	Other	4	6.03%	22.05%	2.91352	4.66786
1038	Other	4	1.09%	20.32%	2.19760	3.46275
1055	Southeast	4	16.61%	61.30%	5.77933	9.12366
1111	Southeast	4	0.06%	30.72%	3.64555	5.86927

1075	Midatlantic	4	21.07%	70.21%	9.03824	15.5697
1029	Midatlantic	4	6.88%	26.76%	3.24037	5.68472
1032	Midatlantic	4	0.26%	9.91%	1.83533	3.12065
1015	Great Lakes	4	3.81%	87.17%	8.54552	14.4242
1012	Great Lakes	4	22.46%	61.53%	4.54532	12.6232
1060	Great Lakes	4	36.55%	48.16%	2.41258	9.48471
1010	Great Lakes	4	0.30%	1.68%	1.29234	3.07094
1009	Great Lakes	4	0.18%	11.67%	1.59877	2.52783
1092	Arid Mountain	4	0.04%	18.56%	2.48380	4.68498
1112	LA/ San Diego	4	0.98%	93.17%	11.83710	21.7466
1070	LA/ San Diego	4	2.43%	67.37%	9.90926	15.8458
1066	LA/ San Diego	4	0.00%	30.66%	4.77215	10.2278
1062	LA/ San Diego	4	0.04%	21.24%	2.75800	4.5341
1088	Pacific Northwest	4	17.33%	56.27%	3.34696	11.3595
1050	Pacific Northwest	4	1.18%	51.05%	6.16190	10.0093
1047	Pacific Northwest	4	1.20%	5.65%	1.32087	2.21805
1077	Other	3	0.13%	58.12%	1.51780	11.4029
1041	Other	3	0.00%	49.42%	5.29595	8.45987
1065	Other	3	0.06%	41.94%	5.15584	8.39516
1036	Other	3	3.47%	24.13%	1.16293	7.74924
1080	Other	3	0.50%	36.11%	3.78353	6.10162
1099	Other	3	0.01%	28.80%	3.51047	5.84237
1039	Other	3	1.72%	20.48%	2.79599	4.50245
1046	Other	3	2.71%	2.37%	0.61900	0.99671
1008	Type 3	3	20.29%	89.26%	11.69460	18.8619
1104	Type 3	3	0.10%	85.23%	7.93965	17.3497
1006	Type 3	3	23.67%	66.01%	5.70332	8.9368
1113	Type 3	3	0.00%	54.30%	5.46040	8.73158
1110	Type 3	3	0.00%	38.19%	4.16807	6.69272
1090	Southeast	3	0.04%	43.41%	2.78513	7.37904
1056	Southeast	3	0.00%	5.80%	0.90178	1.53714
1030	Midatlantic	3	3.76%	62.27%	6.05090	9.6807
1014	Great Lakes	3	19.05%	59.48%	9.01060	14.9446
1018	Great Lakes	3	2.47%	60.68%	5.65883	12.5442
1017	Great Lakes	3	14.21%	43.87%	4.02997	8.58094
1016	Great Lakes	3	0.20%	11.61%	1.62568	2.9004
1011	Great Lakes	3	0.00%	8.83%	1.34816	2.08406
1003	Arid Mountain	3	2.85%	30.56%	4.89790	7.63468
1091	Arid Mountain	3	0.09%	22.27%	3.25313	5.34625
1058	Arid Mountain	3	2.14%	14.68%	2.73114	4.32562

1001	Arid Mountain	3	4.68%	1.33%	0.87791	1.72016
1106	Inland Desert	3	0.26%	72.23%	9.04154	14.9151
1107	Inland Desert	3	0.12%	68.33%	4.78076	14.7071
1109	Inland Desert	3	0.00%	29.86%	2.95728	7.62115
1074	LA/ San Diego	3	21.38%	82.31%	12.79480	21.1333
1083	LA/ San Diego	3	0.00%	59.82%	7.38058	11.9542
1082	LA/ San Diego	3	0.00%	59.82%	5.35323	11.9542
1078	LA/ San Diego	3	0.09%	45.72%	0.00000	11.1571
1073	LA/ San Diego	3	0.00%	42.17%	5.26881	8.81519
1067	LA/ San Diego	3	1.10%	9.47%	1.17432	1.90445
1087	Pacific Northwest	3	11.73%	51.53%	5.77372	10.8899
1043	Other	2	0.00%	40.31%	3.80240	6.17761
1044	Other	2	0.00%	17.64%	2.09462	3.45538
1081	Other	2	0.00%	8.10%	1.51691	2.2403
1054	Southeast	2	0.85%	16.65%	2.49793	3.93864
1076	Midatlantic	2	8.47%	68.74%	8.75582	15.1975
1031	Midatlantic	2	1.77%	28.93%	4.25766	6.88417
1028	Midatlantic	2	1.50%	11.12%	1.56034	2.40585
1013	Great Lakes	2	0.00%	81.73%	9.23303	14.9153
1019	Great Lakes	2	4.62%	68.84%	8.46315	13.3964
1097	Great Lakes	2	0.16%	13.33%	1.95208	3.12243
1057	Arid Mountain	2	3.22%	18.54%	2.95205	4.94268
1063	Inland Desert	2	0.16%	32.90%	7.62300	13.5886
1023	Inland Desert	2	2.14%	33.92%	5.31457	8.40378
1021	Inland Desert	2	0.00%	33.74%	4.79770	7.64665
1026	LA/ San Diego	2	0.00%	22.60%	4.13672	6.79692
1045	Other	1	0.21%	22.42%	2.60963	4.32015
1007	Type 3	1	2.12%	58.53%	8.47587	13.5222
1042	Other	0	1.74%	46.12%	5.42928	8.80795

Appendix 3.2: Projects ranked by percentage of all commuters that use public transportation within each project's census tract

GW_ID	Region code	LEED Aggregate	% of all commuters who use public transportation	Percent Total Developed within 12.5 Mile	Average Global Transportation Density	Average Local Transportation Density
1027	Midatlantic	6	57.52%	67.63%	4.22989	15.2304
1033	Midatlantic	5	47.74%	70.24%	9.32625	14.5823
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1006	Type 3	3	23.67%	66.01%	5.70332	8.9368
1012	Great Lakes	4	22.46%	61.53%	4.54532	12.6232
1074	LA/ San Diego	3	21.38%	82.31%	12.79480	21.1333
1075	Midatlantic	4	21.07%	70.21%	9.03824	15.5697
1008	Type 3	3	20.29%	89.26%	11.69460	18.8619
1053	Southeast	5	20.11%	30.14%	4.06472	6.39739
1014	Great Lakes	3	19.05%	59.48%	9.01060	14.9446
1088	Pacific Northwest	4	17.33%	56.27%	3.34696	11.3595
1055	Southeast	4	16.61%	61.30%	5.77933	9.12366
1017	Great Lakes	3	14.21%	43.87%	4.02997	8.58094
1049	Pacific Northwest	5	12.39%	44.98%	2.69824	9.28232
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1035	Other	4	6.03%	22.05%	2.91352	4.66786
1004	Arid Mountain	5	5.97%	37.73%	4.29190	7.04752
1001	Arid Mountain	3	4.68%	1.33%	0.87791	1.72016
1019	Great Lakes	2	4.62%	68.84%	8.46315	13.3964
1048	Pacific Northwest	5	4.51%	37.20%	2.48161	6.84694
1015	Great Lakes	4	3.81%	87.17%	8.54552	14.4242
1030	Midatlantic	3	3.76%	62.27%	6.05090	9.6807
1051	Pacific Northwest	5	3.65%	37.85%	6.26916	10.1529
1036	Other	3	3.47%	24.13%	1.16293	7.74924

1034	Other	5	3.38%	14.50%	2.38067	3.73646
1057	Arid Mountain	2	3.22%	18.54%	2.95205	4.94268
1037	Midatlantic	5	3.12%	49.89%	4.16006	9.87952
1003	Arid Mountain	3	2.85%	30.56%	4.89790	7.63468
1046	Other	3	2.71%	2.37%	0.61900	0.99671
1018	Great Lakes	3	2.47%	60.68%	5.65883	12.5442
1070	LA/ San Diego	4	2.43%	67.37%	9.90926	15.8458
1023	Inland Desert	2	2.14%	33.92%	5.31457	8.40378
1058	Arid Mountain	3	2.14%	14.68%	2.73114	4.32562
1007	Type 3	1	2.12%	58.53%	8.47587	13.5222
1031	Midatlantic	2	1.77%	28.93%	4.25766	6.88417
1042	Other	0	1.74%	46.12%	5.42928	8.80795
1039	Other	3	1.72%	20.48%	2.79599	4.50245
1028	Midatlantic	2	1.50%	11.12%	1.56034	2.40585
1024	LA/ San Diego	5	1.37%	45.98%	6.07820	10.0176
1047	Pacific Northwest	4	1.20%	5.65%	1.32087	2.21805
1050	Pacific Northwest	4	1.18%	51.05%	6.16190	10.0093
1101	Midatlantic	5	1.16%	63.01%	8.99902	14.2662
1067	LA/ San Diego	3	1.10%	9.47%	1.17432	1.90445
1038	Other	4	1.09%	20.32%	2.19760	3.46275
1068	LA/ San Diego	5	1.04%	49.88%	5.26985	9.61374
1112	LA/ San Diego	4	0.98%	93.17%	11.83710	21.7466
1054	Southeast	2	0.85%	16.65%	2.49793	3.93864
1002	Arid Mountain	6	0.78%	3.99%	1.02676	1.60131
1080	Other	3	0.50%	36.11%	3.78353	6.10162
1061	Other	4	0.49%	48.99%	6.54314	10.8017
1105	Type 3	5	0.44%	54.45%	3.15580	8.92801
1010	Great Lakes	4	0.30%	1.68%	1.29234	3.07094
1106	Inland Desert	3	0.26%	72.23%	9.04154	14.9151
1032	Midatlantic	4	0.26%	9.91%	1.83533	3.12065
1045	Other	1	0.21%	22.42%	2.60963	4.32015
1084	Other	4	0.20%	27.48%	3.43619	5.38088
1016	Great Lakes	3	0.20%	11.61%	1.62568	2.9004
1009	Great Lakes	4	0.18%	11.67%	1.59877	2.52783
1097	Great Lakes	2	0.16%	13.33%	1.95208	3.12243
1063	Inland Desert	2	0.16%	32.90%	7.62300	13.5886
1085	Arid Mountain	5	0.15%	0.28%	0.44142	1.5934
1077	Other	3	0.13%	58.12%	1.51780	11.4029
1107	Inland Desert	3	0.12%	68.33%	4.78076	14.7071
1104	Type 3	3	0.10%	85.23%	7.93965	17.3497

1091	Arid Mountain	3	0.09%	22.27%	3.25313	5.34625
1078	LA/ San Diego	3	0.09%	45.72%	0.00000	11.1571
1040	Other	4	0.07%	9.13%	2.42443	5.02406
1111	Southeast	4	0.06%	30.72%	3.64555	5.86927
1071	Other	5	0.06%	18.80%	5.19813	8.62462
1065	Other	3	0.06%	41.94%	5.15584	8.39516
1062	LA/ San Diego	4	0.04%	21.24%	2.75800	4.5341
1092	Arid Mountain	4	0.04%	18.56%	2.48380	4.68498
1090	Southeast	3	0.04%	43.41%	2.78513	7.37904
1103	LA/ San Diego	5	0.03%	43.24%	5.90241	9.61374
1022	Inland Desert	5	0.03%	54.86%	7.64923	12.2775
1102	Southeast	5	0.03%	32.46%	4.43852	7.03273
1099	Other	3	0.01%	28.80%	3.51047	5.84237
1066	LA/ San Diego	4	0.00%	30.66%	4.77215	10.2278
1041	Other	3	0.00%	49.42%	5.29595	8.45987
1113	Type 3	3	0.00%	54.30%	5.46040	8.73158
1110	Type 3	3	0.00%	38.19%	4.16807	6.69272
1056	Southeast	3	0.00%	5.80%	0.90178	1.53714
1011	Great Lakes	3	0.00%	8.83%	1.34816	2.08406
1109	Inland Desert	3	0.00%	29.86%	2.95728	7.62115
1083	LA/ San Diego	3	0.00%	59.82%	7.38058	11.9542
1082	LA/ San Diego	3	0.00%	59.82%	5.35323	11.9542
1073	LA/ San Diego	3	0.00%	42.17%	5.26881	8.81519
1043	Other	2	0.00%	40.31%	3.80240	6.17761
1044	Other	2	0.00%	17.64%	2.09462	3.45538
1081	Other	2	0.00%	8.10%	1.51691	2.2403
1013	Great Lakes	2	0.00%	81.73%	9.23303	14.9153
1021	Inland Desert	2	0.00%	33.74%	4.79770	7.64665
1026	LA/ San Diego	2	0.00%	22.60%	4.13672	6.79692

Appendix 3.3: Projects ranked by percentage of total developed land within 12.5 miles of each project

GW_ID	Region code	LEED Aggregate	% of all commuters who use public transportation	Percent Total Developed within 12.5 Mile	Average Global Transportation Density	Average Local Transportation Density
1112	LA/ San Diego	4	0.98%	93.17%	11.83710	21.7466
1008	Type 3	3	20.29%	89.26%	11.69460	18.8619
1015	Great Lakes	4	3.81%	87.17%	8.54552	14.4242
1104	Type 3	3	0.10%	85.23%	7.93965	17.3497
1025	LA/ San Diego	5	27.68%	84.92%	4.51393	19.9104
1074	LA/ San Diego	3	21.38%	82.31%	12.79480	21.1333
1013	Great Lakes	2	0.00%	81.73%	9.23303	14.9153
1106	Inland Desert	3	0.26%	72.23%	9.04154	14.9151
1033	Midatlantic	5	47.74%	70.24%	9.32625	14.5823
1075	Midatlantic	4	21.07%	70.21%	9.03824	15.5697
1019	Great Lakes	2	4.62%	68.84%	8.46315	13.3964
1076	Midatlantic	2	8.47%	68.74%	8.75582	15.1975
1107	Inland Desert	3	0.12%	68.33%	4.78076	14.7071
1027	Midatlantic	6	57.52%	67.63%	4.22989	15.2304
1070	LA/ San Diego	4	2.43%	67.37%	9.90926	15.8458
1006	Type 3	3	23.67%	66.01%	5.70332	8.9368
1052	Southeast	5	35.51%	65.83%	7.72172	12.5809
1101	Midatlantic	5	1.16%	63.01%	8.99902	14.2662
1030	Midatlantic	3	3.76%	62.27%	6.05090	9.6807
1072	LA/ San Diego	5	8.94%	61.86%	3.14372	14.0504
1012	Great Lakes	4	22.46%	61.53%	4.54532	12.6232
1055	Southeast	4	16.61%	61.30%	5.77933	9.12366
1018	Great Lakes	3	2.47%	60.68%	5.65883	12.5442
1083	LA/ San Diego	3	0.00%	59.82%	7.38058	11.9542
1082	LA/ San Diego	3	0.00%	59.82%	5.35323	11.9542
1014	Great Lakes	3	19.05%	59.48%	9.01060	14.9446
1007	Type 3	1	2.12%	58.53%	8.47587	13.5222
1077	Other	3	0.13%	58.12%	1.51780	11.4029
1088	Pacific Northwest	4	17.33%	56.27%	3.34696	11.3595
1022	Inland Desert	5	0.03%	54.86%	7.64923	12.2775

1105	Type 3	5	0.44%	54.45%	3.15580	8.92801
1113	Type 3	3	0.00%	54.30%	5.46040	8.73158
1087	Pacific Northwest	3	11.73%	51.53%	5.77372	10.8899
1086	Pacific Northwest	5	24.98%	51.06%	3.73900	10.7869
1050	Pacific Northwest	4	1.18%	51.05%	6.16190	10.0093
1037	Midatlantic	5	3.12%	49.89%	4.16006	9.87952
1068	LA/ San Diego	5	1.04%	49.88%	5.26985	9.61374
1041	Other	3	0.00%	49.42%	5.29595	8.45987
1061	Other	4	0.49%	48.99%	6.54314	10.8017
1060	Great Lakes	4	36.55%	48.16%	2.41258	9.48471
1042	Other	0	1.74%	46.12%	5.42928	8.80795
1024	LA/ San Diego	5	1.37%	45.98%	6.07820	10.0176
1078	LA/ San Diego	3	0.09%	45.72%	0.00000	11.1571
1049	Pacific Northwest	5	12.39%	44.98%	2.69824	9.28232
1017	Great Lakes	3	14.21%	43.87%	4.02997	8.58094
1090	Southeast	3	0.04%	43.41%	2.78513	7.37904
1103	LA/ San Diego	5	0.03%	43.24%	5.90241	9.61374
1073	LA/ San Diego	3	0.00%	42.17%	5.26881	8.81519
1065	Other	3	0.06%	41.94%	5.15584	8.39516
1043	Other	2	0.00%	40.31%	3.80240	6.17761
1110	Type 3	3	0.00%	38.19%	4.16807	6.69272
1051	Pacific Northwest	5	3.65%	37.85%	6.26916	10.1529
1004	Arid Mountain	5	5.97%	37.73%	4.29190	7.04752
1048	Pacific Northwest	5	4.51%	37.20%	2.48161	6.84694
1080	Other	3	0.50%	36.11%	3.78353	6.10162
1023	Inland Desert	2	2.14%	33.92%	5.31457	8.40378
1021	Inland Desert	2	0.00%	33.74%	4.79770	7.64665
1063	Inland Desert	2	0.16%	32.90%	7.62300	13.5886
1102	Southeast	5	0.03%	32.46%	4.43852	7.03273
1111	Southeast	4	0.06%	30.72%	3.64555	5.86927
1066	LA/ San Diego	4	0.00%	30.66%	4.77215	10.2278
1003	Arid Mountain	3	2.85%	30.56%	4.89790	7.63468
1089	Pacific Northwest	6	11.06%	30.34%	5.80133	9.36126
1053	Southeast	5	20.11%	30.14%	4.06472	6.39739
1109	Inland Desert	3	0.00%	29.86%	2.95728	7.62115
1031	Midatlantic	2	1.77%	28.93%	4.25766	6.88417
1099	Other	3	0.01%	28.80%	3.51047	5.84237
1084	Other	4	0.20%	27.48%	3.43619	5.38088
1029	Midatlantic	4	6.88%	26.76%	3.24037	5.68472
1036	Other	3	3.47%	24.13%	1.16293	7.74924

1026	LA/ San Diego	2	0.00%	22.60%	4.13672	6.79692
1045	Other	1	0.21%	22.42%	2.60963	4.32015
1091	Arid Mountain	3	0.09%	22.27%	3.25313	5.34625
1035	Other	4	6.03%	22.05%	2.91352	4.66786
1062	LA/ San Diego	4	0.04%	21.24%	2.75800	4.5341
1039	Other	3	1.72%	20.48%	2.79599	4.50245
1038	Other	4	1.09%	20.32%	2.19760	3.46275
1071	Other	5	0.06%	18.80%	5.19813	8.62462
1092	Arid Mountain	4	0.04%	18.56%	2.48380	4.68498
1057	Arid Mountain	2	3.22%	18.54%	2.95205	4.94268
1044	Other	2	0.00%	17.64%	2.09462	3.45538
1054	Southeast	2	0.85%	16.65%	2.49793	3.93864
1058	Arid Mountain	3	2.14%	14.68%	2.73114	4.32562
1034	Other	5	3.38%	14.50%	2.38067	3.73646
1097	Great Lakes	2	0.16%	13.33%	1.95208	3.12243
1009	Great Lakes	4	0.18%	11.67%	1.59877	2.52783
1016	Great Lakes	3	0.20%	11.61%	1.62568	2.9004
1028	Midatlantic	2	1.50%	11.12%	1.56034	2.40585
1032	Midatlantic	4	0.26%	9.91%	1.83533	3.12065
1067	LA/ San Diego	3	1.10%	9.47%	1.17432	1.90445
1040	Other	4	0.07%	9.13%	2.42443	5.02406
1011	Great Lakes	3	0.00%	8.83%	1.34816	2.08406
1081	Other	2	0.00%	8.10%	1.51691	2.2403
1056	Southeast	3	0.00%	5.80%	0.90178	1.53714
1047	Pacific Northwest	4	1.20%	5.65%	1.32087	2.21805
1002	Arid Mountain	6	0.78%	3.99%	1.02676	1.60131
1046	Other	3	2.71%	2.37%	0.61900	0.99671
1010	Great Lakes	4	0.30%	1.68%	1.29234	3.07094
1001	Arid Mountain	3	4.68%	1.33%	0.87791	1.72016
1085	Arid Mountain	5	0.15%	0.28%	0.44142	1.5934

Appendix 3.4: Projects ranked by globally calculated road network density

GW_ID	Region code	LEED Aggregate	% of all commuters who use public transportation	Percent Total Developed within 12.5 Mile	Average Global Transportation Density	Average Local Transportation Density
1074	LA/ San Diego	3	21.38%	82.31%	12.79480	21.1333
1112	LA/ San Diego	4	0.98%	93.17%	11.83710	21.7466
1008	Type 3	3	20.29%	89.26%	11.69460	18.8619
1070	LA/ San Diego	4	2.43%	67.37%	9.90926	15.8458
1033	Midatlantic	5	47.74%	70.24%	9.32625	14.5823
1013	Great Lakes	2	0.00%	81.73%	9.23303	14.9153
1106	Inland Desert	3	0.26%	72.23%	9.04154	14.9151
1075	Midatlantic	4	21.07%	70.21%	9.03824	15.5697
1014	Great Lakes	3	19.05%	59.48%	9.01060	14.9446
1101	Midatlantic	5	1.16%	63.01%	8.99902	14.2662
1076	Midatlantic	2	8.47%	68.74%	8.75582	15.1975
1015	Great Lakes	4	3.81%	87.17%	8.54552	14.4242
1007	Type 3	1	2.12%	58.53%	8.47587	13.5222
1019	Great Lakes	2	4.62%	68.84%	8.46315	13.3964
1104	Type 3	3	0.10%	85.23%	7.93965	17.3497
1052	Southeast	5	35.51%	65.83%	7.72172	12.5809
1022	Inland Desert	5	0.03%	54.86%	7.64923	12.2775
1063	Inland Desert	2	0.16%	32.90%	7.62300	13.5886
1083	LA/ San Diego	3	0.00%	59.82%	7.38058	11.9542
1061	Other	4	0.49%	48.99%	6.54314	10.8017
1051	Pacific Northwest	5	3.65%	37.85%	6.26916	10.1529
1050	Pacific Northwest	4	1.18%	51.05%	6.16190	10.0093
1024	LA/ San Diego	5	1.37%	45.98%	6.07820	10.0176
1030	Midatlantic	3	3.76%	62.27%	6.05090	9.6807
1103	LA/ San Diego	5	0.03%	43.24%	5.90241	9.61374
1089	Pacific Northwest	6	11.06%	30.34%	5.80133	9.36126
1055	Southeast	4	16.61%	61.30%	5.77933	9.12366
1087	Pacific Northwest	3	11.73%	51.53%	5.77372	10.8899
1006	Type 3	3	23.67%	66.01%	5.70332	8.9368
1018	Great Lakes	3	2.47%	60.68%	5.65883	12.5442
1113	Type 3	3	0.00%	54.30%	5.46040	8.73158
1042	Other	0	1.74%	46.12%	5.42928	8.80795

1082	LA/ San Diego	3	0.00%	59.82%	5.35323	11.9542
1023	Inland Desert	2	2.14%	33.92%	5.31457	8.40378
1041	Other	3	0.00%	49.42%	5.29595	8.45987
1068	LA/ San Diego	5	1.04%	49.88%	5.26985	9.61374
1073	LA/ San Diego	3	0.00%	42.17%	5.26881	8.81519
1071	Other	5	0.06%	18.80%	5.19813	8.62462
1065	Other	3	0.06%	41.94%	5.15584	8.39516
1003	Arid Mountain	3	2.85%	30.56%	4.89790	7.63468
1021	Inland Desert	2	0.00%	33.74%	4.79770	7.64665
1107	Inland Desert	3	0.12%	68.33%	4.78076	14.7071
1066	LA/ San Diego	4	0.00%	30.66%	4.77215	10.2278
1012	Great Lakes	4	22.46%	61.53%	4.54532	12.6232
1025	LA/ San Diego	5	27.68%	84.92%	4.51393	19.9104
1102	Southeast	5	0.03%	32.46%	4.43852	7.03273
1004	Arid Mountain	5	5.97%	37.73%	4.29190	7.04752
1031	Midatlantic	2	1.77%	28.93%	4.25766	6.88417
1027	Midatlantic	6	57.52%	67.63%	4.22989	15.2304
1110	Type 3	3	0.00%	38.19%	4.16807	6.69272
1037	Midatlantic	5	3.12%	49.89%	4.16006	9.87952
1026	LA/ San Diego	2	0.00%	22.60%	4.13672	6.79692
1053	Southeast	5	20.11%	30.14%	4.06472	6.39739
1017	Great Lakes	3	14.21%	43.87%	4.02997	8.58094
1043	Other	2	0.00%	40.31%	3.80240	6.17761
1080	Other	3	0.50%	36.11%	3.78353	6.10162
1086	Pacific Northwest	5	24.98%	51.06%	3.73900	10.7869
1111	Southeast	4	0.06%	30.72%	3.64555	5.86927
1099	Other	3	0.01%	28.80%	3.51047	5.84237
1084	Other	4	0.20%	27.48%	3.43619	5.38088
1088	Pacific Northwest	4	17.33%	56.27%	3.34696	11.3595
1091	Arid Mountain	3	0.09%	22.27%	3.25313	5.34625
1029	Midatlantic	4	6.88%	26.76%	3.24037	5.68472
1105	Type 3	5	0.44%	54.45%	3.15580	8.92801
1072	LA/ San Diego	5	8.94%	61.86%	3.14372	14.0504
1109	Inland Desert	3	0.00%	29.86%	2.95728	7.62115
1057	Arid Mountain	2	3.22%	18.54%	2.95205	4.94268
1035	Other	4	6.03%	22.05%	2.91352	4.66786
1039	Other	3	1.72%	20.48%	2.79599	4.50245
1090	Southeast	3	0.04%	43.41%	2.78513	7.37904
1062	LA/ San Diego	4	0.04%	21.24%	2.75800	4.5341
1058	Arid Mountain	3	2.14%	14.68%	2.73114	4.32562
1049	Pacific Northwest	5	12.39%	44.98%	2.69824	9.28232

1045	Other	1	0.21%	22.42%	2.60963	4.32015
1054	Southeast	2	0.85%	16.65%	2.49793	3.93864
1092	Arid Mountain	4	0.04%	18.56%	2.48380	4.68498
1048	Pacific Northwest	5	4.51%	37.20%	2.48161	6.84694
1040	Other	4	0.07%	9.13%	2.42443	5.02406
1060	Great Lakes	4	36.55%	48.16%	2.41258	9.48471
1034	Other	5	3.38%	14.50%	2.38067	3.73646
1038	Other	4	1.09%	20.32%	2.19760	3.46275
1044	Other	2	0.00%	17.64%	2.09462	3.45538
1097	Great Lakes	2	0.16%	13.33%	1.95208	3.12243
1032	Midatlantic	4	0.26%	9.91%	1.83533	3.12065
1016	Great Lakes	3	0.20%	11.61%	1.62568	2.9004
1009	Great Lakes	4	0.18%	11.67%	1.59877	2.52783
1028	Midatlantic	2	1.50%	11.12%	1.56034	2.40585
1077	Other	3	0.13%	58.12%	1.51780	11.4029
1081	Other	2	0.00%	8.10%	1.51691	2.2403
1011	Great Lakes	3	0.00%	8.83%	1.34816	2.08406
1047	Pacific Northwest	4	1.20%	5.65%	1.32087	2.21805
1010	Great Lakes	4	0.30%	1.68%	1.29234	3.07094
1067	LA/ San Diego	3	1.10%	9.47%	1.17432	1.90445
1036	Other	3	3.47%	24.13%	1.16293	7.74924
1002	Arid Mountain	6	0.78%	3.99%	1.02676	1.60131
1056	Southeast	3	0.00%	5.80%	0.90178	1.53714
1001	Arid Mountain	3	4.68%	1.33%	0.87791	1.72016
1046	Other	3	2.71%	2.37%	0.61900	0.99671
1085	Arid Mountain	5	0.15%	0.28%	0.44142	1.5934
1078	LA/ San Diego	3	0.09%	45.72%	0.00000	11.1571

Appendix 3.5: Projects ranked by locally calculated road network density

GW_ID	Region code	LEED Aggregate	% of all commuters who use public transportation	Percent Total Developed within 12.5 Mile	Average Global Transportation Density	Average Local Transportation Density
1112	LA/ San Diego	4	0.98%	93.17%	11.83710	21.7466
1074	LA/ San Diego	3	21.38%	82.31%	12.79480	21.1333
1025	LA/ San Diego	5	27.68%	84.92%	4.51393	19.9104
1008	Type 3	3	20.29%	89.26%	11.69460	18.8619
1104	Type 3	3	0.10%	85.23%	7.93965	17.3497
1070	LA/ San Diego	4	2.43%	67.37%	9.90926	15.8458
1075	Midatlantic	4	21.07%	70.21%	9.03824	15.5697
1027	Midatlantic	6	57.52%	67.63%	4.22989	15.2304
1076	Midatlantic	2	8.47%	68.74%	8.75582	15.1975
1014	Great Lakes	3	19.05%	59.48%	9.01060	14.9446
1013	Great Lakes	2	0.00%	81.73%	9.23303	14.9153
1106	Inland Desert	3	0.26%	72.23%	9.04154	14.9151
1107	Inland Desert	3	0.12%	68.33%	4.78076	14.7071
1033	Midatlantic	5	47.74%	70.24%	9.32625	14.5823
1015	Great Lakes	4	3.81%	87.17%	8.54552	14.4242
1101	Midatlantic	5	1.16%	63.01%	8.99902	14.2662
1072	LA/ San Diego	5	8.94%	61.86%	3.14372	14.0504
1063	Inland Desert	2	0.16%	32.90%	7.62300	13.5886
1007	Type 3	1	2.12%	58.53%	8.47587	13.5222
1019	Great Lakes	2	4.62%	68.84%	8.46315	13.3964
1012	Great Lakes	4	22.46%	61.53%	4.54532	12.6232
1052	Southeast	5	35.51%	65.83%	7.72172	12.5809
1018	Great Lakes	3	2.47%	60.68%	5.65883	12.5442
1022	Inland Desert	5	0.03%	54.86%	7.64923	12.2775
1083	LA/ San Diego	3	0.00%	59.82%	7.38058	11.9542
1082	LA/ San Diego	3	0.00%	59.82%	5.35323	11.9542
1077	Other	3	0.13%	58.12%	1.51780	11.4029
1088	Pacific Northwest	4	17.33%	56.27%	3.34696	11.3595
1078	LA/ San Diego	3	0.09%	45.72%	0.00000	11.1571
1087	Pacific Northwest	3	11.73%	51.53%	5.77372	10.8899
1061	Other	4	0.49%	48.99%	6.54314	10.8017

1086	Pacific Northwest	5	24.98%	51.06%	3.73900	10.7869
1066	LA/ San Diego	4	0.00%	30.66%	4.77215	10.2278
1051	Pacific Northwest	5	3.65%	37.85%	6.26916	10.1529
1024	LA/ San Diego	5	1.37%	45.98%	6.07820	10.0176
1050	Pacific Northwest	4	1.18%	51.05%	6.16190	10.0093
1037	Midatlantic	5	3.12%	49.89%	4.16006	9.87952
1030	Midatlantic	3	3.76%	62.27%	6.05090	9.6807
1103	LA/ San Diego	5	0.03%	43.24%	5.90241	9.61374
1068	LA/ San Diego	5	1.04%	49.88%	5.26985	9.61374
1060	Great Lakes	4	36.55%	48.16%	2.41258	9.48471
1089	Pacific Northwest	6	11.06%	30.34%	5.80133	9.36126
1049	Pacific Northwest	5	12.39%	44.98%	2.69824	9.28232
1055	Southeast	4	16.61%	61.30%	5.77933	9.12366
1006	Type 3	3	23.67%	66.01%	5.70332	8.9368
1105	Type 3	5	0.44%	54.45%	3.15580	8.92801
1073	LA/ San Diego	3	0.00%	42.17%	5.26881	8.81519
1042	Other	0	1.74%	46.12%	5.42928	8.80795
1113	Type 3	3	0.00%	54.30%	5.46040	8.73158
1071	Other	5	0.06%	18.80%	5.19813	8.62462
1017	Great Lakes	3	14.21%	43.87%	4.02997	8.58094
1041	Other	3	0.00%	49.42%	5.29595	8.45987
1023	Inland Desert	2	2.14%	33.92%	5.31457	8.40378
1065	Other	3	0.06%	41.94%	5.15584	8.39516
1036	Other	3	3.47%	24.13%	1.16293	7.74924
1021	Inland Desert	2	0.00%	33.74%	4.79770	7.64665
1003	Arid Mountain	3	2.85%	30.56%	4.89790	7.63468
1109	Inland Desert	3	0.00%	29.86%	2.95728	7.62115
1090	Southeast	3	0.04%	43.41%	2.78513	7.37904
1004	Arid Mountain	5	5.97%	37.73%	4.29190	7.04752
1102	Southeast	5	0.03%	32.46%	4.43852	7.03273
1031	Midatlantic	2	1.77%	28.93%	4.25766	6.88417
1048	Pacific Northwest	5	4.51%	37.20%	2.48161	6.84694
1026	LA/ San Diego	2	0.00%	22.60%	4.13672	6.79692
1110	Type 3	3	0.00%	38.19%	4.16807	6.69272
1053	Southeast	5	20.11%	30.14%	4.06472	6.39739
1043	Other	2	0.00%	40.31%	3.80240	6.17761
1080	Other	3	0.50%	36.11%	3.78353	6.10162
1111	Southeast	4	0.06%	30.72%	3.64555	5.86927
1099	Other	3	0.01%	28.80%	3.51047	5.84237
1029	Midatlantic	4	6.88%	26.76%	3.24037	5.68472

1084	Other	4	0.20%	27.48%	3.43619	5.38088
1091	Arid Mountain	3	0.09%	22.27%	3.25313	5.34625
1040	Other	4	0.07%	9.13%	2.42443	5.02406
1057	Arid Mountain	2	3.22%	18.54%	2.95205	4.94268
1092	Arid Mountain	4	0.04%	18.56%	2.48380	4.68498
1035	Other	4	6.03%	22.05%	2.91352	4.66786
1062	LA/ San Diego	4	0.04%	21.24%	2.75800	4.5341
1039	Other	3	1.72%	20.48%	2.79599	4.50245
1058	Arid Mountain	3	2.14%	14.68%	2.73114	4.32562
1045	Other	1	0.21%	22.42%	2.60963	4.32015
1054	Southeast	2	0.85%	16.65%	2.49793	3.93864
1034	Other	5	3.38%	14.50%	2.38067	3.73646
1038	Other	4	1.09%	20.32%	2.19760	3.46275
1044	Other	2	0.00%	17.64%	2.09462	3.45538
1097	Great Lakes	2	0.16%	13.33%	1.95208	3.12243
1032	Midatlantic	4	0.26%	9.91%	1.83533	3.12065
1010	Great Lakes	4	0.30%	1.68%	1.29234	3.07094
1016	Great Lakes	3	0.20%	11.61%	1.62568	2.9004
1009	Great Lakes	4	0.18%	11.67%	1.59877	2.52783
1028	Midatlantic	2	1.50%	11.12%	1.56034	2.40585
1081	Other	2	0.00%	8.10%	1.51691	2.2403
1047	Pacific Northwest	4	1.20%	5.65%	1.32087	2.21805
1011	Great Lakes	3	0.00%	8.83%	1.34816	2.08406
1067	LA/ San Diego	3	1.10%	9.47%	1.17432	1.90445
1001	Arid Mountain	3	4.68%	1.33%	0.87791	1.72016
1002	Arid Mountain	6	0.78%	3.99%	1.02676	1.60131
1085	Arid Mountain	5	0.15%	0.28%	0.44142	1.5934
1056	Southeast	3	0.00%	5.80%	0.90178	1.53714
1046	Other	3	2.71%	2.37%	0.61900	0.99671

Appendix 4: Kolmogorov-Smirnov Tests for Normality

Tests of Normality

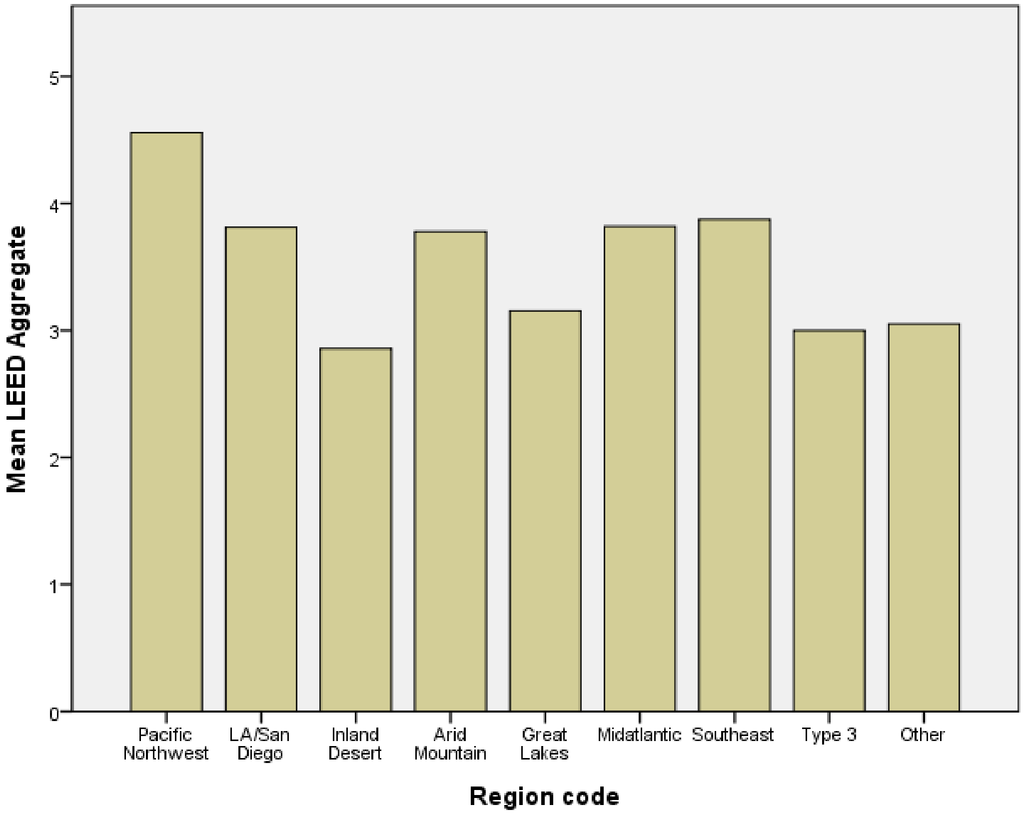
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
% of all commuters who use public transp	.302	100	.000	.604	100	.000
Percent Total Developed within 12.5 Mile	.074	100	.192	.972	100	.034
LEED Aggregate	.200	100	.000	.927	100	.000
Average Global Transportation Density	.080	100	.113	.949	100	.001
Average Local Transportation Density	.056	100	.200*	.968	100	.016

a. Lilliefors Significance Correction

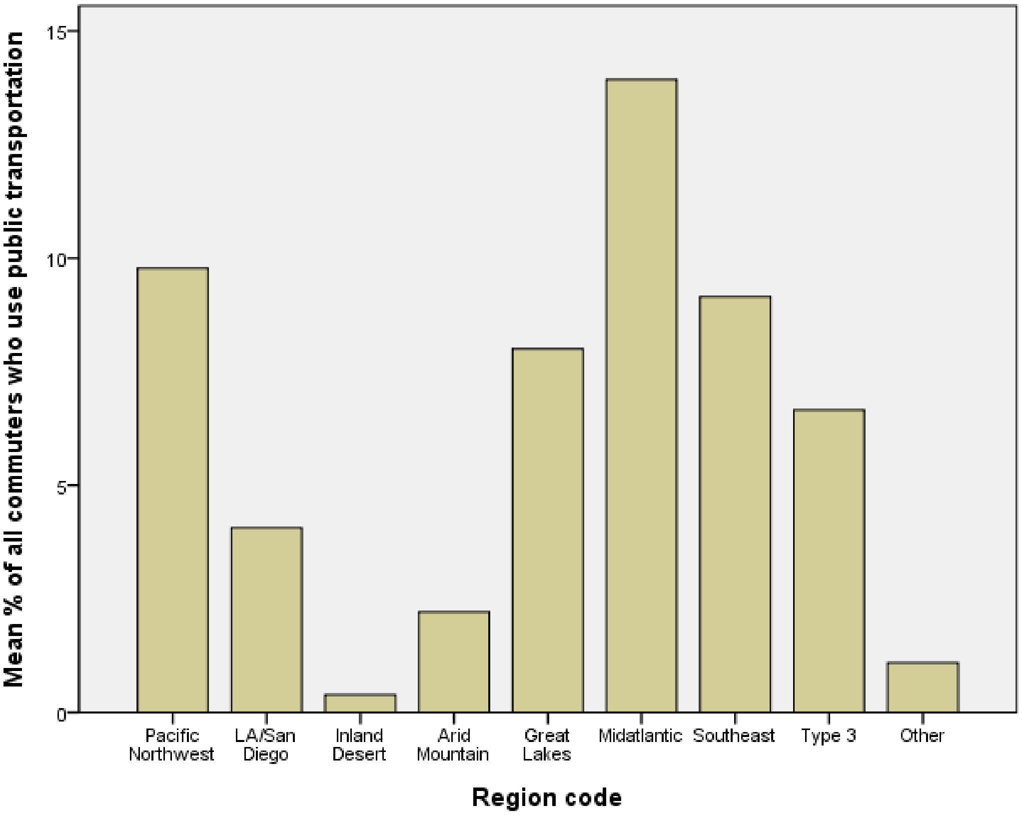
*. This is a lower bound of the true significance.

Appendix 5: Metric Averages by Climatic Zones

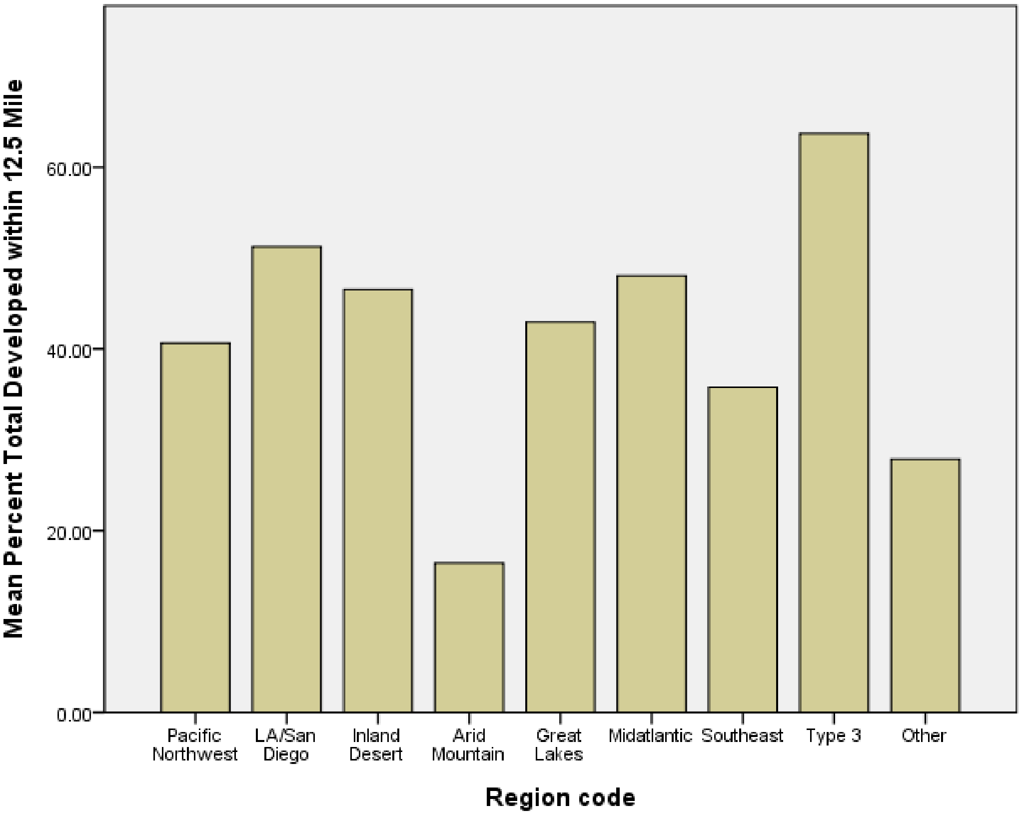
Appendix5.1: Bar Chart of the average of the LEED Aggregate Metric by climatic zone



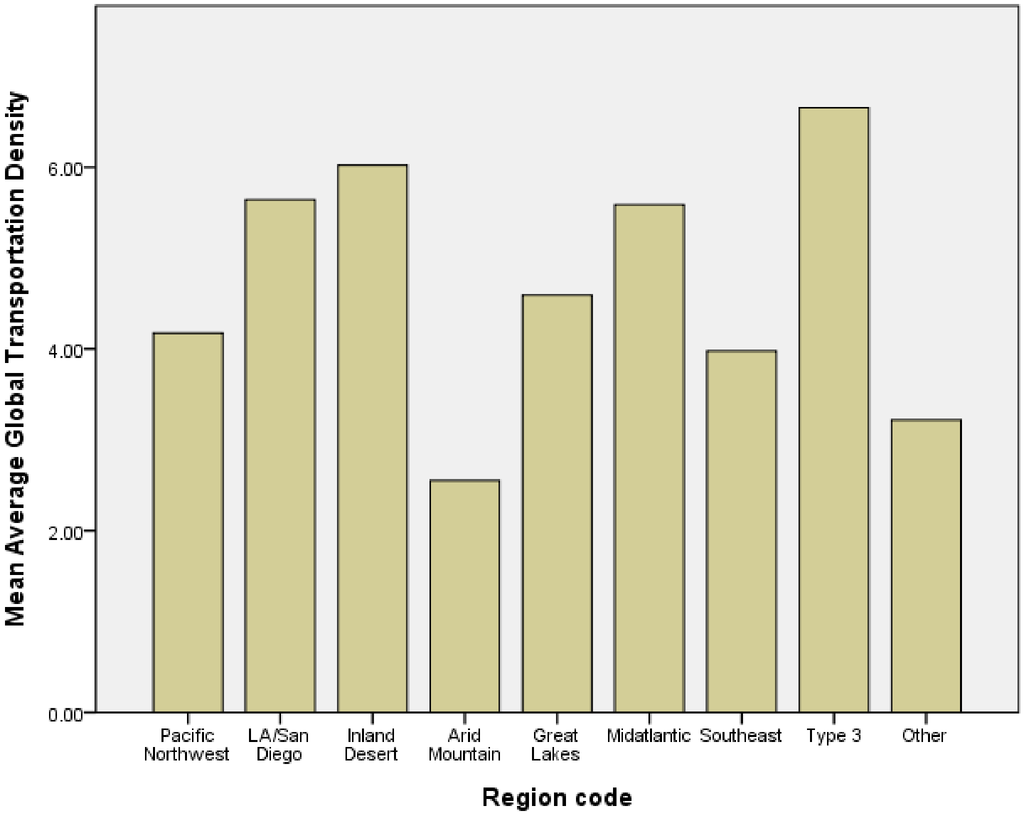
Appendix 5.2: Bar Chart of the average of the Public Transportation Metric by climatic zone



Appendix 5.3: Bar Chart of the average of the Built Density Metric by climatic zone



Appendix 5.4: Bar Chart of the average of the Global Transportation Density Metric by climatic zone



Appendix 5.5: Bar Chart of the average of the Local Transportation Density Metric by climatic zone