5-2015

Labor Force Commute Mode Preferences and the Natural Environment

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By

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An Honors Thesis in partial fulfillment of the requirements for the degree Bachelor of Science in Business Administration in Accounting

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Fayetteville, Arkansas

December 11, 2014

Abstract

In commuting to work, commuters select from a limited variety of transportation modes, including alternative modes like cycling and walking, based on needs and preferences. Understanding these needs and preferences, and how the conditions of the immediate environment can influence them can benefit both businesses and local governments in their efforts to accommodate the commute needs of their workers and better serve their communities. Though the body of commute preference research has grown significantly over recent decades, the study of the effects of the natural environment has remained mostly overlooked. In my research, I examined the relationships between selected weather conditions of the natural environment and the percentage of the labor force that cycled or walked to work in large U.S. cities.

To explore these relationships, I employed multicollinaerity and multiple linear regression analysis of the percentage of the labor force that commuted by cycling or walking in the two largest cities of each state with eight observed conditions of the natural environment in each city: the mean daily maximum temperature; the mean daily minimum temperature; the number of days per year in which fog limited visibility to less than or equal to one-quarter mile; the number of days per year with thunderstorms; the mean wind speed; the total water equivalent precipitation; the total amount of snow, ice, pellets, and hail; and the total number of days with snowfall greater than or equal to one inch.

The results of my statistical analysis revealed that only two variables (the number of days per year with thunderstorms and the total water equivalent precipitation) exhibited significant relationships with the percentage of work commuters who cycled or walked. Furthermore, the number of days per year with thunderstorms exhibited a strong inverse relationship, meaning that

thunderstorms deterred workers from cycling or walking to work. These relationships confirmed the significant influence that precipitation, as a condition of the natural environment, can bear on commute preferences. Based on these findings, businesses can better understand their employees and improve their productivity and reputations within their communities by accommodating the differences in commute mode preferences across varying climatological regions.

Acknowledgments

Throughout the completion of my honors thesis, I met and received invaluable guidance and assistance from a collection of knowledgeable individuals within the faculty of the Sam M. Walton College of Business and the University of Arkansas Library. First, I would like to express my appreciation to Dr. Susan Bristow for her commitment and continual encouragement as my thesis advisor. With her counsel, I developed exponentially my research acumen, and gained substantial experience in the process. Additionally, I would like to thank JaLynn Thomas for her auxiliary perusal and consideration of my research.

For their considerable assistance during the preliminary diagnostics and statistical analysis procedures of my methodology, I would like to thank Dr. Christina Serrano and Ruba Aljafari. I would also like to thank Mark Minton of the Walton College Writing Center for offering additional guidance in the writing of my research. Finally, I would like to express my gratitude to Donna Daniels of the University of Arkansas Library for providing me with numerous resources which, in turn, provided momentum in the completion of my literature review. As a former data analysis and scholastic research novice, I have a sincere and deep appreciation for all of the enthusiastic and considerate experts to whom I have been introduced throughout this process.

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Introduction

Workers select from a limited variety of transportation modes to decide how they will commute to their places of work every day. Though the automobile is often the sole practical option for long-distance work commuters, modes such as walking and cycling provide alternatives for those with different commute needs and preferences. Understanding these needs and preferences, particularly how they interact with the various conditions of the immediate environment, is crucial not only for infrastructural and urban planning in cities with large populations, but for businesses seeking to assimilate into their environments and intuitively attract and retain employees as well. I elected to research the relationship between the share of the labor force that commuted by walking or cycling with the conditions of the natural environment in large cities throughout the United States to better understand commuter preferences and discover ways to benefit businesses' interactions with their employees and host communities in different climatological regions.

The advent of the information age, in concurrence with the current trend of increasing globalization, warrants that businesses adopt more intuitive approaches to not only recognize, but better satisfy non-financial stakeholders like host communities, local governments, customers, and particularly employees. Information about worker preferences and a holistic understanding of a firm's immediate surroundings provide opportunities for the firm to improve hiring and retention, and strengthen its reputation. Understanding the interactions between the conditions of the natural environment and labor force preferences provides just such activities for businesses operating throughout the various climatological regions of the United States.

Examining commute mode preferences cannot be accomplished with a singular focus, but instead requires a multi-faceted approach that considers all relevant conditions. With my research, I seek to explore the mostly overlooked effects of the natural environment and contribute to a growing abundance of research in the broader study of work commute preferences. This thesis attempts to review the existent research of work commute preferences, define the relationship between work commute preferences and the natural environment, and provide insights that will aid businesses in responding to their environmental conditions, accommodating their employees and communities, and improving their financial performance.

Literature Review

History of Commute

In the late 19th century, private developers with extensive, but sprawled real estate holdings created America's first transit-oriented communities by constructing trolley lines that reached from more densely populated areas to the significantly less-populated outskirts (Cervero, 1996). These "streetcar suburbs" laid the foundation for the emergence of the American suburb in the 1940s and its explosive growth in tandem with the major postwar infrastructure developments of the 1950s and 1960s. The steady decentralization of concentrated metropolitan areas to low-density suburbs dispersed large populations and, therefore, increased the travel distances between homes and frequented destinations (Committee, 2005). As a result, the private automobile became the primary mode of transport for residents of suburbs.

Despite the continued dominance of the private automobile as a transport mode, alternative modes have achieved moderate success and gained considerable legitimacy over the past 60 years. Carpooling first emerged in U.S. policy during World War II, in the midst of national oil and rubber shortages, and reappeared in public policy as a response to growing shortages during the OPEC oil crisis in the mid-1970s (Ferguson, 1997). As a major form of commute, cycling emerged in city planning in the 1970s and has since experienced renewed interest in public policy and rising popularity beginning in the mid-to-late 1990s with the construction of expansive new, interconnected bicycle infrastructure, including bike paths and street lanes (Buehler, Hamre, Sonenklar, & Goger, 2011a; Buehler & Pucher, 2011b). The population cycling to work increased by 60% over the last decade alone, though the current size is merely 786,000 people. In addition, walking to work has recovered from a decline in popularity in the 1990s and stabilized at a mere 3% (Tracy, 2014).

These modest successes in alternative modes of transportation, though promising areas for development in the coming decades, are minuscule in comparison to the trend of increasing single-person car drivers. Between 1970 and 1990, the population driving alone increased while carpooling decreased, and since 1980, the number of miles that Americans drive has grown three times faster than the U.S. population (DeLoach & Tiemann, 2010; Ewing, Bartholomew, Winkelman, Walters, & Chen). These findings corroborate the trend of accelerating suburbanization of populations and jobs throughout the 1990s, and the current dominance of driving alone over carpooling, public transit, cycling, walking, and other modes of transport (Lawson, 1997).

Current Research on Work Commute

Modern research has employed U.S. Census data and American Community Survey findings to explore new subject areas with the potential for discussion in public policy, such as the national distribution and international comparisons of commute preferences. According to an analysis by McKenzie & Rapino (2011) of the 2009 American Community Survey, over three-fourths of the American labor force drove to work alone with an average trip duration of 25.1 minutes. In examining the distribution by commute mode of the U.S. labor force, this study also confirms the dominance of driving personal vehicles (86.1%) and, more specifically, driving alone as a mode of transport (76.1%), and provides insight into the gradual growth of alternative transportation modes. These findings confirm the analysis of data from the 2000 U.S. Census by Handy, Boarnet, Ewing, & Killingsworth (2002), in which 86.5% of all commute trips were in personal vehicles, 5.3% were on public transit, and 3.9% were walking. Modern research on the national distribution of commute preferences corroborates the already significant, yet growing gap between personal vehicle trips and alternative modes identified throughout previous decades.

Aside from analysis of trends in the United States, modern research has also addressed the differences in commute mode preference between developed nations collecting demographic data comparable in both scope and validity. European studies have noted the stark contrast between European and American commute preferences and explored the health effects of routine travel (Audrey, Procter, & Cooper, 2014; Buehler, Pucher, Merom, & Bauman, 2011c; Gottholmseder, Nowotny, Pruckner, & Theurl, 2008; von Huth Smith, Borch-Johnsen, & Jørgensen, 2007). In a study comparing the United States with Germany, researchers found that Europeans employ walking, cycling, and public transit significantly more than Americans, averaging more than twice as many walk trips per day as Americans (Buehler, Pucher, Merom, et al., 2011c). In addition, the increases in frequency, duration, and distance of walk and bicycle trips per capita between 2001/2002 and 2008/2009 were much larger in Germany than in the U.S. Other European studies detail the effects of work commute on stress perception, the favorable relationship between commuting physical activity and biological risk factors for cardiovascular disease, and the overall health benefits of walking to work (Audrey et al., 2014; Gottholmseder et al., 2008; von Huth Smith et al., 2007).

Driving

The share of commuters driving private vehicles to work and other desired destinations significantly dwarfs all other modes of transportation despite yearly increases in gas prices (Lipman, 2006). Between 1980 and 1990, the share of work trips made by people driving alone in private vehicles increased from 64.4% to 73.2%, and reached 76.1% in 2011 (Cervero, 1996;

McKenzie & Rapino, 2011). In addition, a 2006 study found that more than 85% of low-to-moderate income workers in the United States drove to work in private vehicles (Lipman, 2006).

Many studies have emerged throughout the past three decades to explain the preeminence of private vehicle drivers and connect these statistics with population settlement trends, economic conditions, and psychology and sociology (Cassidy, 1992; Evans, Wener, & Phillips, 2002; Gottholmseder et al., 2008; Lawson, 1997; Lee, Gordon, Richardson, & Moore, 2009; Lipman, 2006). In accordance with the accelerating suburbanization that occurred during the second half of the 20th century, driving has increased to allow workers to commute to job centers distant from their homes (Lawson, 1997; Lipman, 2006). Others point to strong income growth during the late 1990s and the general affordability of private vehicles for regular work and leisure trips (Lawson, 1997; Lee et al., 2009). And, in contrast to common conceptions of "road rage" and perceived stress associated with driving, a study by Cassidy (1992) reported that car users had more positive travel experiences than those taking public transit. This positive experience is suggested to be a manifestation of greater control, which was shown to influence stress perception be positively correlated with lower stress, hostility, and blood pressure (Cassidy, 1992; Evans et al., 2002; Gottholmseder et al., 2008).

Carpooling

Though carpooling emerged in U.S. policy during the 1940s, the first major publications on carpooling appeared in the late 1970s as the share of commuters driving with others declined (Ferguson, 1997). Carpooling, like other alternative modes of transportation, has consistently declined over the past 50 years. However, a reversal in the long-run trend of decline in carpooling occurred during 2005-2010 when the number of commuters sharing vehicles increased slightly. To explain this anomaly, Ferguson (1997) points to the relatively recent advent of "ride-sharing" programs, the openings of new rapid transit systems, the increased demand for public transit, and rising gasoline prices. A 2010 study shows that carpooling exhibits a relatively large elasticity in relation to gas prices (DeLoach & Tiemann, 2010). These findings support the economic theory that increases in commuting time and the cost of gasoline decrease the likelihood of driving alone.

Cycling

Though the share of work commuters cycling is relatively minuscule, it has increased exponentially throughout the past two decades and has become an initiative for public policy across the world (Buehler, Hamre, et al., 2011a; Buehler & Pucher, 2011b; Tracy, 2014). The population of commuters cycling to work across the United States increased from 488,000 in the 2000 U.S. Census to 786,000 in the 2008-2012 American Community Survey – a greater than 60% increase in a single decade (Tracy, 2014). This nationwide increase is attributed to the "renaissance" in bicycle planning that occurred in the late 1990s, as cities increased the volume of cycling infrastructure and modified the local urban design to seem safer and more bicycle-friendly (Buehler, Hamre, et al., 2011a). Over the past two decades, Washington, D.C. has expanded its bicycle infrastructure dramatically and has experimented with new infrastructure innovations. Traffic lights for cyclists, bicycle boxes, contra-flow bicycle lanes, and Bikeshare – the nation's first regional bicycle sharing program – are only a few of the improvements implemented in the D.C. region.

Recent research has confirmed the utility of these increases in bicycle infrastructure, both in the D.C. area and across the nation (Buehler, Hamre, et al., 2011a; Buehler & Pucher, 2011b).

Cities, like Washington, D.C., with a greater supply of bicycle paths and lanes, safer cycling, less sprawl, less car ownership, and higher gasoline prices exhibit more cycling than automobile-oriented cities (Buehler & Pucher, 2011b). However, improvements in bicycle infrastructure have been found to be beneficial at both the municipal level and the private business level (Buehler, Hamre, et al., 2011a). Businesses offering bicycle parking, clothes lockers, and cyclist showers at work are associated with more cycling. In addition, businesses offering free car parking with work are associated with less cycling. Such results have encouraged public policy increasingly to support bicycle infrastructure.

According to Tracy (2014), "the logic behind the [cycling] push is that government cannot continue building roads indefinitely," especially considering that additional lanes on roadways provide, "only temporary relief from congestion," (p. 1). While traditional thought would propose increases in roadway volume to combat growing traffic congestion, recent research has shown that increased cycling is associated with higher population density, closer proximities to work and other destinations, and increased interconnectivity of the existent bicycle infrastructure (Buehler, Hamre, et al., 2011a). Understanding the environmental conditions that encourage cycling, as well as the psychological causes that lead commuters to cycle, will be key to addressing future traffic congestion in public policy.

Determinants of Commute Mode Preference

Analysis of the factors which determine whether an individual commutes by vehicle, public transit, bicycle, walking, or other means is of equal importance to commute research as current trends. Perhaps the most obvious determinant of commute mode is monetary cost. A 2006 study by the U.S. Center for Housing Policy found that housing and transportation costs are rising at rates faster than those of incomes (Lipman, 2006). This proves especially problematic because housing (28%) and transportation (29%) are the two largest expenses for most households in 28 observed metropolitan areas.

Aside from basic economics, psychological factors and perceived convenience have been examined as significant determinants (Adams, 2010; Heinen, Maat, & van Wee, 2011). A 2011 study conducted in the Netherlands considered the attitudes and psychological factors that impact bicycle commuters and found that perceived environmental benefits, physical exercise, and flexibility were significant contributors (Heinen et al., 2011). In addition, researchers pointed to, "time, comfort, and flexibility," as the bases for the decisions of commuter cyclists. A similar study examined the perceived barriers to walking to and from work, and found that 31.4% of reported barriers were associated with the perceived convenience of using a car instead (Adams, 2010). In making decisions about how they get to work, commuters are affected by both financial and psychological factors.

Health and the Benefits of Alternative Commute Modes

The World Health Organization (WHO) estimates that 60-80% of the world's population does not meet the recommendations required to induce health benefits (WHO, 2007). In the United States, the Surgeon General recommends daily physical activity of greater than or equal to 30 minutes continuously or intermittently (Centers for Disease Control and Prevention, 1996; Ham, Yore, Fulton, & Kohl, 2004). In a 2005 study by the Committee on Physical Activity, Health, Transportation, and Land Use, researchers found that a full 55% of the U.S. adult population fails to meet these federal guidelines, and that 25% of respondents were completely inactive when not at work (Committee, 2005). Such large-scale inactivity directly resulted in medical expenses of more than $76 billion in 2000. Although there may be more serious health implications, given the observed relationship between physical inactivity and the risks of cardiovascular disease and mortality (von Huth Smith et al., 2007).

The first U.S. Surgeon General report on Physical Activity and Health, issued in 1996, was the first report to document the well-established causal connection between physical activity and health (Committee, 2005). Since then, regular moderate physical activity has been proven to reduce the risks of numerous chronic diseases, obesity, colon cancer, and other physical maladies, as well as to improve overall psychological well-being. Despite these well-established correlations, reduced physical demands of work and increasingly sedentary uses of free time have caused physical activity levels to decline over the past 60 years.

An abundance of research regarding the potential health benefits of taking public transit, cycling, or walking to work has emerged throughout the past decade. Actively commuting to work, whether cycling or walking, has been shown to reduce risk factors for heart disease, prevent excess weight gain, and improve triglyceride levels, insulin levels, blood pressure, and overall health (Bello, Claussen, Johnson, & Morrison, 2009; Lindström, 2008; von Huth Smith et al., 2007). In a study conducted in the United Kingdom, people who walked to work were found to be 40% less likely to develop diabetes and 17% less likely to develop high blood pressure than those who drove (Anonymous, 2013). Such positive health effects confirm the well-established link between physical activity and health, as a separate study found that participants who walked to work engage in activity levels 44% higher than those who drove (Audrey et al., 2014). In a 2008 study of Australian male commuters, those who cycled to work (39.8%) were significantly less likely to be overweight or obese than those who drove (60.8%) (Wen & Rissel, 2008). However, the potential health benefits of alternative commute modes are not limited solely to more active activities. Public transit commuters – those who walk or cycle to board public transit vehicles – were found in multiple studies to have appreciably increased physical activity levels (Besser & Dannenberg, 2005; Lachapelle, Saelens, Sallis, and Conway, 2011; Wener & Evans, 2007).

The Built Environment and Its Effects on Commute

As defined by Handy, et al. (2002), the "built environment" comprises the urban design, land use, and transportation system of a defined area (p. 65). Research on the built environment has emerged in tandem with the transportation research of recent decades. The built environment, as it relates to daily commute, is characterized by urban planners as "pedestrian-oriented" or "automobile-oriented", depending on the connectivity of local infrastructure and the aesthetic qualities of the community conducive to certain modes of transportation. Since the 1960s, urban planners generally designed communities under the assumption that the private automobile would be the primary mode of transport between homes and frequently visited destinations (schools, shopping, the workplace, etc.) (Ewing et al., 2007; Handy, et al., 2002). However, this trend of dispersion in urban design has caused land to be consumed for development at more than three times the rate of population growth. In response to such rapid development, as well as various economic and environmental reasons, compact development has reentered urban planning. New Urbanism, a movement which first emerged and gained popularity in the late 1980s, promotes mixed-use development that brings destinations closer to residences through increased street interconnectivity, more prevalent bicycle infrastructure and sidewalks, and vertical construction (building "up" instead of "out"). To discourage driving and encourage use of walking, cycling, and public transit, many communities are now revitalizing traditional town centers and downtowns with additional housing and infrastructure in what is described as, “smart growth”.

Since the early 1990s, research has increasingly addressed the link between the built environment and travel behavior, though the challenge of developing useful models that apply these emerging concepts in urban planning to urban planning to encourage more physically-active development patterns remains (Handy, et al., 2002). Residential density, employment density, land-use mix, and proximity to public transit have all been shown to have a positive relationship with alternative commute mode usage and, therefore, daily physical activity levels (Besser & Dannenberg, 2005; Cervero, 1996; Ferguson, 1997; Frank & Pivo, 1994; Lawrence, Schmid, Sallis, Chapman, & Saelens, 2005). The relationship between the built environment and public health was more clearly articulated in a 2003 study in which obesity was found to be more prevalent in areas where land use discouraged walking (Saelens, Sallis, Black, & Chen, 2003).

The Natural Environment

The United States has nearly twice the ecological footprint of other high income countries (Zheng, 2008). It is the largest emitter worldwide of greenhouse gases that cause global warming, of which transportation accounts for 33% (Ewing et al., 2007). Levels of carbon dioxide have increased rapidly since 1990, and would require cuts in emissions by 60-to-80% to reach climate stabilization by the year 2050. Though public policy tends to focus on direct sources of emissions, recent research has proposed an intuitive approach that could link urban planning to the curtailment of harmful emissions. In a Washington study, researchers found that per-capita energy consumption increased with population density (Frank & Pivo, 1994). Though research in this area is still lacking, these findings confirm the importance of the link between the built environment and commuting levels. By bringing destinations and workplaces closer to residences, urban planning has the capability to significantly reduce transportation levels, and, therefore, contribute to the national effort to curtail harmful emissions. The relationship between commute and the natural environment will likely play a significant role in future environmental policy.

Business Perspectives and Responses

From a macroeconomic standpoint, commuting time costs America an estimated $90 billion per year in lost productivity and wasted energy (Florida, 2010). Additionally, it is estimated that every minute by which commuting time is reduced in America is worth an estimated $19.5 billion to the economy. The opportunity costs of productivity and energy represent real economic costs to American businesses. Therefore, it is in their best interest not only to be aware of commute's relationship with productivity and financial performance, but also to actively take steps to mitigate work commute's negative labor-related and financial impacts.

Though businesses cannot force their employees to live closer to their places of work or employ certain commute modes, some businesses have implemented alternative approaches to combat commute-related losses in productivity. Telecommuting, in which physical work commute is eliminated altogether, has been shown to increase productivity by 22% in those who worked from home (Bowers, 2000). This observed increase in productivity accompanied a greater sense of freedom among telecommuters in comparison with their office co-workers. Alterations in work time distribution, including compressed workweeks and flexible scheduling, have been shown to both reduce total commute time and improve employee attitudes (DeHart-Davis & Guensler, 2005; Lucas & Heady, 2002). Flextime, a variable working schedule that seeks to increase work flexibility, has been shown to decrease driver stress and increase commute satisfaction (Lucas & Heady, 2002). These effects in employee attitude translated into better health, which would improve productivity at work by minimizing absences and illness.

Given the relationship between commute and productivity at work, businesses can improve financial performance by better understanding and accommodating the commute preferences of their employees. Exploring the effects of the natural environment on commute mode preferences, by extension, could yield related useful information.

Description of Research

Hypothesis

In theory, the natural environmental conditions of a large city affect the behaviors of its inhabitants. The percentage of a large city's labor force that walks or cycles to work regularly is therefore influenced by the weather conditions of the city. Unlike private vehicle drivers, carpoolers, and patrons of public transit, walkers and cyclists are directly exposed to the conditions of the natural environment, whether favorable or unfavorable for their mode of transport. The relationship between these conditions and workers' commute preferences, if defined, would provide useful information for businesses to better understand and accommodate their employees and host communities and, in doing so, increase productivity and financial performance. This study hypothesizes that the weather conditions of large cities both significantly affect and influence, in some relationship, the percentage of these cities' labor forces that commute to work by walking or cycling. The weather conditions examined are the mean daily maximum temperature in degrees Fahrenheit ($\beta 1$); the mean daily minimum temperature in degrees Fahrenheit ($\beta 2$); the total number of days per year in which fog limited visibility to less than or equal to one-quarter mile ($\beta 3$); the total number of days per year with thunderstorms ($\beta 4$); the mean wind speed in miles-per-hour ($\beta 5$); the total water equivalent precipitation in inches ($\beta 6$); the total amount of snow, ice, pellets, and hail in inches ($\beta 7$); and the total number of days with snowfall greater than or equal to one inch ($\beta 8$). These measures directly affect the natural environmental conditions of a given large city, and may therefore affect the likelihood that commuters select walking or cycling for work commute. In statistics terms, there are two hypotheses: one null hypothesis and one research hypothesis:

H0: The measures of weather conditions of large cities do not affect the percentage of the labor force that walks or cycles to work regularly.

$$H0: Ywalk/bicycle = \beta1 = \beta2 = \beta3 = \beta4 = \beta5 = \beta6 = \beta7 = \beta8 = 0$$

H1: At least one measure of the weather conditions of large cities significantly affects the percentage of the labor force that walks or cycles to work regularly.

$$H1: Ywalk/bicycle \neq \beta1 \neq \beta2 \neq \beta3 \neq \beta4 \neq \beta5 \neq \beta6 \neq \beta7 \neq \beta8 \neq 0$$

Data and Methodology

This research focused on the labor force and weather conditions in each of the two largest cities by population of each state in the United States. Because most of America's largest cities are concentrated in a relatively small number of states where conditions are likely to be similar, the two largest cities by population of each state were selected to increase spatial variability with regard to the conditions of the natural environment. This research used the five-year estimates from the 2008-2012 American Community Survey for population data, including the total population and the labor force composition of each of the 100 U.S. cities selected (U.S. Department of Commerce, 2014a). The American Community Survey is conducted throughout the country annually by the United States Census Bureau and is used by federal, state, and local government bodies for guidance in planning and policymaking (McKenzie & Rapino, 2011). With regard to labor force behavior, respondents answer questions about commute-related subjects including the location of their work, their means of transportation, and their travel time to work. Once aggregated, this data represents the distribution by percentage of the means of transport employed by work commuters. The sum of the percentages of those who walked and cycled to work in each city from the 2008-2012 American Community Survey was used as the dependent variable (Ywalk/bicycle) for this research.

For weather conditions in each city, data from the National Climatic Data Center of the National Oceanic and Atmospheric Administration (NOAA) and the NOAA Satellite and Information Service was used (U.S. Department of Commerce, 2014b). The specific local climatological database used summarized daily weather conditions and patterns observed in major airport weather stations over various periods of time. For the purposes of this research, the 2012 annual reports from the weather stations in or nearest to the 100 selected cities were used. Within each annual report, eight observed measures were isolated: the mean daily maximum temperature in degrees Fahrenheit (β1); the mean daily minimum temperature in degrees Fahrenheit (β2); the total number of days per year in which fog limited visibility to less than or equal to one-quarter mile (β3); the total number of days per year with thunderstorms (β4); the mean wind speed in miles-per-hour (β5); the total water equivalent precipitation in inches (β6); the total amount of snow, ice, pellets, and hail in inches (β7); and the total number of days with snowfall greater than or equal to one inch (β8). These eight measures of weather conditions represent the independent variables of this research.

Statistical Analysis

First, a spreadsheet listing the name of each city; the state; the percentage of the labor force commuting to work by walking or cycling; the mean daily maximum temperature in degrees Fahrenheit; the mean daily minimum temperature in degrees Fahrenheit; the total number of days per year in which fog limited visibility to less than or equal to one-quarter mile; the total number of days per year with thunderstorms; the mean wind speed in miles-per-hour;

the total water equivalent precipitation in inches; the total amount of snow, ice, pellets, and hail in inches; and the total number of days with snowfall greater than or equal to one inch was created.

The units of measure of each variable varied between degrees Fahrenheit, number of days, miles-per-hour, and inches. To account for this variance in units of measure and to increase comparability, each variable was standardized into a single unit of measure based on the distance from the mean of each variable. First, the mean (μ) and standard deviation (σ) of each variable were calculated. Then, each variable was standardized by dividing the difference between each individual amount (X) and the mean of each variable (μ) by the standard deviation of each variable (σ), as represented in this formula:

$$\text{Standardization of variable: } (X - \mu) / \sigma$$

This was performed for each variable in each of the 100 selected cities.

Once all of the variables were in standardized form, the analysis proceeded with examination of multicollinearity between the variables. Multicollinearity refers to the degree of correlation between any two variables, whether independent variables or the dependent variable. When two variables exhibit high multicollinearity, it means that each variable can be used to predict the other. This represents a redundancy that may cause the results of the regression analysis to not accurately represent the relationships between all of the examined variables. The output from the multicollinearity test performed is illustrated in Table 1.

Table 1. Initial Multicollinearity Test Results for Observed Variables

	W/B	β1	β2	β3	β4	β5	β6	β7	β8
W/B	1.00								
β1	-0.35	1.00							
β2	-0.17	**0.88**	1.00						
β3	0.16	-0.39	-0.35	1.00					
β4	-0.32	0.50	0.36	-0.29	1.00				
β5	-0.04	-0.21	-0.25	-0.12	-0.14	1.00			
β6	0.15	0.09	0.33	0.08	0.24	-0.41	1.00		
β7	0.26	**-0.80**	**-0.73**	0.24	-0.39	0.16	-0.10	1.00	
β8	0.18	**-0.76**	**-0.72**	0.23	-0.35	0.17	-0.13	**0.96**	1.00

Note. Emboldened cells represent instances of high correlation, and therefore high multicollinearity between variables.

W/B = Walked/Bicycle
β1 = AVGMAXTEMP
β2 = AVGMINTEMP
β3 = CTDAYSFOG
β4 = CTDAYSSTORMS
β5 = AVGSPEEDWIND
β6 = TOTALPRECIP
β7 = TOTALSNOW
β8 = CTDAYSSNOW

To define what values constitute high correlation between variables, the parameter was set to be any value greater than 0.5 or less than -0.5. As indicated by the emboldened cells in Table 1, there were multiple instances of high correlation between variables. These instances were primarily the result of interactions between the mean maximum temperature in degrees Fahrenheit (AVGMAXTEMP); the mean minimum temperature in degrees Fahrenheit (AVGMINTEMP); the total amount of snow, ice, pellets, and hail in inches (TOTALSNOW); and the total number of days with snowfall greater than or equal to one inch (CTDAYSSNOW).

To correct these instances of multicollinearity, three variables were eliminated from consideration in the hypothesis and further analysis: the mean maximum temperature in degrees Fahrenheit, the mean minimum temperature in degrees Fahrenheit, and the total amount of snow, ice, pellets, and hail in inches. Because this research focused on the conditions that could directly affect a worker's commute mode preference, the mean maximum and minimum temperatures were not of significant relation and, therefore, were subject to elimination. In addition, the total amount of snow, ice, pellet, and hail in inches, though a relevant condition, was already represented in the total water equivalent precipitation in inches variable and the total number of days with snowfall greater than or equal to one inch variable. To reflect these omissions, the null and alternative hypotheses were adjusted:

H0: The measures of weather conditions of large cities do not affect the percentage of the labor force that walks or cycles to work regularly.

$$H0: Ywalk/bicycle = \beta 3 = \beta 4 = \beta 5 = \beta 6 = \beta 8 = 0$$

H1: At least one measure of the weather conditions of large cities significantly affects the percentage of the labor force that walks or cycles to work regularly.

H1: Ywalk/bicycle ≠ β3 ≠ β4 ≠ β5 ≠ β6 ≠ β8 ≠ 0

After eliminating the three highly correlated variables, the Excel spreadsheet was reconfigured and tested again for multicollinearity. The output from the second test is illustrated in Table 2.

Table 2. Secondary Multicollinearity Test Results for 5 Observed Variables

	W/B	β3	β4	β5	β6	β8
W/B	1.00					
β3	0.16	1.00				
β4	-0.32	-0.29	1.00			
β5	-0.04	-0.12	-0.14	1.00		
β6	0.15	0.08	0.24	-0.41	1.00	
β7	0.18	0.23	-0.35	0.17	-0.13	1.00

W/B = Walked/Bicycled
β3 = CTDAYSFOG
β4 = CTDAYSSTORMS
β5 = AVGSPEEDWIND
β6 = TOTALPRECIP
β8 = CTDAYSSNOW

Using the same parameters for high correlation of greater than 0.5 or less than -0.5, it was determined that none of the five independent variables exhibited significant multicollinearity. This step completed the preliminary analysis of the data, allowing research to proceed with the construction of a multiple linear regression model.

The final step of the analysis of the data was the construction of a multiple linear regression model. To assess the results of the regression, multiple parameters were established for both the significance of the model as a whole and the significance of each individual variable. To determine whether the regression model was valid, the R Square, Significance F, and F statistics were evaluated. R Square represented the percentage by which the model could predict the variance in the dependent variable. Significance F and F represented the overall significance of the regression model. The parameters to determine significance for Significance F and F were set at less than 0.05 and greater than 1.96, respectively.

To determine whether each individual variable was significant, the P values and confidence intervals were evaluated. The P value represented the probability that the result occurred by mere chance rather than statistical probability (Trochim & Donnelly, 2008). The confidence interval represented the reliability of the result, and was closely associated with the associated P value. The parameter to determine significance of the P value was set at less than 0.05, meaning that there would be less than a 5% chance that the result was based on chance. In addition, it was established that any variable with 0 in its confidence interval would not be considered significant. The results of the multiple linear regression are illustrated in Table 3.

Table 3. Overall Multiple Linear Regression Results

n = 100							
Variable	Coefficient	P Value	Lower 95%	Upper 95%	R Square	Significance F	F
					0.171	0.003	3.878
CTDAYSFOG	0.021	0.841	-0.182	0.223			
CTDAYSSTORMS	-0.347	0.002	-0.559	-0.136			
AVGSPEEDWIND	0.005	0.961	-0.203	0.213			
TOTALPRECIP	0.250	0.020	0.040	0.460			
CTDAYSSNOW	0.088	0.393	-0.116	0.292			

Results of Research

Multiple Linear Regression Model

Table 4. Multiple Linear Regression Results for the Model

R Square	0.171
Significance F	0.003
F	3.878

As illustrated in Table 4, the multiple linear regression model exhibited an R Square value of 0.171, meaning that the model could explain 17.1% of the variance of the dependent variable. Significance F for the model was 0.003, which was less than the established Significance F parameter of 0.05. F for the model was 3.878, which was greater than the established F parameter of 1.96. These results confirmed the validity of the regression model and the usefulness of the output information for each individual variable. With significance established for the overall model, I proceeded to analyze each individual variable.

Total Number of Days with Heavy Fog Causing Visibility to Be Less than or Equal to One-Quarter Mile (CTDAYSFOG)

Table 5. Multiple Linear Regression Results for "CTDAYSFOG"

P value	0.841
Lower 95%	-0.182
Upper 95%	0.223
Coefficient	0.021

As illustrated in Table 5, the independent variable "CTDAYSFOG", the total number of days with heavy fog causing visibility to be less than or equal to one-quarter mile, exhibited a P value of 0.841, which was greater than the established P value parameter of 0.05. In addition, the output indicated that the confidence interval contained 0. These results meant that the total number of days with heavy fog causing visibility to be less than or equal to one-quarter mile exhibited no significant relationship with the percentage of the labor force in the 100 observed U.S. cities that walked or cycled to work.

Though fog may directly affect walkers and cyclists, the related risks of limited visibility may be more likely to affect motorists. Automobile drivers travel at much greater speeds than those of walkers and cyclists, and may be more susceptible to the safety hazards of limited visibility. The lack of significance with regard to the two examined modes, however, meant that the null hypothesis H0 was not rejected for this variable.

Total Number of Days with Thunderstorms (CTDAYSSTORMS)

Table 6. Multiple Linear Regression Results for "CTDAYSSTORMS"

P value	0.002
Lower 95%	-0.559
Upper 95%	-0.136
Coefficient	-0.347

As illustrated in Table 6, the independent variable "CTDAYSSTORMS", the total number of days with thunderstorms, exhibited a P value of 0.002, which was less than the established P value parameter of 0.05. In addition, the output indicated that the confidence interval did not contain 0. These results meant that the total number of days with thunderstorms exhibited a significant relationship with the percentage of the labor force in the 100 observed U.S. cities that walked or cycled to work. The coefficient -0.347 indicated an inverse relationship between these two variables, meaning that additional days with observed thunderstorms would be associated with a decrease in the percentage of those who walk or cycle to work.

This negative correlation confirmed what common intuition would assume with regard to the relationship between the number of observed thunderstorms and the preference to walk or cycle. These findings confirm that the threat of precipitation, thunder, and other related hazardous conditions would deter commuters from walking and cycling. The significance of this relationship meant that the null hypothesis H0 was rejected for this variable.

Mean Wind Speed in Miles-per-Hour (AVGSPEEDWIND)

Table 7. Multiple Linear Regression Results for "AVGSPEEDWIND"

P value	0.962
Lower 95%	-0.203
Upper 95%	0.213
Coefficient	0.005

As illustrated in Table 7, the independent variable "AVGSPEEDWIND", the mean wind speed in miles-per-hour, exhibited a P value of 0.962, which was greater than the established P value parameter of 0.05. In addition, the results indicated that the confidence interval contained 0. These results meant that the mean wind speed in milers-per-hour exhibited no significant relationship with the percentage of the labor force in the 100 observed U.S. cities that walked or cycled to work.

This finding was somewhat surprising, as one would assume that a significant direct relationship would exist between wind speeds and the preference to walk or cycle. Wind speed is an environmental condition that directly affects walkers and cyclers, much more so than motorists and other commuters. However, the lack of significance of this relationship meant that the null hypothesis H0 was not rejected for this variable.

Total Water Equivalent Precipitation in Inches (TOTALPRECIP)

Table 8. Multiple Linear Regression Results for "TOTALPRECIP"

P value	0.020
Lower 95%	0.040
Upper 95%	0.460
Coefficient	0.250

As illustrated in Table 8, the independent variable "TOTALPRECIP", the total water equivalent precipitation in inches, exhibited a P value of 0.020, which was less than the established P value parameter of 0.05. In addition, the confidence interval for this variable did not contain 0. These results meant that the total water equivalent precipitation in inches exhibited a significant relationship with the percentage of the labor force in the 100 observed U.S. cities that walked or cycled to work. The coefficient 0.250 indicated a direct relationship, meaning that an increase in the water equivalent precipitation would be associated with an increase in the percentage of those who walk or cycle to work.

Though one would expect a relationship to exist between the total water equivalent precipitation and the percentage of those who walk or cycle to work, it is surprising that the relationship would exhibit a positive correlation. Increased precipitation would deter commuters from selecting walking or cycling, according to common intuition. Nonetheless, this significant relationship meant that the null hypothesis H0 was rejected for this variable.

Total Number of Days with Snowfall Greater than or Equal to 1.0 Inch (CTDAYSSNOW)

Table 9. Multiple Linear Regression Results for "CTDAYSSNOW"

P value	0.393
Lower 95%	-0.116
Upper 95%	0.292
Coefficient	0.088

As illustrated in Table 9, the independent variable "CTDAYSSNOW", total number of days with snowfall greater than or equal to 1.0 inch, exhibited a P value of 0.393, which was greater than the established P value parameter of 0.05. In addition, the confidence interval for this variable contained 0. These results meant that the total number of days with snowfall greater than or equal to 1.0 inch did not exhibit a significant relationship with the percentage of the labor force in the 100 observed U.S. cities that walked or cycled to work.

This finding was somewhat surprising, as snowfall is a condition that walkers and cyclists directly confront on their routes to work. Common intuition would predict an inverse relationship, meaning that additional days with significant snowfall would deter commuters from walking or cycling to work. However, the lack of significance of this relationship meant that the null hypothesis H0 was not rejected for this variable.

Discussion of Research

Summary

For this study, the hypothesis was that the weather conditions of large U.S. cities significantly affected the percentage of the labor force that walks or cycles to work regularly. To preface this study, previous research regarding the history and current study of commute mode preference, as well as commute's relationships with health conditions, the built environment, and the natural environment was examined.

To evaluate this hypothesis, statistical analysis tools were employed to define the relationships between the percentage of the labor force that cycled or walked to work regularly and eight weather conditions: the mean daily maximum temperature in degrees Fahrenheit; the mean daily minimum temperature in degrees Fahrenheit; the total number of days per year in which fog limited visibility to less than or equal to one-quarter mile; the total number of days per year with thunderstorms; the mean wind speed in miles-per-hour; the total water equivalent precipitation in inches; the total amount of snow, ice, pellets, and hail in inches; and the total number of days with snowfall greater than or equal to one inch. After testing for multicollinearity and running a multiple linear regression, it was found that the two precipitation-related variables (the total number of days per year with thunderstorms and the total water equivalent precipitation in inches) exhibited significant relationships with the percentage of the labor force that cycled or walked to work regularly.

The results from this research indicate that observed precipitation has been shown to deter workers from commuting using alternative modes of transportation (cycling and walking). The strong significant direct relationship between the number of days with thunderstorms and the percentage of cyclists and walkers confirms that potentially hazardous conditions may influence commute preferences. Overall, this study confirms that the conditions of the natural environment can affect the commute mode preferences of the labor force in large U.S. cities.

Limitations of Methodology

Though examining data from the two largest cities of each state maintained population size commonality while simultaneously assuring spatial variability, the selection process was somewhat arbitrary with regard to other potentially influential factors such as the variance in population between the observed cities, differences in population density and infrastructure connectivity, and prevalence of bicycle or sidewalk infrastructure. For instance, this methodology weighted all cities equally, regardless of the differences in population characteristics between them. Therefore, a relatively small city like Hilo, Hawaii was compared equivocally with a much larger city like New York, New York despite major statistical differences in population distribution and infrastructure volume. In addition, this selection process disregards the relationships between the geographic concentrations of large metropolitan areas to assure diversity in climatological conditions, sacrificing representativeness for spatial variability. The nation's largest cities tend to be concentrated in only a few states, therefore many large cities were excluded from consideration in this research. These limitations in the selection process diminish the applicability of these results to cities of moderate and small population sizes, and weaken the representativeness of the results with regard to the true geographic distribution of the largest U.S. cities.

In addition, this methodology does not consider qualitative measures that could affect the commute preferences of the labor force. The primary objective of this research was to define the relationship between environmental conditions and commute preferences so as to create a useful model that would enable businesses to better respond to its non-financial stakeholders. Without intuitive qualitative data collected through surveys or questionnaires of work commuters and potentially entire businesses in the examined cities, the model fails to holistically capture the forces that compel commute preferences like the general attitudes and proclivity to aversion that work commuters may exhibit toward specific climatological conditions. This lack of qualitative data represents another significant limitation to this methodology.

In providing sufficient information to define the relationship between the natural environment and commute mode preferences, this methodology also fails to consider variance over time. Though climate is relatively stable over long periods of time, weather conditions can vary significantly from year to year. Therefore, the conclusions provided from this research, particularly that precipitation is a significant environmental factor, may not be representative of the long-term trends in each city. An examination of Census data and weather data collected over a 5-or 10-year period would provide source material for a more representative and useful model.

Implications

Based on the results of this research, precipitation variables, specifically the number of days with observed thunderstorms and the total water equivalent precipitation, exhibit the most significant influence on the variance in the percentage of workers that commute by cycling or walking. Therefore, precipitation is the condition of the natural environment which businesses and governments must consider influential on the behaviors of their employees and residents. Attention to precipitation maps and patterns can improve businesses’ relationships with their host communities and employees by helping them match local infrastructure with commute patterns, accommodate workers with bicycle storage lockers, showers, and protective covered facilities that facilitate alternative transportation modes, and better allocate company resources like real estate for parking lot space. Local governments can benefit from attention to precipitation information through more intuitive urban planning that considers the conditions of both the built environment and the natural environment.

Given these associations between commute, worker attitude, and productivity at work, businesses that plan and construct facilities in accordance with commute mode preferences in varying climatological regions can expect to witness improved psychological well-being among their employees and, therefore, increased productivity across their enterprises (Lucas & Heady, 2002). By understanding the relationships established in prior research between employee psychological factors and productivity and taking steps to mitigate the negative aspects of commute, businesses can maximize their financial performance. These relationships confirm the utility and value of human capital investments as a means of improving operational efficiency and effectiveness.

Future Research

To refine the methodology of this study, future research should take a more focused approach by examining data at a regional or state level. More useful information could be derived from studies that isolate each state and consider the variance in climatological conditions that occur within and across state boundaries. Reducing the total area examined would provide more precise and useful information for local urban planning and state infrastructure planning.

In addition, future research should examine changes in commute and climatological patterns over time. Though this research examined the relationships between environmental conditions and work commute preferences, it included data only from the year 2012.

Examination of data over a 10-year period, for instance, would yield more useful information for businesses and governments and would diminish the potential adverse effects of short-term anomalies in climatological conditions.

To expand the current knowledge base of commute preferences and provide additional evidence that would confirm the results of this research, future research should examine the potential relationships between the non-significant environmental variables in this study (the number of days with heavy fog, the mean wind speed, and the number of days with heavy snowfall) and the percentages of the work force that partake in motorized modes of transportation (private automobiles and public transit). For instance, heavy fog did not exhibit any significant relationship with the percentage of workers that cycled or walked to work. However, heavy fog may have exhibited a significant relationship with motorized modes of transportation which could have been more affected than alternative modes. Defining these relationships would add value to the current body of research in commute preferences.

All of these potential areas for future research would contribute to the growing body of research in commute preferences and develop a model that can be employed by businesses and urban planners to better understand and respond to the conditions of their natural environments.

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