EXPLORATION OF THE IMPACTS OF TRANSPORTATION AND SOCIOECONOMIC FACTORS ON PUBLIC HEALTH IN US CITIES

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ABSTRACT

The exploration of transportation and socioeconomic factors on public health plays a crucial role in the development of comprehensive city planning. The data used for this study include transportation, socioeconomic, and health factors gathered for 69 cities in the United Stated. This data contains various variables such as transportation facilities, populations, income levels, land area, and health indicator rates. A variable importance ranking was employed using random forest method prior to discovering the linear associations between the independent and dependent variables. The results and findings of this paper are expected to produce more insights to transportation agencies and practitioners.

Keywords: Health Impacts; Transportation Facilities; Random Forest; Linear Regression; Biking.

INTRODUCTION

The United States is ranked among the wealthiest countries in the world; however, there is a considerable gap between health and wealth. People in the United States are susceptible to diabetes and obesity at every age and U.S. adults' prevalence rate of diabetes is among the highest rates compared to peer countries. A poor health care at younger ages will raise the risk of suffering and dying from cardiovascular diseases in adulthood. In addition, heart disease is a widespread threat among people older than 50 years, and U.S. death rate from ischemic heart disease is ranked second among 17 peer countries. Moreover, mobility and physical inabilities like arthritis are prevalent among people in the United States (National Research Council (US) and Institute of Medicine (US), 2013).

Health is among the central concerns in the world, and it can affect human life in various aspects. As an example, obesity which is an epidemic disease can result in increased diabetes, heart disease, and cancer (Bray, 2004). However, a large proportion of the mentioned health hazards can be mitigated through appropriate physical activities. Researchers reveal that routine physical activities can effectively prevent premature death and chronic diseases such as obesity, cardiovascular disease, and diabetes, to name a few (Darren et al., 2006). Additionally, in the case that such preventions and health cares are planned for people as they are younger, billions of dollars can be saved each year (National Center for Health Statistics (US) and National Center for Health Services Research, 1999)

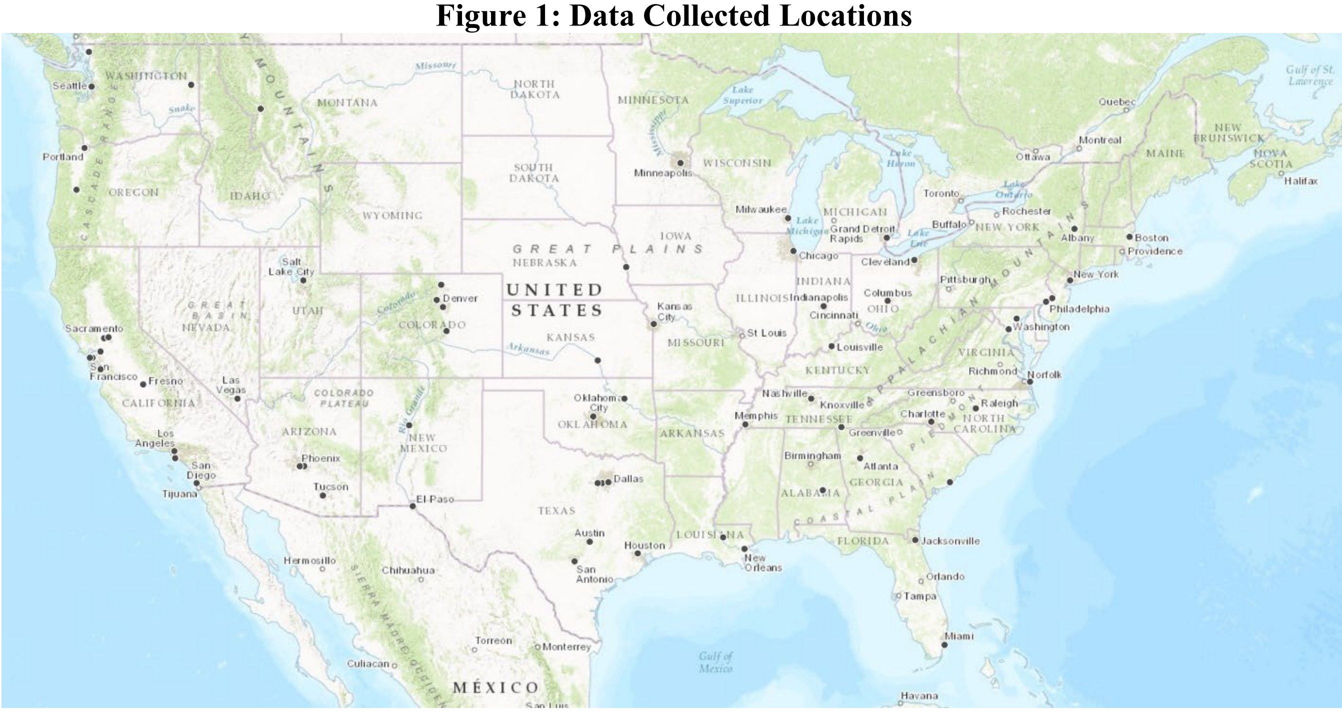
In today's life, many people suffer from harmful lifestyles such as physical inactivity. According to the National Center for Health Statistics, less than 25% of the United States population gain enough physical activity (CDC, 2019). One possible reason for this sedentary lifestyle can be the working hours per week which is typically 40 hours (Harrison, 2021). In addition, for people who live in neighborhoods that do not benefit from adequate sidewalks and streets, and more importantly there are few destinations such as transit stops to make it convenient for people to walk or bike to use transit (CDC, 2022). As technology advances, less human labor is needed, which leads to less active lifestyle (Dobbs and Manyika, 2015).

Transportation systems has various impacts on environment, economy, and public health. As an illustration, emphasis on using active transportation offers substantial benefits including reduction in fatness, different chronic diseases, fuel consumption, and transportation costs, to name but a few. Adequate infrastructure and funding sources are two critical factors in the rate of using active transportation by people. To achieve this goal and encourage people to utilize active transportation, well-connected neighborhood streets and appropriate separate paths and boulevards for bicyclists are of vital importance (Dill, 2009). It is an inevitable fact that transportation affects many aspects of human lives especially public health. Considering this, many researchers have explored different relations and implications for various factors such as air pollution, roadway crashes, and crash severity. However, to the authors' best knowledge, less research has been conducted on the other types of health measures. This paper aims to discover the relationships between transportation facilities and activities as well as the socioeconomic data and five important health indicators. A random forest method was conducted to sort the independent variables based on their importance. Then, linear regression model utilized to calculate correlation coefficients for each variable.

DATA DESCRIPTION

The data utilized for this paper was collected from different sources. Generally, the data can be categorized into three categories, namely transportation, socioeconomic and demographic, and health data. The first two categories, which constitute independent variables, were collected from Alliance for Biking & Walking in the U.S. Benchmarking Report (2016).

Figure 1: Data Collected Locations



Note: Cities are illustrated by black dots.

The transportation data includes city transportation spending, biking/walking /transit rate, miles of sidewalks/bike lanes, bike parking, and bus/ferry/rail stations rate. The socioeconomic and demographic data consist of area, total population, population by gender, population by age, population with disabilities, race, income, immigrant proportion, and number of workers. Both transportation and socioeconomic datasets were collected for 69 cities across the United States. In Figure 1, all 69 cities are displayed with a black circle. Following this, health data was collected from City Health Dashboard including obesity and diabetes rates, high blood pressure percentages, and cardiovascular disease deaths. For comparison purposes between the datasets and to be consistent with each other, all datasets were gathered for the same 69 cities and the same duration (2011 to 2014). For the missing values which were not available such as city transportation spending and miles of sidewalk, they were assumed as zero. Additionally, log base 10 was applied to the values of the dataset. This conversion was utilized for inputting data to R and obtaining an easier approach to compare the variables. For the ease of illustration just the compiled dataset for the first 11 cities is shown in Tables 1 to 3.

Table 1: Compiled Data for the First 11 cities. Part 1.

City	Area (sq mi)	2011-2013 Total Pop.	Men Pop.	Women Pop.	Pop. Under 18	Pop.18-64	Pop. age 65+	Immigrant	Hisp or Lat	Tot. Wrks
Albuquerque, NM	2.276232	5.743749	5.430111	5.454971	5.114217	5.547866	4.852169	4.768949	5.415144	5.408918
Arlington, TX	1.997561	5.574674	5.26581	5.281338	5.005691	5.381853	4.522796	4.867385	5.026913	5.261225
Atlanta, GA	2.134496	5.644502	5.343344	5.3436	4.912934	5.498588	4.643739	4.536192	4.369939	5.310483
Austin, TX	2.434249	5.935948	5.637763	5.632055	5.273342	5.786812	4.800325	5.198377	5.465524	5.66598
Baltimore, MD	1.964024	5.793676	5.46713	5.516746	5.119302	5.619488	4.868315	4.665937	4.442558	5.419786
Boston, MA	1.684307	5.804565	5.483871	5.522348	5.028022	5.66673	4.824341	5.234259	5.072562	5.516595
Charlotte, NC	2.49031	5.888984	5.56978	5.605398	5.286715	5.70892	4.840921	5.073986	5.015238	5.577367
Chicago, IL	2.369216	6.433288	6.120209	6.143982	5.783921	6.258868	5.460904	5.764048	5.89679	6.086763
Cleveland, OH	1.916401	5.592529	5.272994	5.309247	4.957119	5.401347	4.687975	4.272167	4.612996	5.157442
Colorado Springs, CO	2.291813	5.637108	5.332969	5.339165	5.027195	5.443848	4.692697	4.550876	4.868997	5.306116
Columbus, OH	2.354108	5.908692	5.597207	5.617872	5.272426	5.741046	4.858952	4.955774	4.668926	5.595246

Table 2: Compiled Data for the First 11 cities. Part 2.

City	< $15,000	$15,000 - $34,999	$35,000 - $64,999	> $65,000	City Transp Spending	Biking	Walking	Transit	Bike Parking	Miles of SW

Albuquerque, NM	4.77009317	4.901839592	4.86405994	4.64874046	0	3.52878819	3.73021684	3.6834073	0	0
Arlington, TX	4.62344571	4.753115577	4.719679246	4.4967083	0	2.55022835	3.50092224	2.63042788	0	3.04139269
Atlanta, GA	4.62515805	4.729221504	4.71457283	4.75408829	6.954242509	3.28262211	3.99982625	4.28280331	0	0
Austin, TX	4.98240693	5.156340131	5.090289804	5.00372327	8.154728207	3.86284666	4.07867427	4.27911917	2.68841982	3.40891802
Baltimore, MD	4.74026792	4.888072733	4.921998431	4.67245808	7.77815125	3.36059341	4.25321681	4.68780532	3.13257985	0
Boston, MA	4.85576137	4.912668348	4.963041333	4.9200137	7.477504698	3.79934055	4.68773402	5.04184254	3.71273386	3.23879856
Charlotte, NC	4.89659786	5.068649604	5.002412308	4.91005849	0	2.89376176	3.92396896	4.18395279	2.29885308	3.30599588
Chicago, IL	5.39923401	5.568057326	5.504530667	5.44850381	0	4.24711364	4.90994629	5.52234641	3.91089109	0
Cleveland, OH	4.6119144	4.729399699	4.554101332	4.12483015	7.58500928	2.88195497	3.82477646	4.17926446	1.76342799	3.32221929
Colorado Springs, CO	4.64752967	4.79385322	4.741191007	4.60833345	0	3.09307131	3.63002085	3.25551371	0	3.36248247
Columbus, OH	4.92967432	5.114056922	5.065934325	4.79402772	8.144574208	3.50839503	4.06160325	4.10605484	1.44715803	3.16375752

Table 3: Compiled Data for the First 11 cities. Part 3.

City	Miles of Bk Fac	Bus Sta	Ferry Sta	Rail Sta	Disabilities	Obesity	Diabetes	High Bld Pressure	Cardiovascular Disease
Albuquerque, NM	2.579783597	0	0	0	12.8049788	25.3	9.3	26	0.2008
Arlington, TX	1.67669361	0	0	0	9.82105879	32.2	9.9	29.9	0.1961
Atlanta, GA	1.959041392	0	0	0	11.3793167	30.5	11.5	32	0.2567
Austin, TX	3.138618434	0.60205999	0	0.95424251	9.22436508	28.7	7.7	23.4	0.1683
Baltimore, MD	1.477121255	0	0	1.94939001	15.8209921	34.9	13.5	37.6	0.2125
Boston, MA	2.254741376	0.47712125	0.84509804	2.40654018	12.0106983	24	8.6	24.6	0.1449
Charlotte, NC	2.354108439	0.60205999	0	1.2787536	8.79930055	28.7	9.2	31.8	0.1669
Chicago, IL	2.779235632	0	0	2.5865873	11.0292056	30.7	11.2	29.1	0.2364
Cleveland, OH	1.834547858	1.53147892	0	1.71600334	19.1101687	41.9	17.1	39.1	0.2862
Colorado Springs, CO	2.67669361	0	0	0	12.0388488	23.3	7	27.1	0.1901
Columbus, OH	2.221674997	0.69897	0	0	12.1620278	33.9	10.5	29.8	0.203

METHODOLOGY

To develop a model to explore the health impacts of transportation facilities and activities, socioeconomics, and demographics, both random forest method and linear regression model was conducted.

Random Forest

First, to evaluate the importance of each independent variable, a random forest method using multiple decision trees was performed in R programming tool. Random forest is a method that builds multiple decision trees for the classification and prediction purposes. Random forest methodology was utilized to rank the independent variables based on their importance for classification. Through this process, the mean of deference in error was calculated for each tree before and after permutation (Breiman and Cutler, 2004). The value of the mean decreased accuracy indicates that how significant an independent variable is correlated with the dependent variable. The higher values of the mean decreased accuracy reveal the greater importance of the independent variable. The negative values indicate no importance, and zero values shows no effect of the variable.

Linear Regression

Following the random forest method, a linear regression model was conducted to explore the association between the independent variables and dependent variable for each health indicator. Prior to perform the linear model, for each health metric, 25% of the independent variables was eliminated to achieve more precise result. The eliminated variables include the 6 less important variables for each health indicator. Coefficient, standard error, and p-value for each variable were calculated. In this model, coefficients indicate the numeric relation between dependent and independent variables, and the p-value shows if the relationship is statistically significant (Frost). Multiple regression model is illustrated by equation (1).

$$y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p \qquad (1)$$

In equation (1), y_i is the predicted variable, β_0 is the y_i-intercept, $\beta_1$to β_p are estimated regression coefficients, and $X_1$to X_p are the independent variables.

RESULTS

The main purpose of this paper is to develop modeling tools to evaluate health impacts of transportation facilities and activities, socioeconomics, and demographics. To achieve this goal, first, a random forest method was conducted to rank the independent variables based on their significance. In Table 4, the mean decreased accuracy is shown for each health indicator and its relevant independent variables. Second, after eliminating 25% of less important independent variables, a linear regression model was employed to explore the importance of each independent variable. Table 5 illustrates the coefficients and the standard deviation for each independent variable. Values with bolded font indicate that the independent variable is statistically significantly associated with the dependent variable.

Population with Disabilities

As shown in Table 5, prevalence of disability is highly correlated with the population of immigrants, people who earn less than $15,000 a year, and population with more than $65,000 wage a year. The coefficient for the immigrant population variable is -2.893 representing that in a population with a higher percentage of immigrants, the disability rate is lower. Another research study with similar results revealed that disability rates was 1.2% and 3.9% among East Asia and Southeast Asia immigrants, respectively. These rates were relatively lower compared to native-born Americans with 7.4% disability rate (Huang et al., 2011). Another worth mentioning point is that the population with less than $15,000 and more than $65,000 income per year have a large, negative correlation with disability rate.

Population with Obesity

The results state that the population with more than $65,000 income a year, city transportation spending, and biking levels are statistically significantly correlated with obesity rate. The population who earns more than $65,000 a year has a considerable, negative coefficient value of -25.105 indicating that as income decreases, the rate of obesity increases. A study revealed that people with obesity earn less income compared to their non-obese counterparts (Kim and Knesebeck, 2018). As illustrated in Table 5, it can be achieved that city transportation spending is positively associated with obesity rates meaning that increase in spending decreases the obesity rate. Additionally, biking level and obesity rate are statistically significantly correlated with each other with a coefficient of -4.807. One comparable study discovered that among people, the population that uses walking and cycling mode to work more than the others has a higher rate of recommended physical activity, and lower rates of obesity and diabetes (Pucher et al., 2010).

Population with Diabetes

Similar to the obesity results, the higher rates of biking to work are associated with a lower percentage of diabetes rate. People with obesity are more prone to have diabetes (Pucher et al., 2010). Nevertheless, in contrast to biking levels, transit rate is positively correlated with diabetes rate meaning that higher rates of transit result in higher rates of obesity in a population.

Population with High Blood Pressure

As shown in Table 5, Hispanic/Latino population, total number of workers, and biking levels are the three independent variables that are statistically significantly associated with high blood pressure rate. The coefficients for the variables are negative indicating that increase in the explanatory variables generates lower rates of high blood pressure. High blood pressure in patients who suffer from hypertension can be mitigated through having regular aerobic exercise (Kokkinos and Papademetriou, 2000). Accordingly, as cycling is categorized as an aerobic activity, it can contribute significantly to lower blood pressure rates.

Population with Cardiovascular Disease

Aging can lead to a higher risk of cardiovascular diseases in a person since it generates changes in the heart and blood vessels (McNeil et al., 2018). The results show that cardiovascular disease is correlated with the population between the ages of 18 to 64 by a coefficient value of 3.785. In addition, cardiovascular disease rate is negatively correlated with the population that make less than $15,000 and the population that earn between $35,000-$64,999.

Table 4: Mean Decreased Accuracy Results from Random Forest for each Independent Variable Categorized by Health Indicators

Mean Decreased Accuracy					
	Health Indicators				
Variables	Pop. with Disability	Obesity	Diabetes	High Blood Pressure	Cardiovascular Disease
Area	0.2886	1.7581	-0.8560	0.7632	2.7033
Total Pop. (2011-2013)	1.4046	0.0123	2.3050	1.6626	1.8677
Men Pop.	1.2225	1.8065	1.7955	0.8903	0.9473
Women Pop.	0.9494	2.1312	1.7302	1.3971	0.8858
Pop. Under 18	0.8782	2.1498	3.8599	1.9823	2.7293
Pop. 18-64	1.8916	1.8382	0.1280	1.0679	1.9214
Pop. age 65+	0.5261	1.2848	2.9159	2.0239	1.6798
Immigrant	3.1247	0.8766	2.1152	1.8021	0.9723
Hispanic or Latino	0.7235	1.5817	2.4628	1.3771	-0.6774
Total Workers	0.5233	1.2049	1.8627	0.9599	2.2099
< $15,000	1.1576	1.1288	-1.7317	1.4898	1.0717
$15,000 - $34,999	0.9243	1.6814	1.2389	-1.1406	1.9865
$35,000 - $64,999	0.9703	0.6738	1.3641	-0.1402	2.6996
> $65,000	3.5724	1.6964	1.0422	-0.1185	2.2345
City Transp Spending	-0.0326	0.1616	-0.4935	-1.3660	-1.0995
Biking	0.6036	3.0822	0.8796	2.6663	0.5798
Walking	-0.2562	1.5093	-0.4222	-0.3247	-0.1352
Transit	0.3934	1.2677	0.5424	0.6228	0.8669
Bike Parking	-1.0119	0.3343	-0.2502	0.0725	-0.9050
Miles of Sidewalks	-0.4615	-0.8432	0.2802	-0.3016	0.1180
Miles of Bike Fac	2.0241	-0.5233	-0.6983	1.3183	0.3387
Bus Stations	-0.5977	0.0520	0.4125	1.4192	-0.8364
Ferry Stations	1.0050	0.0000	-1.0050	0.0000	0.0000
Rail Stations	-0.0243	-0.1579	2.1312	-0.8828	-1.4161

Table 5: Correlation Coefficient Results from Linear Regression Model for each Independent Variable Categorized by Health Indicators

	Pop. with Disability	**Obesity**	**Diabetes**	**High Bld Pressure**	**Cardiovascular Disease**
Variables	**Coefficient (SD)**	**Coefficient (SD)**	**Coefficient (SD)**	**Coefficient (SD)**	**Coefficient (SD)**
Area	-0.333 (0.775)	1.0726 (1.6282)	--	2.834 (1.576)	-0.025 (0.025)
Total Pop. (2011-2013)	-352.410 (1828.723)	--	2274.000 (2011)	4674.714 (3797.763)	-5.455 (60.607)
Men Pop.	161.489 (894.360)	-84.394 (72.460)	-1146.000 (992.2)	-2378.521 (1860.759)	-0.421 (29.654)

Women Pop.	142.770 (924.881)	-55.4689 (83.527)	-1164.000 (1025)	-2421.009 (1923.503)	1.442 (30.644)
Pop. Under 18	13.239 (14.621)	51.897 (30.768)	11.380 (14.99)	30.867 (29.251)	0.929 (0.469)
Pop. 18-64	54.823 (49.943)	116.328 (103.106)	41.510 (51.98)	123.145 (102.785)	**3.785** **(1.647)**
Pop. age 65+	14.102 (7.838)	7.801 (16.460)	10.320 (8.36)	27.592 (15.981)	0.503 (0.257)
Immigrant	**-2.893** **(1.441)**	-0.880 (2.946)	0.202 (1.414)	1.101 (2.944)	0.060 (0.035)
Hispanic or Latino	0.281 (0.934)	-2.182 (2.003)	-0.573 (0.962)	**-4.344** **(1.888)**	--
Total Workers	-11.049 (21.893)	33.076 (47.062)	-28.900 (18.33)	**-40.965** **(15.920)**	-0.123 (0.707)
< $15,000	**-12.192** **(5.484)**	-21.966 (11.237)	--	-3.053 (9.467)	**-0.401** **(0.181)**
$15,000 - $34,999	-0.045 (7.635)	-2.912 (15.960)	10.170 (7.493)	--	0.297 (0.247)
$35,000 - $64,999	1.127 (6.089)	-17.462 (12.705)	-7.608 (5.207)	--	**-0.544** **(0.194)**
> $65,000	**-9.862** **(4.777)**	**-25.105** **(10.190)**	1.301 (3.75)	-4.755 (5.421)	-0.070 (0.155)
City Transp Spending	--	**0.210** **(0.104)**	--	--	--
Biking	-0.368 (0.655)	**-4.807** **(1.356)**	**-2.812** **(0.672)**	**-4.406** **(1.398)**	-0.007 (0.021)
Walking	--	2.955 (3.505)	--	--	--
Transit	0.989 (0.724)	2.918 (1.770)	**1.521** **(0.723)**	1.019 (1.545)	-0.024 (0.023)
Bike Parking	--	-0.287 (0.318)	0.271 (0.217)	-0.014 (0.357)	--

Note: 1. Values with bolded font represent the 95% confidence level for the correlation coefficient. 2. Values in parentheses represent standard deviation.

CONCLUSION

Considering the health issues and the gap between health and wealth in the United States, the authors conducted research on the impacts of transportation and socioeconomic factors such as city transportation spending, biking and walking levels, transit, miles of bike facilities, and demographics on five health indicators: disability, obesity, diabetes, high blood pressure, and cardiovascular disease. First, through utilizing random forest method, the independent variables were ranked based on their importance. Second, the association between the top 75% most important variables for each health issue was explored with linear regression model. The data was collected and compiled from two different sources: Alliance for Biking & Walking Benchmarking Report (2016) and City Health Dashboard. Estimated correlation coefficients were interpreted. The findings show that most health indicators, high blood pressure, obesity, and diabetes, demonstrate negative correlation with biking levels indicating that more cycling can mitigate such health risks in a population. It appears that there is no evident correlation between other independent variables and health impacts. However, income levels seem to have significant impacts on certain health issues like population with disability and cardiovascular disease. The results can aid city planners and transportation agencies to take some important health impacts into consideration. Although numerous relationships between independent and dependent variables were explored in this study, the results would be different and more precise if the data was available for larger number of cities and populations. In addition, different methods and assumptions such as employing mean decreased Gini for ranking independent variables or a non-linear regression assumption between the datasets can be considered.

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