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Transportation System and Its Association with Human Health – A Review and Modeling Approach

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16. Abstract

Transportation systems constitute of infrastructure, commute modes, land use and other policies. The purpose of transportation is to provide easy access to goods and services. While attaining this purpose, impacts of transportation on human health and well-being have been ignored to some extent. Recently, studies have begun analyzing the impact of transportation systems on quality of life and health disparities. While many studies have discussed the impact of the transportation system on individual factors from health, a very limited number of studies have focused on the impact of multiple factors associated with multiple morbidity and mortality forms. The focus of this study is to analyze how transportation infrastructure can promote physical activities resulting in better health outcomes. Lack of data on transportation infrastructure at county-level in Michigan restricted the study. The Transportation and Health Tool developed by the US Department of Transportation was reviewed and applied to Michigan at a county-level to examine how different counties rank with respect to different transportation indicators corresponding to health conditions. Further, correlation analyses and multinomial linear regression analyses were conducted to determine relationships and impact magnitudes of transportation and socioeconomic factors on human health.

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Abstract

Transportation systems constitute of infrastructure, commute modes, land use and other policies. The purpose of transportation is to provide easy access to goods and services. While attaining this purpose, impacts of transportation on human health and well-being have been ignored to some extent. Recently, studies have begun analyzing the impact of transportation systems on quality of life and health disparities. While many studies have discussed the impact of the transportation system on individual factors from health, a very limited number of studies have focused on the impact of multiple factors associated with multiple morbidity and mortality forms. The focus of this study is to analyze how transportation infrastructure can promote physical activities resulting in better health outcomes. Lack of data on transportation infrastructure at county-level in Michigan restricted the study. The Transportation and Health Tool developed by the US Department of Transportation was reviewed and applied to Michigan at a county-level to examine how different counties rank with respect to different transportation indicators corresponding to health conditions. Further, correlation analyses and multinomial linear regression analyses were conducted to determine relationships and impact magnitudes of transportation and socioeconomic factors on human health.

Chapter 1 Introduction

Transportation is one of the core needs of every community as it provides access to goods and services. Transportation services may also enhance the quality of life and economic development of society (Ewing & Cervero, 2010). There has been a lot of research and studies in the past which suggest the involvement of transportation in facilitating the health behavior. Substantial research has proved the impact of the transportation system on human health concerning physical activity, safety, air quality, accessibility. Even though health is not the primary objective of the transportation system, there is evidence that changes in transportation network can reap better health outcomes. (Ross et al. 2014). This study deals with the relationship between various transportation factors and human health collaboratively to determine their linkage with mortality at a county level in Michigan.

1.1 Research Problem

Transportation and human health are interrelated to a varying extent. There have been many studies that suggest that transportation has a notable impact on human health. Transportation system has a significant impact on how different communities are designed and how it results in various forms of human health. This research mainly focuses on physical activity and safety, which in general have direct relation to human health associated with transportation. These factors contribute to some transportation indicator that could relate to human health (Ingles, 2013).

Previous studies mostly focused on transportation health impacts. The objective of the research conducted is to review the works done in this aspect and perform multiple statistical analyses on how different transportation system factors are related to human health. As mentioned earlier, changes in the transportation system may result in better health outcomes and may further impact changes in the mortality trend. Studies have provided various suggestions based on their analyses and assumptions. This research adds possible justification of multiple proposals relating transportation and health factors at a county level in Michigan.

1.2 Research Objectives

Major contributing factors of transportation on human health are physical activities, safety, and air quality. There are different socioeconomic, and transportation factors which can affect the active transportation. Changes in these factors would help promote active transportation, which in turn suggests considerable health benefits. Altering health modifies lifestyle and livability of a community. Significant insight on active transportation and reaching out to communities with suggestions of adopting more livable and sustainable transportation measures are expected to reap out better health outcomes for the communities.

The primary connotation of physical activity from transportation is “active transportation” which comprises of walking and bicycling measures. The guidelines from the United States Department of Human Health and Services (USDHHS) suggest that at least 1 hour of physical activity a week results in some health benefits, but an average of two and a half hours of physical activity a week reduces the risk for many chronic diseases and adverse health outcomes. Some major chronic diseases that physical activity lessens the risk of developing are hypertension, diabetes, arthritis, and heart disease. The levels of physical inactivity in the U.S. are a noted concern for health experts. Studies from the Center for Disease Control and Prevention (CDC) and other health organizations show that 30-40% of the U.S. population are engaged in the regular physical activity whereas 30% of the population is completely physically inactive.

Safety in this research primarily deals with road traffic safety that involves vehicle-related crashes in the transportation system. Motorized transportation is the primary mode share in the United States, providing unprecedented levels of mobility. Irrespective of the advantages for motorized use, injuries, and fatalities caused by vehicles is a major issue that needs to be resolved. Injuries and deaths from motor vehicle crashes are considered as one of the leading causes of mortality in the U.S.

Researchers previously have suggested a relation between air pollution and human health. Environmental pollution from transportation is an issue that is widely discussed these days. The ecological imbalance caused by pollutants is a prime concern. Pollutants from transportation affect air, water, soil and other environmental factors which in turn are considered to have adverse effects on human health. Different pollutants including particulate matter, carbon monoxide, nitrogen oxide, and carcinogens are released into the environment by the use of motorized transport. (Dora & Phillips, 2000). American Public Health Association suggests studies that link air pollution to adverse health outcomes, including asthma, respiratory illness, heart disease, poor birth outcomes, cancer, and premature death. Efforts are being made to overcome the health issues caused by transportation systems. The transportation and health experts collaborate and contribute towards the betterment of transportation and the health system. The prime focus of the research mainly deals with physical activity, safety, and air quality. The emphasis on transportation and health acknowledges the underlying trend such as the increase in sustainable forms of transportation which further encourages livable communities and capital preservations (Raynault & Christopher, 2013).

1.3 Purpose of the research

This research deals with human health and transportation. The purpose of this research is to provide the significance of different transportation factors that affect human health. Transportation system plays a significant role in the behavior of a community. The research investigates various transportation-related factors that may affect human health. It is intended to identify and adopt healthy and sustainable transportation alternatives to prevent the deficient effects of transport systems on human health. The convergence of health, environment and other social concerns on transportation are stated in this research, and their correlation is derived. Statistical analysis of the relationship is also processed in this research.

1.4 Scope of the research

The intent behind this study is to obtain a logical relation between human health and transportation. There have been studies that analyze significant factors contributing to different health behavior and the link between individual transportation and health factors. For instance, Amir Samimi et al. (2008) showed the relation between automobile use and obesity with statistical parameters. Similarly, to earlier studies, the objective is to evaluate all the possible research in this aspect and add the missing pieces by adopting multiple factors from transportation and health and analyzing their relations. There have not been many studies analyzing statistical associations between various factors from transportation and health, and further relating to mortality.

Different modes, measures, and their behavior are analyzed to derive a significant relation between lists of various parameters. This research further performs statistical analysis and depicts how multiple factors from transportation are related to factors from health and corresponding outcomes. Further, this study focuses on evaluating the factors from transportation system by reviewing earlier studies, revises a few parameters based on the evaluation. Statistical relations between different parameters from transportation and health are also derived.

1.5 Methodology

The credibility of the findings and research results extensively depends on upon the data that was collected and then analyzed. Different factors in transportation affect diverse groups of people on health. This study was progressed to obtain the extent to which transportation system about socioeconomic factors affect human health. A descriptive approach was followed to collect data for different indicators that was required for the research and analysis. The prime intention of this study is to show how and what extent the factors from transportation systems impact human health.

The Transportation and Health Tool (THT) developed by the U.S. Department of Transportation (DOT) and CDC is also used in the study. The THT comprises different transportation and health indicators for states, metropolitan areas and urbanized areas in the U.S. This tool describes how transportation system has an impact on physical activity, safety, air quality and connectivity. This tool can also be used for comparisons of transportation and health indicators between different states, MSA's and UZA's. It can be further used to identify measures which can improve health outcomes through transportation studies and policies. A county-level analysis is intended to be derived for the Michigan Case in our study. A THT is created for Michigan using the methodology of the USDOT. The indicators that are listed in the THT (USDOT) are used, and the data is collected at county-level. After collecting appropriate data for THT, the data is normalized and then represented by scoring measures. The purpose of this derived tool is to depict how transportation system impacts physical activity, safety, air quality and connectivity and how different counties in Michigan are performing on transportation and health. Further, this tool is used to create a better understanding of the factoring links between transportation and health.

This research performs a county-level analysis of different transportation and socioeconomic factors that are derived from earlier studies. The focus is on the factors which account to a possible relation between transportation system and human health. All the factors derived from various literature are presented. Data for all factors mentioned are collected from different sources. Further, a correlation test shows their relations. The data is graphically represented to depict the trend of the relation among different factors. After finding the correlations and the trend of the data, a multinomial linear regression is performed for the factors that tend to have significant relations. The multinomial linear regression models are derived to determine the relationship and significance of how the different factors affect human health, showing the factors, outcomes, and the magnitude of the relationships obtained.

Chapter 2 Literature Review

2.1 Impact of Transportation on Human Health

Transportation systems provide accesses to entities like jobs, education, markets and other services. They play a pivotal role in the daily operations of a community. However, the transportation systems also result in numerous concerns on environmental impacts, human health and traffic-related injuries and deaths. Considerable amount of studies has addressed such issues and numerous studies are still in progress.

Wesley et al. (2014) attempts to connect the street network designs with public health. A multilevel hierarchical model was obtained in their research to associate the pair of statistical models corresponding to micro and macro level relationships and interactions among them (Healy, 2001). The model demonstrates the influence of street networks on obesity, diabetes, high blood pressure, heart disease and asthma. The research was conducted by performing a survey in 24 California cities. Those cities exhibited a range of street network typologies using health data from California Health Interview Survey. The dependent variables used for the study were land use, commuting time, socioeconomic status and street design. The independent variables used in the study were categorized through street network characteristics, street design features, land use and socioeconomic factors. The study was used to determine the link between the street system and health disparities. The relation between the infrastructure and socio-economic factors also tends to correlate with health (Boone-Heinonen et al., 2011). The study included alternative methods of street design elements to promote healthy communities. The study results show that the rates of obesity, diabetes, high blood pressure and heart disease decrease in communities using small street networks. The research proposed the health considerations when choosing a place to live. The analysis stated that compact cities tend to have better health outcomes. Finally, the research indicates that refining the classification of street networks and their attributes can help in attaining evidence-based suggestions. Policy makers could use those suggestions to enhance the infrastructure features of a community.

Oliver Tristan et al. (2016) evaluated the link between active commuting (walking and bicycling) and body mass index (BMI). Self-reported data on an individual's height, weight, and active commuting were obtained from the Commuting and Health in Cambridge study for the years 2009-2012. A linear regression model was developed using the reports from 809 test subjects. It acquires the correlation between conservation of an annual active commute and BMI at the end of the year. The changes in active commuting time weekly and change in BMI over a year were also linked to determine their significance. The BMI was calculated by dividing the self-reported weight of the individuals by the square of their self-reported height (World Health Organization, 2000). The self-reported commuting characteristics of individuals were obtained and analyzed using a weekly reviewed travel record. Two analyses were conducted to determine the longitudinal associations. The first one linked the conservation of walking and bicycling to work with the BMI. The second one connected the change in active commuting with a change in BMI. The dependent variables used in this study were age, sex, education, physical wellbeing, commuting distance, and non-commuting physical activities. The study found that longer bicycling commutes to work were linked to a lower BMI or the individuals who were overweight at baseline. The reduction in BMI on walking was only significant when the analysis was restricted to persons who typically had not moved at home or work. The other associations of walking were not significant with BMI. Finally, this research tends to provide evidence on the contribution of active commuting in reducing the BMI of various individuals, which in turn results in better health outcomes. The findings of this research elaborate the values of commuting to work and helps promote active transportation.

Ester Cerin et al. (2009) conducted a study linking the socioeconomic status with the differences in walking for transportation. The study obtained a perception of social and physical environmental variables related to an individual and an area level socioeconomic status, which further related to walking for transportation. The data was collected through mailed surveys, which collected information on transport-related walking and its hypothesized individual, social and environmental correlates. The data was collected from 2194 adults, accommodated in 154 census, collection districts in Adelaide, Australia. The different socioeconomic status was determined by self-reported data on educational attainment, employment characteristics, and household income. The area-level socioeconomic status was determined by analyzing census data on median household income and household size for each selected census collection district. A bootstrap generalized linear model showed the links between socioeconomic status and frequency of walking for transportation. Variables such as demographic, leisure time physical activity, and environmental factors were a consideration in the analysis. The study was used to analyze an individual's social and environmental mediators in the relations of socioeconomic factors with walking for transportation. As a result, this study accomplished the immediate and aberrant impacts of educational attainment, individual and area level household income on transportation-related walking. The study concluded the possible relations are underlying the association of socioeconomic factors with walking for transportation.

Samimi et al. (2009) studied the effects of transportation and built environment on general health and obesity. The study investigated the generalized effects of transportation, land use, and built environment features with socioeconomic and demographic variables on human health and obesity. The data on demographic, socioeconomic and health-related variables were collected from BRFFS from 300,000 individuals. Transportation, land use and built environment data were obtained from the NHTS, Census Transportation Planning Package, and the Census TIGER/Line GIS data files. These variables include road length, area, population, workers population, road density, etc. The data was collected at a county level using geographical information systems. Initially, the analysis inferred the effects of demographic and socioeconomic variables on health. Components such as income, education, exercise and moderate physical activity are linked to general health and obesity. The relations obtained are demonstrated by using a forward and backward selection linear regression method. The analysis performed focused on transportation, land use and built environment variables with obesity and general health. The variables used were auto-use, transit use, block-size, road density and population density to link transportation and built environment variables with public health and obesity. Various results were concluded from the relations. However, the most significant effect mentioned was a 1% decrease in auto-use reduced the chance of obesity by 0.4%. The study presumed that public health is an imperative issue that needs to be considered as an impact of the transportation systems. The association between auto-use, transit use, block size and health variables with the addition of demographic and socioeconomic variables was delineated.

The transport, environment and health report, by Dora and Phillips for the World Health Organization (2000), stated active means of transportation like walking or bicycling has circumspect advantages. It suggested that a reduction in motorized transport will progressively diminish noise pollution, air pollution, and accident rates. A general assumption of the study stated that a total of 30 minutes of brisk walking or cycling a day reduces the risk to many health atrocities, such as frequent illness, heart disease, obesity, diabetes and some injuries which gradually result in premature death. Dannenberg and Sener (2015) stated that improvements in the non-motorized transportation infrastructure benefits existing and new users, certainly ones possessing physical or economic obstacles, by providing access to essential services and activities. Development in the utilization of active travel modes impacts the standard of accessibility and sustainability. Improvement of public transit facilities is another factor that can promote physical activity, as users tend to walk and bike to the train stations and bus stops. Frank. and Engelke (2003) stated in that physical inactivity is a major risk factor for chronic diseases that affect the mortality rate. Their research concluded that various diseases are linked to the variations in physical activity levels, for instance, heart disease, stroke, certain cancers, diabetes, obesity, and depression.

The study by Duncan et al. (2005) on transportation and built environment characteristics stated that the standards of the built environment could eloquently influence the transportation behavior and levels of physical activity. It also stated that methods used in a community thrive by investments on transportation infrastructure and land, assist with shaping a well-built environment. The progress and development ultimately depend on how, when and where the investments are made collectively. Definite transport and land-use policies preserve the environment and assist the public with health outcomes, frequently analyzing the potency of these intercessions. Public strategies like transportation and land use mix policies need to be assessed with the health perspective. The cost of living, which mainly incorporates housing and transportation costs is an important factor when determining the health of communities. The study concluded that narrow assessments considering a solitary component would give deceiving results with different conceivable impacts of transportation on human health.

A study by Woolf and Braveman (2011) stated that the neighborhood and community feature with the cost of living corresponded with the health disparities of different individuals and households. Center for Neighborhood Technology suggests that active commuting communities offer easier access to goods and services, allow less dependence on motorized transport. Further, furnishing an ecological balance with the increase in physical activity for transportation purpose. Jackson, (2003) stated the essential accentuation is on the transportation system and its designs, which determines the travel behavior immensely. The design and planning of the streets relate to its usage and the ways in which they are connected. The streetscape and its adaptability encourage active modes of transportation. The broader streets are more convenient for motorists to speed and drive without obstacles, demoralize active transport modes. Whereas, streets that are slender and insidious discourage automobile travel at high speeds and highly support active transportation. Streets that have pedestrian and bicycle facilities (bike lanes, sidewalks, crosswalks, etc.) and that are processed under traffic calming (i.e., streets that contain traffic-slowing obstacles and devices) are believed to facilitate more walking and bicycling. Also, transportation systems can increase walking and biking through dedicated bicycle and pedestrian facilities, such as bike paths and walking trails. The study concluded that the major aspect of street designs should accommodate the automobile traffic simultaneously with the non-motorized travelers.

Kavanagh et al. (2005) found that the influence of road traffic injuries and fatalities on human health is the most significant relation between transportation and health. Safety is a primary concern within the transportation systems. Multiple risks associated with motorized transportation can also affect the non-motorized travelers. Road traffic accidents significantly contribute to the mortality in the United States. Road accidents which include motorist, pedestrians, bikers, property, etc., are the primary cause of transportation-related accidents. Studies have shown that road traffic accidents have indirect consequences on the communities and change the community’s view on safety. Driving under the influence of alcohol is another factor that corresponds with the safety of road users. This indicator directs the link between transportation and negative health outcomes. This measure supports the policies and laws against alcohol-impaired driving. The estimated annual cost of alcohol-related motorized crashes in the United States is more than $59 billion (Blincoe et al., 2014). In the year 2012, a total of 10,322 people died in alcohol-impaired driving crashes, which is around (31%) of all traffic-related crashes in the U.S. (U.S. DOT, National Highway Traffic Safety Administration, 2012). Seat-belt usage is considered to be the foremost factor of importance in motorized transport. Researchers show the effectiveness of seat belt usage in preventing the motorized injuries and fatalities. Emergency Nurses Association (2010) affirmed seat belt usage as an effective measure that diminished the severity of injuries and deaths in motor vehicles crashes.

Krzyżanowski et al. (2005) stated the effects of transportation on human health and land-use policies are extensively identified. Whereas, the pollutants from motorized transport are identified as important outcomes of the particular norm of transportation. Air Quality in livable communities is of prime importance. The environment and the air quality in and around a community reckons to the community's livability. The levels of air pollutants have a significant impact on the length of an individual's life. Equitable human subjection to air pollution comes from motorized transport, and there is probably a direct link between respiratory and health issues in the residences near the roads with heavy vehicular coalesce. The proximity of an individuals' residence to higher commuted roadways relates to a negative impact on their health. The betterment of the built environment corresponding to these areas and by adopting strategies which can improve the air quality can mitigate these effects on human health. A county-based study by Perez et al. (2012) indicated that the number of asthma-related cases would go down by 5,900 by decreasing the regional air pollution by 20% and the population within proximity to major roadways by 3.6%. Other studies (U.S. EPA, 2015; Baldauf et al., 2008) suggested that air pollution can be attenuated by applying certain strategies such as vegetative buffers or sound walls, which tend to adulterate the concentrations in the emissions from different vehicles. Research implications on potential health effects of emissions are extensive and are associated with variable pollutants. These pollutants can affect an individual's life expectancy. The vehicle miles traveled is another factor that also has a relation with the air quality. Johnson (2006) stated that the decrease in vehicle miles traveled can directly improve the air quality and improve the overall health of the inhabitants in a community. The emissions increased from the motorized transport is linked to a broad range of cardiovascular and respiratory health problems.

Johnson (2010) stated that access to destinations is one of the key factors that help in determining the time individuals spend in driving, which is assumed to have adverse health effects. Lindstrom (2008) concluded that active commuting deals with bicycling and walking for transportation. This increases physical activity and in turn, lowers the chances of attaining obesity. Supporting evidence verifies the different health measures affected by motorized commuting. The symptoms include cardiovascular diseases and diabetes (Lyons and Chatterjee 2008). Studies from Lindstrom (2008) and Frank et al. (2004) showed that a longer commuting time is linked to higher body mass index (BMI). The latter also depicted that each additional hour spent in a car per day will increase a 6% feasibility of attaining obesity. There are further discussions that relate commuting modes and measures of cardiovascular stress. White and Rotton (1998) showed that commuting is linked to an increased pulse rate and systolic blood pressure.

The Center for Disease Control and Prevention stated the lack of physical activity could result in a threat to diseases like obesity, diabetes, heart disease, strokes and other chronic health conditions. The CDC estimates that 17% of young individuals in the US and one in three adults are obese. The causes of obesity and high blood pressure can be linked to transportation factors, due to the impact on physical activity (Chan & Woo, 2010). Other health issues related to transportation are further discussed in this study. A report from the CDC summarized the research on health benefits of physical activity. The following are the conclusions that were listed in the report:

- The increase in the levels of physical activity further reduces the overall mortality, even for the individuals who are adequately active.
- Lower levels of physical activity can result in obesity.
- High blood pressure can be avoided by regular and routine physical activity.
- Physical activity has a direct link with cardiovascular diseases. Therefore, an increase in physical activity reduces the risk of cardiovascular diseases.
- Cardiovascular benefits of physical activity are critical; it is one of the major factors leading to premature death.

2.1.1 Health Impact Assessment

Definition of HIA

Health Impact Assessment (HIA) might be defined as ‘a methodology which allows the identification, prediction and evaluation of the possible changes in health risk, either positive or negative (single or collective) of a policy program, plan or development action on a defined population. These changes could be direct and immediate or indirect and delayed’ (Morgan, 1998). The aim of HIA is to assign value to the decision-making process and aims to assist decision makers by illustrating the various ways in which a policy could influence health by ensuring that health considerations are not disregarded. An HIA provides feasible recommendations to increase positive health effects and minimize negative health effects. HIA is primarily concerned with policies in non-health sectors such as economic, housing, law and order, transport, energy and many others since these are the areas that include the greatest potential to influence population health (Lock, 1998). HIA can also add to policies with a health objective by exploring the indirect health consequences, which would flow from them. The main steps in conducting an HIA are:

- Screening—determining the usefulness and practicality of the HIA. If all the decisions have been made, an HIA probably is not appropriate. If HIA findings most likely would not change any decisions, an HIA would not be useful.
- Scoping—identify which health effects by what method needs to be considered.
- Assessing risks and benefits—identify who might be affected and how they might be affected. Using data and research to find the probability, direction, magnitude, and distribution of potential health effects.
- Developing recommendations—suggesting changes to promote positive health effects or minimize adverse health effects.
- Reporting—presenting the results to decision makers and the public.
- Evaluating—determining whether the HIA will affect public health decisions and the actual effects of those decisions.

HIA can help communities, decision makers, and practitioners make choices that improve public health through community design. HIA is a useful tool to assess how a proposed decision will affect the health of a population and whether vulnerable populations are more likely to be impacted. The goal of HIA is to provide recommendations during the decision-making process that will protect health and reduce health inequities.

One example of how HIA has been recommended as an important assessment tool is the 2011 National Research Council study. Centers for Disease and Control and Prevention (CDC) sponsored the 2011 National Research Council report Improving Health in the United States: The Role of Health Impact Assessment (NRC, 2011), which found that the HIA holds promise for incorporating aspects of health into decision making due to its

- Applicability to a broad array of policies, programs, plans, and projects.
- Consideration of adverse and beneficial health effects.
- Ability to consider and incorporate various types of evidence.

- Engagement of communities and stakeholders in a deliberative process.

<u>HIA's level of rigor</u>

Part of the scoping step involves determining the rigor or level of HIA which will be conducted, including the number of impacts that will be assessed, the depth of assessment (e.g., extent of data collection, stakeholder involvement, sources of evidence, etc.), and the time length that is offered to complete the HIA. The rigor of the reviewed HIAs was judged using the definitions of four levels of HIA provided by Harris et al. (2007). These levels, listed from least to most rigorous (and least to most resource-intensive), are: desk-based, rapid, intermediate, and comprehensive (Table 1).

Table 1: Levels of Health Impact Assessment

Desk-based	**Rapid**	**Intermediate**	**Comprehensive**
• No more than three impacts • Assessed in less detail	• No more than three impacts • Assessed in more detail	• Three to ten impacts • Assessed in detail	• All potential impacts • Assessed in detail
Provides a broad overview of potential health impact	Provides a broad overview of potential health impact	• Provides a more thorough assessment of potential health impact • More detail on specific predicted impacts	Provides a comprehensive assessment of potential health impact
Collecting and analyzing is based on existing accessible data	Involves collecting and analyzing existing data with limited input from experts and key stakeholders	Involves collecting and analyzing existing data as well as gathering new qualitative data from stakeholders and key informants.	Involves collecting and analyzing data from multiple sources (qualitative and quantitative)

<u>Sectors of HIA</u>

CDC's Healthy Community Design Initiative is the only source of federal expertise to assist states and communities integrate health considerations into transportation and community planning decisions. In the United States, HIA is a rapidly emerging practice among local, state, and federal jurisdictions. Decision makers are using the field of HIA for all levels to consider health, while making decisions in a broad range of sectors, including:

- Agriculture
- built environment
- climate change
- community development
- criminal justice
- economic policy
- education, gambling
- housing
- labor and employment
- natural resources
- physical activity
- transportation
- water

Some examples of completed and in progress HIAs project in the United States in transportation and built environment sectors is shown in Table 2.

Table 2: List of factors influencing human health

Health Impact Assessment	Sector	State	Information
Aberdeen Pedestrian Transportation plan HIA (Buescher et al., 2012)	Transportation	NC	An HIA that evaluated the potential impacts of the Aberdeen Pedestrian Transportation Plan on child health and health disparities.
Active Transportation in Sierra Vista	Transportation	AZ	An HIA will focus on how increased physical activity can improve health and explore the connections between the built environment and individual and community health.
Buford Highway and NE Plaza Redevelopment	Transportation	GA	An HIA that examined the expected health benefits of proposed highway design changes (e.g., reducing lanes, adding sidewalks, medians, bike lanes and on-street

			parking) to the Buford Highway Corridor. Special emphasis was placed on the potential impacts on physical activity and pedestrian injuries.
California High Speed Rail: San Jose to Merced Corridor (Kersten et al., 2011)	Transportation	CA	An HIA to add value to decision-making regarding design alternatives for the San Jose to Merced corridor of the California High Speed Rail (HSR) by identifying opportunities for positive health benefits and recognizing threats and negative health costs.
I-5 Columbia River Crossing: Health Impact Assessment (Goff, Bhat & Johnson, 2008)	Transportation	OR	An HIA that examined the health impacts of proposed alternatives for a renovation and expansion of the Interstate 5 Columbia River crossing between Oregon and Washington.
Augusta Lane Bicycle and Pedestrian Bridge (WCHHS, 2014)	Transportation	OR	A rapid HIA was conducted to identify the potential health impacts of building a bicycle and pedestrian bridge. The HIA analysis focused on impacts to health through physical activity, school accessibility, bus emissions, academic performance, perceived safety, and neighborhood connectivity.
Non-motorized Transportation Plan and Climate Sustainability Plan Recommendations (MDHHS, 2012)	Transportation	MI	The proposed changes to a corridor in East Lansing aim to increase the walkability and bikeability, safety, and environmental sustainability of a busy intersecting corridor. Examples of potential road crossing and sidewalk improvements included in the plan are crossing and bump-out islands; flash signals; traffic calming devices; lane consolidation; additional bike lanes; and sidewalk connectivity.
Columbus North East Area Plan HIA	Built Environment	OH	An HIA addressed a proposed land-use plan for northeast Columbus and explored the impacts on air pollution, mental health, social capital, chronic disease, obesity, and pedestrian injury rates. Ultimately, the HIA recommended specific implementation for each of the six key area plan policies, including mixed-use planning and street tactics

			that profit from existing community centers, job centers, parks and bike trails.
North Aurora Regional Recreation (Roof, et al., 2010)	Built Environment	CO	An HIA conducted to identify the location of regional recreation center. The assessment process used the evidence-based data to make recommendations specific to each potential site. Based on access, equity, and supporting the health, safety, and well being of North Aurora, the HIA recommended one site for the regional recreation facility.
Alabama Avenue Bike Lanes	Built Environment	WA	An HIA on proposed bike lanes on a 2-mile section of Alabama Avenue in Washington, DC. The bike lanes connect two off-road bike trails and connect nearby residents to health care facilities, grocery stores, schools, and recreation centers.

Quantitative estimation of HIA

Quantitative estimation process would be consisted of routinely collected information, such as mortality and census data, which will inform the baseline assessment. It also can include information from social-science and epidemiologic studies concerning the strength of associations between the social and physical environment (such as air and water quality and economic impacts) and health outcomes. A large and growing body of quantitative evidence is available; where specific additional information is required and resources are available, HIA teams might be able to collect new quantitative data (NRC, 2011). Quantitative estimation provides an indication of the magnitude of health effects, thereafter can be easily compared with existing numerical thresholds that define the significance of specific effects. These thresholds enable practitioners to make direct comparisons among alternatives, and provide inputs for economic valuation. The most crucial section to find numerical thresholds is Assigning Monetary Values to Health Consequences. The health consequences of a decision can be characterized according to their economic or monetary valuation. Although monetary effects clearly are not health effects themselves, many decision-makers and stakeholders may give substantial consideration to the economic value of effects, and economic valuation of health effects can facilitate comparison with the costs and benefits of competing alternatives (Brodin & Hodge, 2009) Essential conditions required for quantitative estimation in HIA are (Bhatia & Seto, 2011): 1) availability of enough evidence to be confident in the causal relationships between the policy decision and the health impact outcome. 2) Availability of data on affected populations and on exposures and changes to exposures as well as effect measures, models, or exposure-response (E-R) relationships (O'Connell & Hurley, 2009) Some health determinants will be described in more detail:

Physical and Chemical disease agents

The HIA experience relates to discrete physical, chemical, biological, and radiological hazards, and follows the approach of human health risk assessment (HRA). This approach is the most common approach to quantitative estimation in the U.S (Bhatia & Seto, 2011). Several HIAs used the HRA approach to evaluate health risks from air pollution and noise caused by locating new residential development, expanded, or existing roadways (HIP, 2009)

Road Safety

Several HIAs estimated quantitative impacts on traffic injuries. For instance, SFDCP (2007) used a multivariate regression model of vehicle-pedestrian injury collisions to evaluate impacts of rezoning a neighborhood in San Francisco. These variables included traffic volume; proportion of arterial streets; neighborhood and residential-neighborhood commercial land-use; land area; employee and resident populations; proportion of households in poverty; and proportion of residents older than 65. The HIA applied this model to a rezoning plan that anticipated changes to several model parameters, including a 15% increase in traffic volume and a 16% percent change in population, and estimated a cumulative 17% increase in pedestrian injury collisions or over 30 additional collisions each year.

Another approach to predicting impacts on traffic collision is applying Crash Reduction Factors (CRFs) to planned roadway safety improvements proposed in the redevelopment of a neighborhood corridor (Rutt, et al., 2009). The approach relied on a published database of CRFs along with sources, standard errors, and study quality rankings for a diverse set of interventions and conditions.

A third HIA estimated changes to the number of fatal and non-fatal collisions resulting from a hypothetical reduction in the Maximum Speed Limit in California (Bhabka & Negev, 2009). The

HIA determined the joint distribution of highway traffic volume and speed based on a California Department of Transportation traffic database then applied empirical, before and after studies of the effect of speed limit changes on highway speeds, total collision rates, and fatal injury rates.

EMPLOYMENT, INCOME, AND LABOR STANDARDS

As social policies that facilitate economic development, social safety, or labor standards have direct effect on individual economic status and indirect impacts on health, some epidemiological studies have quantified measures of association between health outcomes and health determinants. For example, Bhatia and Katz (2001) estimated the magnitude of health improvements resulting from a proposed living wage ordinance in San Francisco. They identified effect measures from controlled, prospective empirical studies on income and mortality, morbidity, and child development outcomes then applied effect measures to predicted change in income.

DIET, PHYSICAL ACTIVITY, AND OBESITY

Several U.S. HIAs have quantified the impacts of policies, programs, or projects on physical activity level. In some cases, (Cole, 2004) physical activity changes were considered based on estimates of program participation, distance walked, and activity level. Physical activity change then applied to physical activity-BMI effect measure from prospective intervention study. In another case (Rutt, et al., 2009), changes in population level physical activity were predicted by generalizing a quantitative environment-physical activity associated with a practical study to changes in neighborhood infrastructure in a different location.

2.1.2 Overview

This study attempts to fill the gap in the literature by considering the transportation system and its variables to determine their impact on different factors from health that further lead to mortality. The influence of transportation factors, mainly commute modes on non-communicable diseases is studied in this research. In addition, how these diseases further relate to premature death or early mortality is analyzed. The purpose was to depict a continuous relation of how different transportation factors can lead to morbidity and mortality. A holistic approach is adopted to apprehend the transportation system that leads to health disparities and mortality. A correlation test with significance at 85% is progressed for all the factors and their relations obtained from the literature. A multinomial linear regression model demonstrates the significance and magnitude of relations on the different effect the factors have with each other. The prime focus was determining the links and relations using the data obtained from the various sources at a county-level.

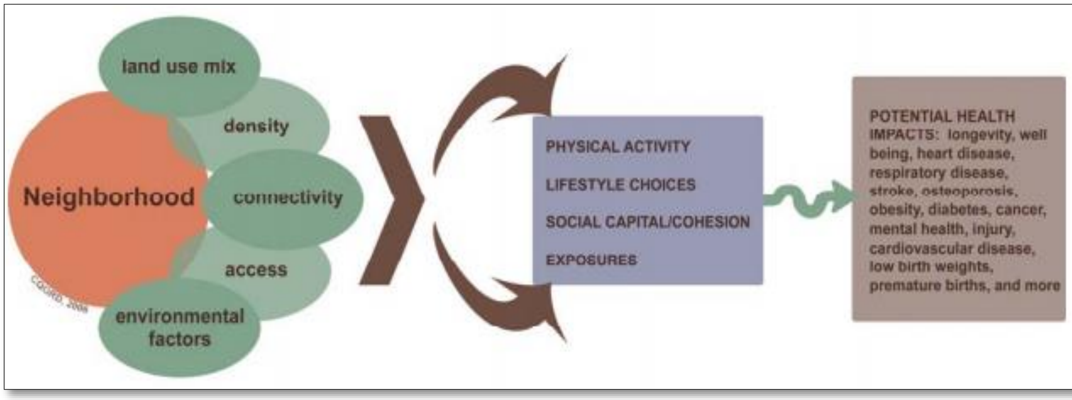

Figure 1: Neighborhood links with health through various intermediate factors

Courtesy: Pathways to a healthy Decatur, Georgia institute of technology

2.2 Factors Impacting Human Health

Previous studies suggest that human health is affected by the various factors of physical activity and safety. A list of all such factors derived from the literature is discussed below. The correlations of how factors from different backgrounds are related to each other are tabulated in Table 3.

Table 3: List of factors influencing human health

Independent Factors	Dependent Factors
Number of People Walking	Number of individuals with Adult Obesity, Hypertension, and Number of Pedestrian Injuries & Fatalities
Number of People Biking	Number of individuals with Adult Obesity, Hypertension, and Number of Bicyclist Injuries & Fatalities
Number of Public Transit Users	Number of individuals with Adult Obesity, Hypertension, and Number of Pedestrian Injuries & Fatalities
Number of Automobile Users	Number of individuals with Adult Obesity, Hypertension, and Number of Motorized Injuries & Fatalities.
Number of Unemployed Individuals	Commute Modes, Number of individuals with Adult Obesity, Hypertension, Diabetes, Heart Disease

Number of Individuals below Poverty Line	Commute Modes, Number of individuals with Adult Obesity, Hypertension, Diabetes, Heart Disease
Number of Individuals with Adult Obesity	Number of individuals with Diabetes, Heart Disease, and Hypertension
Number of Individuals with Hypertension	Commute Modes, Number of individuals with Adult Obesity, Hypertension, Diabetes, Heart Disease Diabetes, Heart Disease and Premature Death
Number of Individuals with Diabetes	Number of individuals with Heart Disease and Number of Premature Deaths
Number of Individuals with Heart Diseases	Number of Premature Deaths

2.2.1 Commute Modes

Number of People Walking and Biking

The number of people walking or biking in a community is highly related to the community design and environmental characteristics, which can promote active transportation. Evidence suggests that walking and bicycling not only counteract health risks from other modes but are also economically beneficial and environmentally sustainable. Walking and bicycling relate to the public transportation system by providing an alternative access to the stops instead of driving. If accessibility to transport the bike while traveling is provided, it can substantially benefit and promote a mode shift to bicycling, which in turn reaps additional advantages. An increase in active transportation promotes health benefits. Various studies have shown the correlation between walking and bicycling with health conditions. Focusing on active modes of transportation will increase health benefits, without any extra costs. Various components support the effectiveness of transportation factors on human health. (Saelens et al. 2003; Wagner et al. 2001) suggested that brisk walking fortifies an individual's health apart from other regular physical activities. Moderate intensive activity like walking for 30 minutes a day and five days in a week is considered as a fit regime in a study (Ströhle, A. 2009).

The built environment affect the levels and frequency of physical activity. Routine physical activity is beneficial for people of all ages, having positive effects on health and quality of life. Adverse health effects which are linked to moderate physical activity include heart disease, cancers, high blood pressure, obesity, diabetes, and higher mortality rates. The facilities and design of the physical environment can either facilitate or reduce the opportunities for physical activity. The description mentioned above suggests that diseases such as cardiovascular diseases, obesity, diabetes hypertension, some types of cancers and increase in mortality and reduction in life expectancy can be caused due to the influence of transportation on health.

Safety of active commuters is a major concern, amidst connectivity and accessibility. These concerns vary with the communities and the individuals. An individual who opts for active transportation is more anxious about safety and connectivity, compared to people who tend to adopt active transportation for other purposes. While walking is a very common practice, bicycling may need some skill. Safety concerns of bicyclists result in the usage of sidewalks for riding bikes, which is a deterrent for pedestrians. Traffic crashes constitute a significant part of health risks associated with transportation. The perceptions of poor safety from road traffic crashes discourage an individual from adopting active modes of transportation. Risk linked to motorized usage is the involvement of other road users in the traffic accidents. The risk of injuries and fatalities is more for people who tend to use active modes of transportation rather than motorists. Therefore, having separate bike lanes for bicyclists and enforcement to use those bicycle lanes for riding may promote healthy and active transportation infrastructure. Availability of bicycle parking facilities at significant locations may result in encouraging individuals to bike more to some locations. There are certain health benefits of active transportation which are discussed further. Also, better planning of highways and safety infrastructure can promote more people to use active modes like walking and bicycling for transportation (Kavanagh et al. 2005).

Decrease in physical activity from transportation modes can result in health complications, which may lead to adverse health conditions. The increase in walking and bicycling can increase the injuries and fatalities for pedestrians and bicyclists. Therefore, changes in the transportation system can decrease the risk injuries, and deaths from crashes and they are further discussed.

Number of Public Transit Users

Public Transportation requires some walking or bicycling to and from the stations and stops and also for interchanges while commuting. A study by Agrawal and Schimek (2007) suggested that 16% of all walking trips in the US are associated with public transit access. A study by Lindstrom (2008) mentioned that public transportation is negatively linked with obesity and being overweight in comparison to commuters using automobiles. The study concluded the fact that commute patterns of non-automobile users can be significantly accounted towards active transportation and physical activity. Lifestyle changes can account for constraints in the commute modes, if these changes are not involved, then increase the levels of physical activity can be substantial by use of public transit instead of automobile usage. The start and finish of a public transport trip typically involve some walking to the destination. This active travel element of a public transport trip might offer a critical chance for physical activity and may also be incomprehensible in some evaluation of physical activity.

The various public transport modes provide a vital, safe and overlapping transport network at intervals in each urban and rural areas, accounting for a large variety of travelers, age, and socioeconomic cluster desires. Public transit vitalizes environmental and health conscious transport behavior, which tends to decrease motorized transport and health risks associated with it. There is a better level of transfer between public transport and additional active styles of transport, wherever on the average, walking to and from public transport will contribute towards 66% of the recommended daily level of moderate physical activity necessary to push physiological condition. The key health problems related to public transit are similar to those of personal vehicle use, and may embody the generation of fundamental level emissions to air, noise, risk of community severance and risk of accident and injury.

The choice of public transport mode corresponds to transportation opportunities, the commuters' requirements, the travel time and distance to the destination, connectivity, and convenience. The primary hurdle to adapt public transportation is linked with health advantages and can vary among particular age and socioeconomic groups, and may embrace actual and perceived issues of comfort, speed, responsibility, convenience and economic feasibility to an extent. The inaccessibility of public transportation forms to various socioeconomically impede groups that can also pose as a major factor accounting the use of public transportation effectively.

Evidence suggests that removing the hurdles to mode choice behavior between the active and public transport modes is essential, where individuals from a variation of age groups indicated considerations of security and safety. Enhancements in the standards and safety of intermodal areas, data systems and addressing the perceptions of safety in public transportation are essential factors that are to be considered to provide efficient transport systems. Public Transit usage is deemed to be relatively safe transport mode when compared with automobile travel. (NHTSA 2012). Various factors increase the risk of a crash, and commuters can improve their safety in a variety of ways. Active modes of transportation are linked with the usage of public transport. Therefore, non-motorized crashes maybe related to public transit usage.

Number of Automobile Users

There have been various studies which tend to suggest the relation between vehicle usage and sedentary behavior or lower levels of active commuting. A study by Saelens et al. (2003) explained the link between vehicle usage and physical inactivity. A study by Wennberg et al. (2006) suggested regular use of the automobile is connected with the risk of heart diseases when compared to active modes of commuting. Thomson et al. (2008) suggested that commute mode shift from automobile usage to active modes increases physical activity of the individuals who typically have no other forms of physical activity.

Frank et al. (2004) found that time spent in an automobile is linked with obesity. He suggested the fact that each additional hour spent in a vehicle per day would account for 6% increase in the likelihood of attaining obesity. The use of automobiles extensively for long commuting and easy access account to more inactive lifestyles. The use of automobiles henceforth accounts to increase the levels of adult obesity and hypertension. Evidence shows that motorized transportation can reduce the physical activity and it decreases active forms of transportation. Further causing health depriving conditions such as cardiovascular diseases, obesity, diabetes, hypertension, some types of cancers and increase in mortality or reduction in life expectancy.

The increase in motorized transport also enhances the risks of motor-vehicle crashes, resulting in injuries or fatalities. The risks associated with these accidents affect a variety of individuals. Motorized crashes have economical and societal impact varying on the type of accident and its effects. The mode shift from motorized transport to active ways of transportation can result in decreasing motorized accidents. Many interventions can be implemented to prevent motor vehicle crashes, which involve policies, assistance, and also engineer controls to avoid accidents. Mode shift considerations and a decrease in automobile travel can have a significant impact on reducing the accidents.

2.2.2 Socioeconomic Factors

Social and economic factors are the major aspects that constitute commute mode choices. Commuting is variably influenced by different socioeconomic characteristics, employment, and poverty level are factors which significantly relate to commuting. Karasek and Theorell suggested that physical activity is higher in the informal and active group of communities when compared to passive and unemployed categories. The hypothesis also refers to the fact that there may be a significant link between unemployment and physical activity. The level of active commuting and physical activity is influenced by socioeconomic characteristics like income, time to destination and availability of diverse transportation. Population with low socioeconomic status are unable to adopt active measures, such as staying in a short distance from the workplace, access to active modes of transport, which limit walking, bicycling and use of public transit. Neighborhoods with low socioeconomic status suffer from the inferior transportation system, high costs, and less connectivity. Lack of non-motorized transportation infrastructure in these communities also brings safety concerns. These factors pertain to relinquishing the use of active modes for commuting.

Past research on public health showed the incorporation of daily physical activity increases public health than other special forms of physical activity. There are assumptions and links that most of the health discrepancies, obesity, and overweight problems are linked to low socioeconomic status. Social and economic factors are shown to have a direct relation with health conditions. Paeratakul et al. stated that the assessment of obesity also regards higher prevalence of diabetes, hypertension and heart disease among unemployed individuals, people with lower education, and low socioeconomic status.

2.2.3 Health Conditions

<u>Number of Individuals with Adult Obesity</u>

Physical activity is considered as a preliminary risk pertaining to obesity. The increase in physical activity can help to lower obesity rates and decrease the danger attaining severe health disparities, such as high blood pressure, diabetes, heart disease, stroke, and cancers. Routine physical activity helps maintain and lose extra weight. Sedentary lifestyles contradict the above statement and result in health disparities.

Number of Individuals with Hypertension

Physical activity is used as a preventative measure for high blood pressure. Evidence has shown a consistent relation between hypertension and physical activity. It also decreases hypertension and which results in reducing the risk of an individual attaining chronic diseases, like cardiovascular diseases and diabetes. Lowering the blood pressure can cause improved lipid profiles which lessen the possibility of diabetes. Substantial cardiovascular benefits can be attained from long-term avoidance of hypertension.

Number of Individuals with Diabetes

Diabetes is linked with physical activity. Routine physical activity helps maintain a healthy weight which can result in the prevention of diabetes. Physical activity helps regulate the blood glucose level which can help with preventing health complications and reduce adverse impacts of diabetes on vascular health. Diabetics are at greater risks of attaining cardiovascular problems and kidney failure, which can lead to mortality.

Number of Individuals with Heart Diseases

Physical activity can help prevent the other chronic health problems linked to cardiovascular diseases. Individuals who possess cardiovascular problems can also minimize their risk to premature death by adapting active techniques. A sedentary lifestyle is considered to be one of the major contributors to heart diseases. A study suggests that walking at least two hours a week reduces the risks of premature death from heart diseases by 50%.

Number of Premature Deaths

Past evidence shows that sedentary behavior is a major risk factor in health and can result in heart diseases and other chronic conditions, resulting in early mortality. The mode change from inactive behavior to moderately active practice is suggested to have a huge difference at the beginning of mortality patterns. Dora and Phillips, World Health Organization (2000), indicated that brisk walking for 20 minutes a day could reduce the risk of premature mortality from 16% to 30%. Other researches suggest that at least 30 minutes of moderate physical activity can decrease the risk of premature death by 19% irrespective of the cause of mortality.

Identifying transportation impacts on health risk needs to employ indicators that address and stratify various components. These indicators include population and demographic information to identify vulnerable populations, baseline health characteristics, causes of death, traffic data, transportation mode share, air quality statistics, and combined indicators. Table 4 represents these indicators and related components.

Table 4: Transportation impact on health indicators and their components

indicator	Component
Study area population profile	Population Educational Attainment Employment status Median Household Income Percent Below the Poverty Level Vehicles Available (rate of households without automobiles) Housing Tenure (renter-occupied) Sex Age Race
Study area population health characteristics	• Disease Asthma Cardiovascular Disease Diabetes Exercise Hypertension Overweight and Obesity (BMI) Physical Activity • Crude death rate (per 100,000 people) attributed to: Heart attack Stroke Diabetes Homicide Suicide
Safety and injury data	• Traffic injury and mortality for: Motor Vehicle Crashes, Bicycle-Motor Vehicle Crashes, Pedestrian-Motor Vehicle Crashes

	• Deaths: Mortality rates Homicide Suicide • Crimes: Violent crime incidence within 0.5 miles of the project area Crime incidence at public transit stops
Transportation data	• Means of transportation to work Car, truck, van Public Transportation Motorcycle Bicycle Walked Other means Worked at home • Traffic Volume (VMT/day) • Mileage of active transportation infrastructure: Bicycle lanes Sidewalks
Study area land use characteristics	• Report total acreage and the percent of total acreage for the existing land uses in the study area: Residential Commercial Industrial Institutional Utility • Affordable Housing
Air quality data	Daily emissions for the project region for Ozone (O3) Sulfur dioxide (SO2) Nitrogen dioxide (NO2) Particulate matter (PM(2.5/10)) Carbon monoxide (CO)
Combined indicators	Park access (acres per 1,000 people)

Chapter 3 Data Collection

This section of the report deals with the collection of all the data that was required for the analysis. The prime focus of the data collection was on attaining transportation infrastructure data and finding its link with factors from human health. Due to the lack of availability of the infrastructure data in Michigan on the county level, other factors from transportation system and socio-economic backgrounds are incorporated into the study to determine the link between those factors and human health. The literature review and studies suggest some of the factors from physical activity, safety, socio-economic and health backgrounds that are a part of transportation and health system. A list of individual factors derived from different studies is demonstrated, and detailed discussions of these factors are progressed.

3.1 Geographical location of the study area

The data for various elements was collected for various counties in Michigan to improve a county-level analysis and correlation of the factors. The map below shows the geography of the 83 Michigan counties that the data was collected from, and the analysis was progressed. Different counties have varying components, such as area, demographic features, socioeconomic behavior, and transportation facilities. With the varying components of the counties in context, the data was normalized to 100,000 population for all the factors to make the analysis balanced. The data for various components were collected from different sources which are further discussed.

The analysis in Transportation and Health Tool from USDOT was applied in the study and a similar analysis for county-level is done for Michigan cases. The data was collected on 11 different components of the THT for the 83 Michigan counties. The indicators from the THT shows how the various components from transportation are linked with health and which of them provide better or worse health throughout the counties. The scoring procedures and the description of the factors are further discussed.

The map below represents the geographical area of Michigan with the 83 counties where the data was collected.

Figure 2: Geography of counties in Michigan

The data of the factors from transportation, socioeconomic, and health backgrounds was collected in 2013. Descriptive statistic relates to the essential characteristics of evidence set in any study. The descriptive statistics depict the data, and all the data is summarized for further analysis. This entity deals with the quantitative description of data and processes it to a manageable form. Descriptive statistics also help in simplifying different data to a feasible summary. Irrespective of the data limitations, descriptive statistics provide an influential overview of the data set which enables correlations and comparisons in the dataset.

3.2 Grouping of factors

- **Transportation factors**: The factors that are related to the transportation system are discussed in detailed under this category.
- **Socioeconomic factors**: Factors that account to the social and economic characteristics of a community are discussed in this section
- **Sociodemographic and environmental factors**: Factors that correspond to the environmental and demographic features are discussed in this section.
- **Health factors**: Some of the health factors assumed to be affected by the transportation and socioeconomic factors in collaboration.

The table below illustrates the description of all the indicators used in the study and analysis.

Table 5: Description of the indicators

Indicator	Description of the indicators
Pedestrians *	Number of People Commuting by Walking
Bicyclist *	Number of People Commuting by Biking
Public Transit Users *	Number of People Commuting by Public Transit
Automobile Users *	Number of People Commuting by Automobiles
Unemployment *	Number of Unemployed Individuals
Poverty Level *	Number of Individuals below Poverty Line
Adult Obesity *	Number of Individuals with Adult Obesity
Hypertension *	Number of Individuals with Hypertension
Diabetes *	Number of Individuals with Diabetes
Heart Disease *	Number of Individuals with Heart Diseases
Road Traffic Injuries and Fatalities by Mode *	Number of Pedestrians Injuries and Fatalities by Commute Mode
Premature Death *	Number of Premature Deaths

Alcohol Related Driving Fatalities *	Number of Alcohol Related Driving Fatalities
Housing and Transportation Costs	Housing and Transportation Costs of a Household with Median Income
Physical Activity from Transportation *	Number of People Commuting 10 Minutes and Longer by Walking or Bicycling
Land Use Mix *	Number of Individuals Accessing Land Use Mix in a County
Proximity to Major Roadways *	Number of Individuals Living in Close Proximity of Major Roadways.
Public Transit Passengers	Number of Public Transit Passengers in a County
Seat Belt Usage	Percentage of Front Seat Riders Using Seat Belt
Vehicle Miles Traveled	Vehicle Miles Traveled By the Population of the County.

Note: * indicates that the data is normalized to 100,000 population measure.

3.3 Data source and descriptive statistics of transportation factors

Different aspects of transportation can contribute to human health. The list below represents the transportation factors which have a significant relation with human health behavior. A detailed description of these aspects and how they relate to health are discussed further. These factors are derived from transportation studies and literature that suggests how different factors in transportation affect human health.

The descriptive statistics of the data are summarized in terms of observations, mean, standard deviation, min, and max. The number of observations refers to the sample size of the data. The mean is the average of the data set. The standard deviation corresponds to the extent of deviation in the data. The min is the least number in the data set for each variable, and the max is the most.

Commute Modes correspond to the use of walking, bicycling, public transit and automobile as a part of an individual's travel. Data for the all the commute patterns was collected from the American Community Survey Data of U.S. Census Bureau. The only commute mode data available was for workers who commuted to work using these means. Active transportation is measured when the pedestrian commutes are 10 minutes and longer. The data was modified for 100,000 worker population to normalize the range for all the counties. The data was collected in 2013.

Table 6: Descriptive statistics for the commute mode walking, bicycling, and public transit usage

Variable	Observations	Mean	Standard Deviation	Min	Max
Number of People Commuting by Walking	83	2934.94	1658.859	800	10200
Number of People Commuting by Biking	83	510.8434	637.834	0	4300
Number of People Commuting by Public Transit	83	655.4217	766.0881	0	5000
Physical Activity from Walking for Transportation	83	387.253	404.3424	45	2211

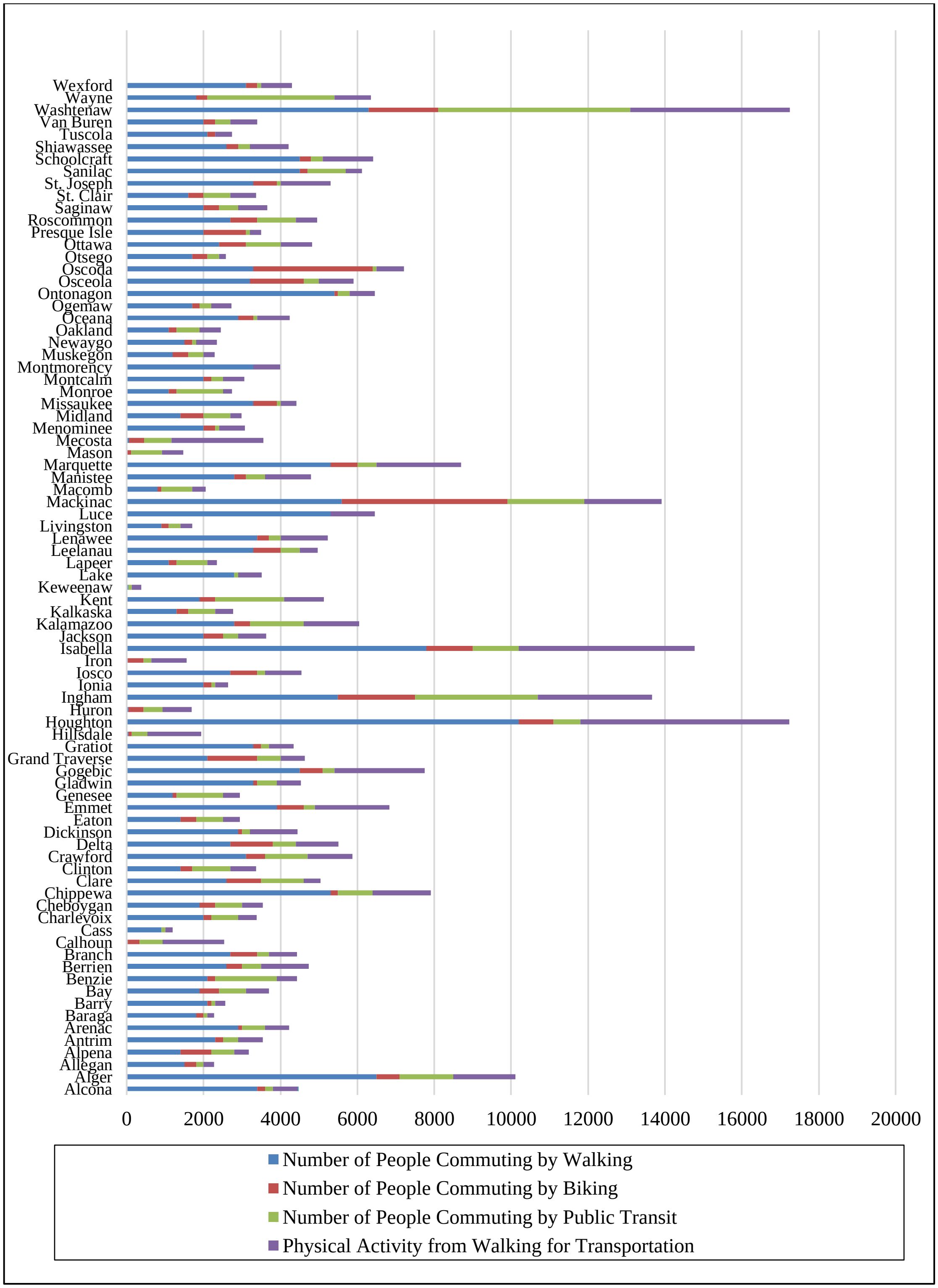

Figure 3: Graphical representation of the data for commute mode walking, bicycling, and public transit users by counties in Michigan

Data for the automobile usage for commuting was collected from the American Community Survey Data of U.S. Census Bureau. The data was modified for 100,000 worker population to normalize the range for all the counties. The data was collected in 2013.

Vehicle miles traveled per capita obtains a measurement by calculating the total annual miles of vehicle travel in a county, divided by the population of the county. The data for VMT was collected from Michigan Department of Transport Annual Vehicle Miles Travelled statistics, in 2013. The data was selected on a county level. Further, the population data was collected from the U.S Census Bureau.

Automobile usage tends to have an adverse effect on the environment due to the pollutants released. Therefore, use of vehicle negates the three aspects of this study which are physical activity, safety, and air quality.

Table 7: Descriptive statistics for the commute mode automobile users and vehicle miles traveled per capita

Variable	Observations	Mean	Standard Deviation	Min	Max
Number of People Commuting by Automobiles	83	90698.8	3028.543	80900	95100
Vehicle Miles Traveled Per Capita	83	10883.99	2756.978	6532	21939

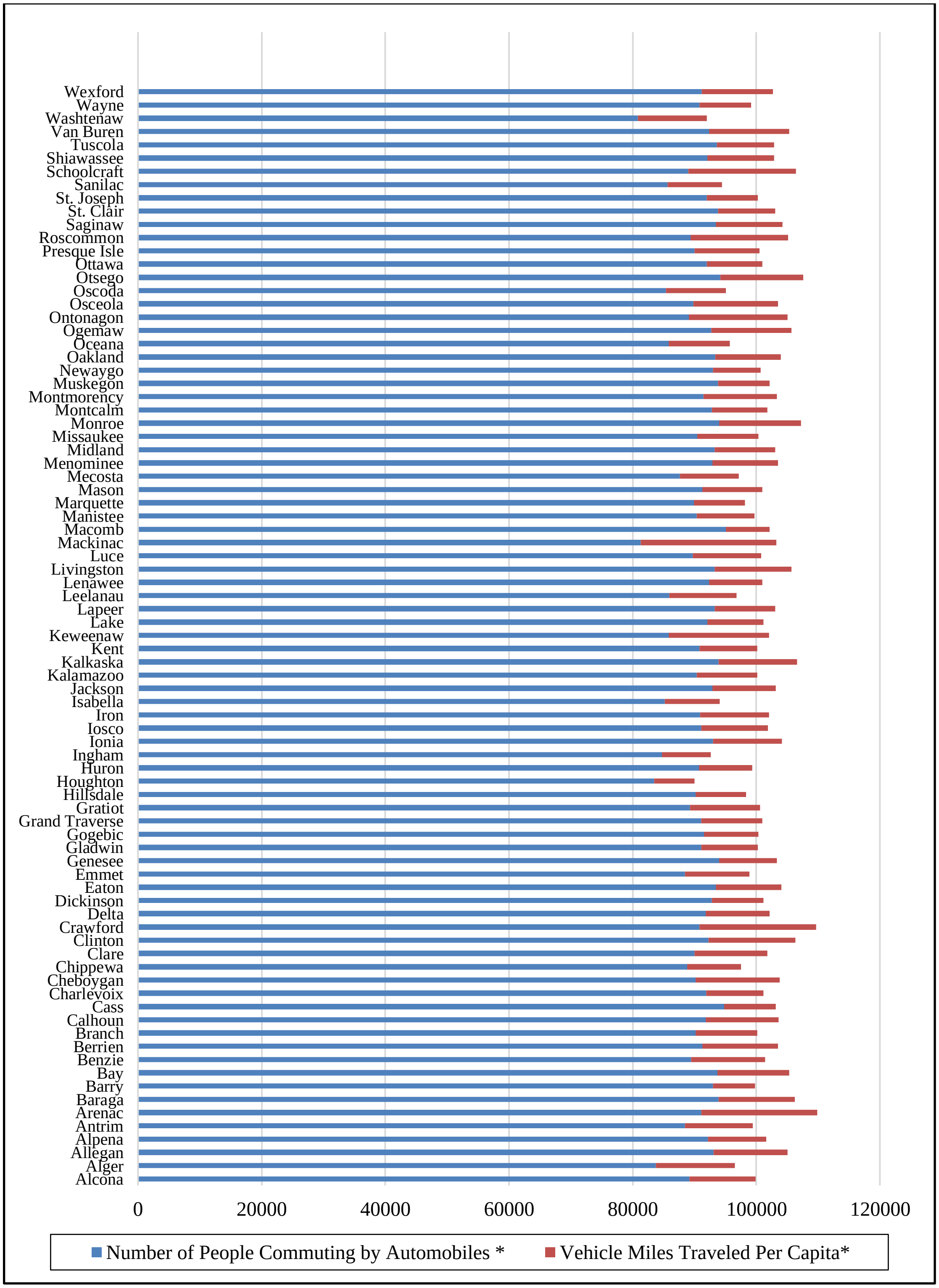

Figure 4: Graphical representation of the data for commute mode automobile usage and vehicle miles traveled per capita by counties in Michigan

3.4 Data source and descriptive statistics of socioeconomic factors

Unemployment and poverty level are the factors that are directly related. An increase in unemployment would increase the poverty level in any given area, and vice-versa. There are also other factors apart from unemployment that tend to have an influence on the poverty level of a community. Both unemployment and poverty level tend to have a relation with mode choice behavior and human health.

Data for the unemployment rate was collected from the United States Department of Labor, Bureau of Labor Statistics for the 83 Michigan counties. The data was obtained for individuals 16 years and older who are unemployed and then modified from percentage of the total population to 100,000 population to normalize the range for the counties. The data was collected in 2013.

The data for poverty level was collected from United States Census Bureau Small Area Income and Poverty Estimates for the 83 Michigan counties. The data for poverty level at the U.S Census Bureau analyzed the percentage of people in a particular geographical area who are below the desired poverty line for that area. The data was in percentage and was changed and modified to 100,000 population to normalize it for the counties. The data for poverty was collected in 2013.

Table 8: Descriptive statistics for number of unemployed individuals and number of individuals below the poverty line

Variable	Observations	Mean	Standard Deviation	Min	Max
Number of Unemployed Individuals	83	9968.675	2331.802	5900	16100
Number of Individuals below Poverty Line	83	17087.95	4169.851	6400	31000

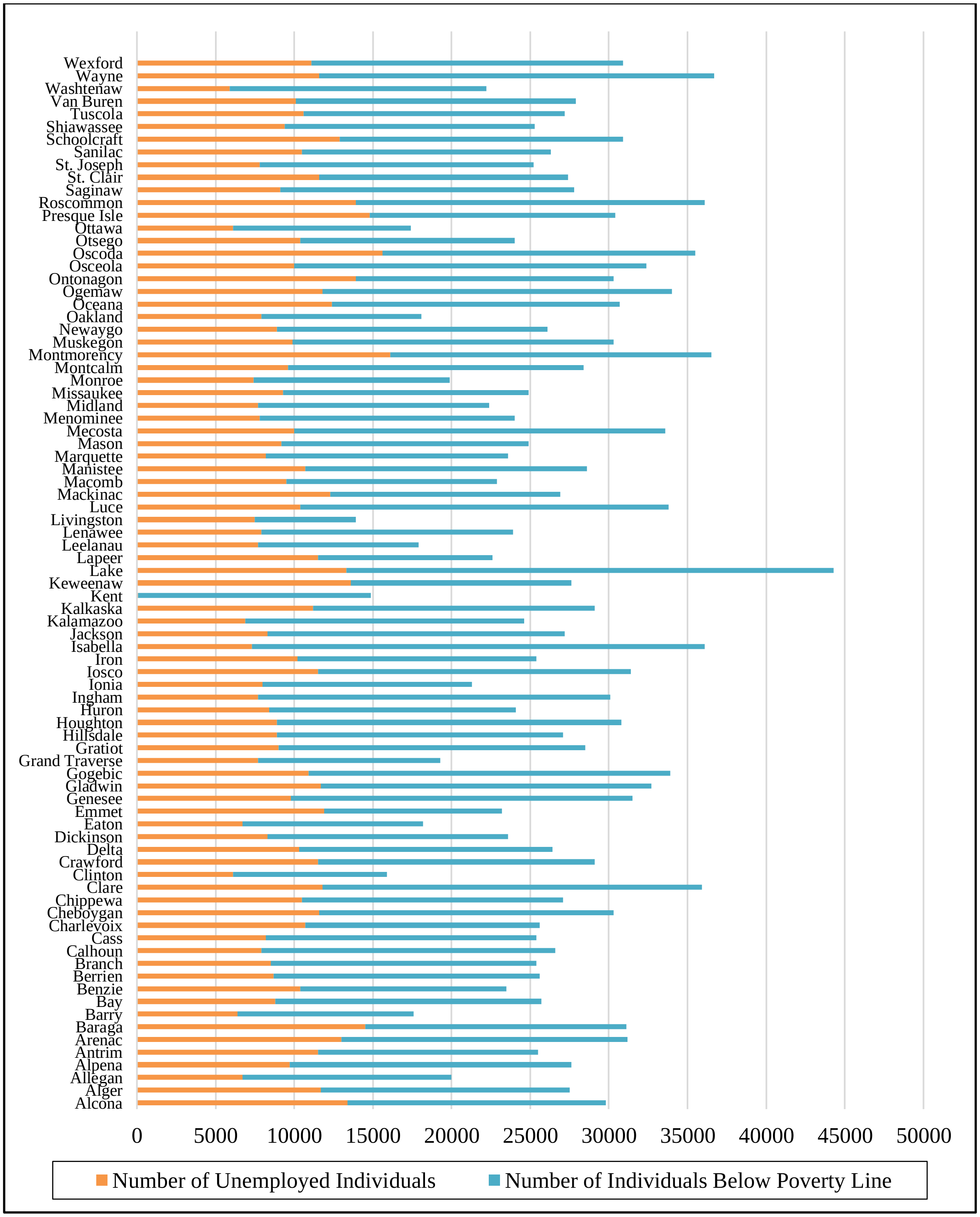

Figure 5: Graphical representation of the data for number of unemployed individuals and number of individuals below poverty line by counties in Michigan

3.5 Data source and descriptive statistics of sociodemographic and environmental factors

The two most important factors influencing expenses of a community are housing and transportation costs. Data was collected for those factors by The Department of Housing and Urban Development Location Affordability Index (LAI). The data was collected in 2014.

Land use mix is the general term defining how land in a community is used to provide a mix of entities. This indicator tends to convey the relation of built environment with commute modes, which in turn account to human health. The data was collected from the Environmental Protection Agencies Smart Location Database. The data is normalized to 100,000 population measure. The data was collected in 2012.

Proximity to major roadways is an indicator that exhibits the amount of people who live within a 200-meter proximity which has AADT more than 12500. The data was processed in ARCGIS using shape files from Michigan State Police and also Census Data. The data is normalized to 100,000 population measure.

Table 9: Descriptive statistics of housing and transportation costs, population accessing land use mix and proximity of population to major roadways

Variable	Observations	Mean	Standard Deviation	Min	Max
Housing and Transportation Costs	83	43383.48	6299.601	30390	59063
Population Accessing Land Use Mix	83	49950.73	8149.958	17583	74687
Proximity of Population to Major Roadways	83	27426.19	19750.04	0	63865

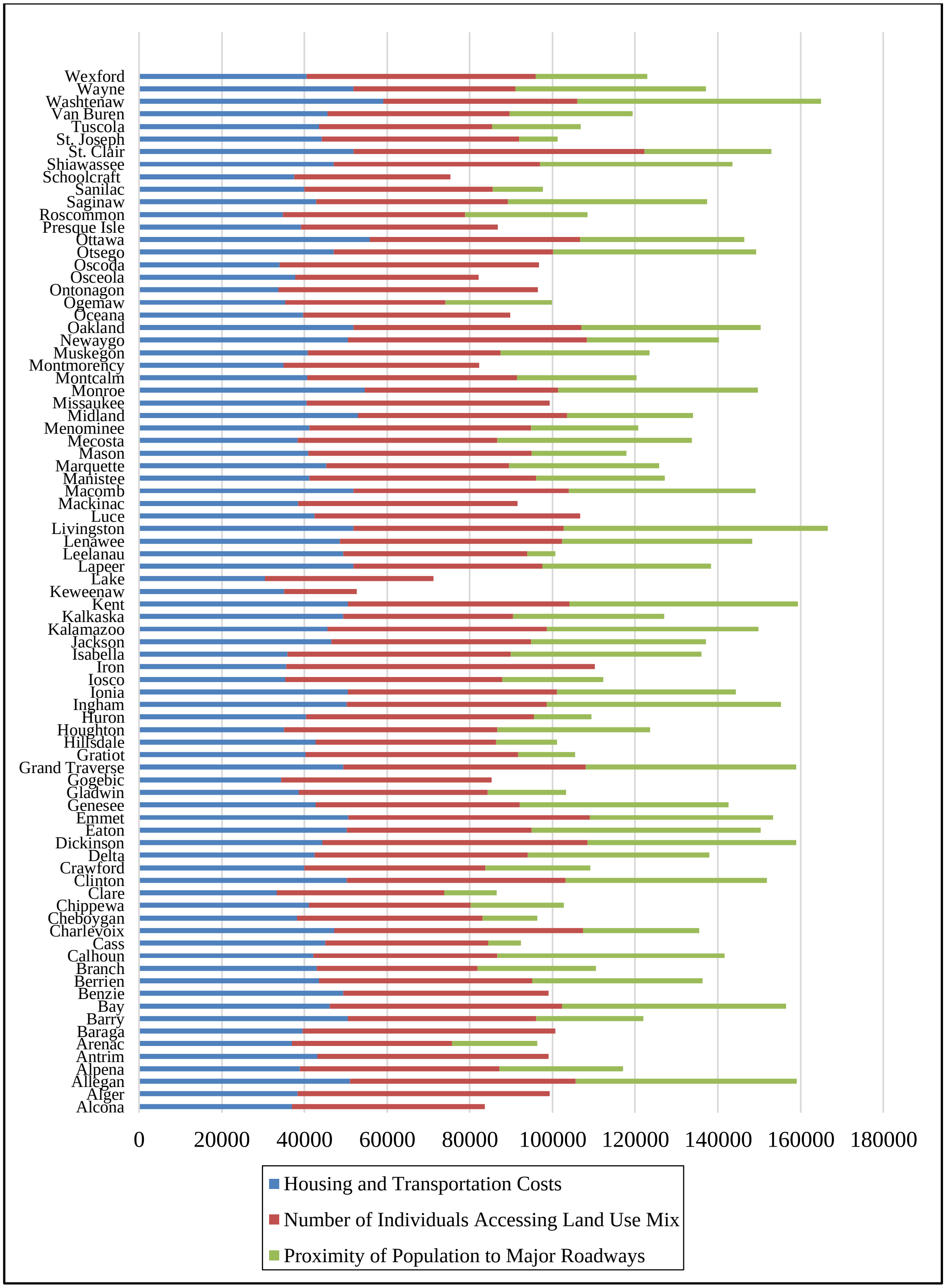

Figure 6: Graphical representation of the data for housing and transportation costs, population accessing land use mix and proximity of population to major roadways by counties in Michigan

3.6 Data source and descriptive statistics of factors contributing to human health

Listed below are the health factors that have relations with transportation and socioeconomic factors.

<u>Adult Obesity, Hypertension, Diabetes, and Heart disease</u>

Factors constituting to these health risks are decreased physical activity, change in forms of transportation, land use, and urbanization. Balanced environment and built form have a pivotal role in the prevention of these health conditions. Transportation forms are significant contributors in determining the health and characteristics of a community.

Adult obesity is a measurement of the population that reports having a BMI of greater than 30 kg/m2 for individuals who are 20 years and older. The data for adult obesity was obtained from the National Diabetes Surveillance System, which uses data from CDC's Behavioral Risk Factor Surveillance System (BRFSS) and data from the U.S. Census Bureau's Population Estimates Program. The data was modified from percentage to 100,000 population. The data was collected in 2013.

The data for Hypertension was collected from Michigan Department of Human and Health Services and is further processed from percentage to 100,000 population. Hypertension or high blood pressure has to do with the increased rate of blood flow in the human body. The data shows the quantity of adults that were diagnosed by a health practitioner with hypertension. The data for hypertension was collected in 2013.

Diabetes is a disease caused by an increase in blood glucose levels. The data for diabetes was obtained from the National Diabetes Surveillance System, which uses data from CDC's Behavioral Risk Factor Surveillance System (BRFSS) and is further processed from percentage to 100,000 population. The data shows the quantity of adults that were diagnosed by a health practitioner with diabetes. The data for Diabetes was also collected in 2013.

Heart disease is the general term used to define several types of heart conditions. The data for heart diseases was collected from Michigan Department of Human and Health Services and was further processed from percentage to 100,000 population. The data shows the quantity of adults that were diagnosed by a health practitioner with a heart disease. The data was collected in 2013.

Table 10: Descriptive statistics for number of individuals with adult obesity, hypertension, diabetes and heart disease

Variable	Observations	Mean	Standard Deviation	Min	Max
Number of Individuals with Adult Obesity	83	32081.93	2558.446	24400	38900
Number of Individuals with Hypertension	83	36130.12	5440.65	26200	48700
Number of Individuals with Diabetes	83	11371.08	1544.347	7600	14600
Number of Individuals with Heart Diseases	83	13858.67	4223.49	6700	25390

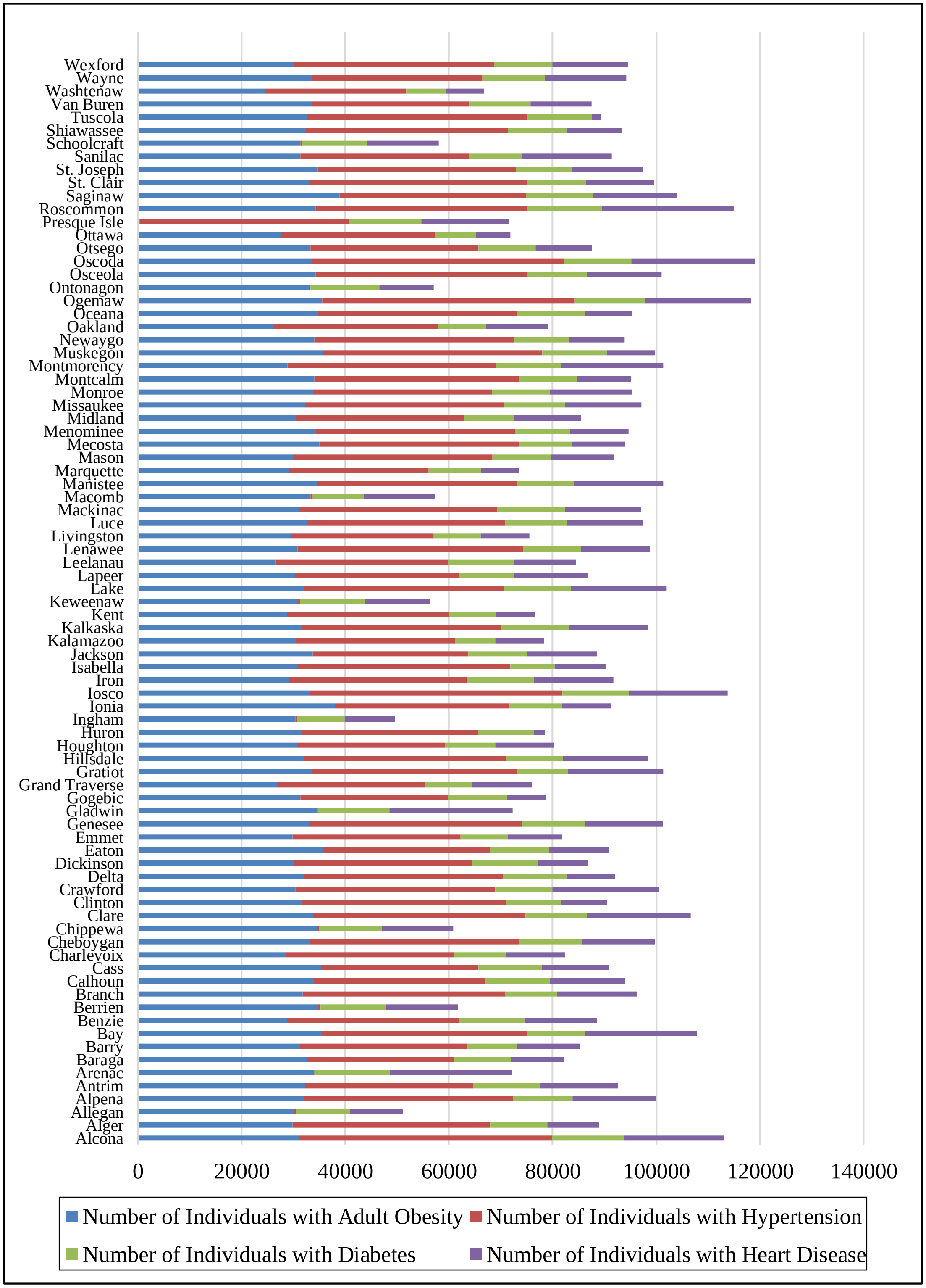

Figure 7: Graphical representation of the data for number of individuals with adult obesity, hypertension, diabetes and heart disease by counties in Michigan

3.7 Data source and descriptive statistics of road traffic injuries and fatalities

Road traffic injuries and deaths have a direct relation with transportation system and human health and are categorized as pedestrian injuries and fatalities, bicyclist injuries and fatalities, motorist injuries and fatalities and alcohol related driving fatalities.

The data was obtained from Michigan State Police Office of Highway and Safety Planning (OHSP), Crash Statistics. The data was collected for the years 2010-2014 for fatal (K) and incapacitating injuries (A) type of crashes. The data was obtained for the total number of crashes for the whole population, but adjustments were made to convert it to 100,000 population.

Alcohol-related driving fatalities are computed by tracking all road traffic fatalities with the involvement of an inebriated individual. The data is obtained from Michigan State Police Office of Highway and Safety Planning (OHSP), Crash Statistics. The data was collected in 2014 and was normalized for 100,000 population.

Table 11: Descriptive statistics for number of pedestrian, bicyclist and motorized injuries, and fatalities

Variable	Observations	Mean	Standard Deviation	Min	Max
Number of Pedestrians Injuries and Fatalities	83	7.072289	5.212048	0	19
Number of Bicyclist Injuries and Fatalities	83	8.180723	5.768173	0	25
Number of Motorist Injuries and Fatalities	83	47.40964	29.23331	3	183
Number of Alcohol Related Driving Fatalities	83	3.024096	3.38928	0	15

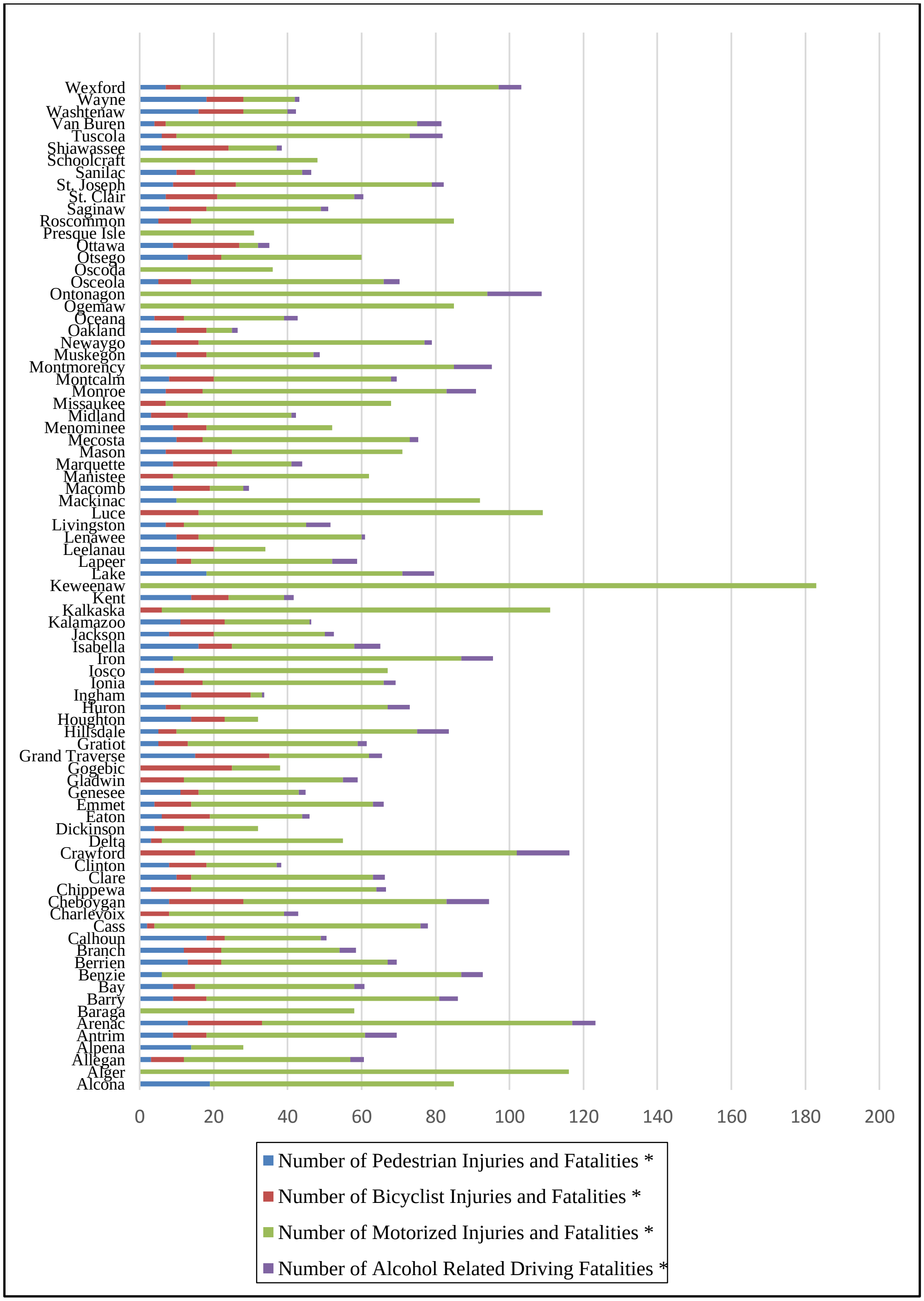

Figure 8: Graphical representation of the data for number of pedestrian, bicyclist, and motorist injuries, and fatalities by counties in Michigan

3.8 Data source and descriptive statistics for premature death

Premature deaths are measured by the years of life lost before the age of 75. This action marks 75 years as the average lifespan of an individual. The data for premature death was obtained from National Center for Health Statistics and drawn from the National Vital Statistics System (NVSS). The data was readily available for 100,000 population. This indicator computes the number of people that died before the age of 75 in the different counties. The data for premature death was collected in 2013.

The intent of measuring the premature death is to bring attention to the deaths that could have been avoided. There are various sources to premature death and transportation accounts for a significant share.

Table 12: Descriptive statistics for number of premature deaths

Variable	Observations	Mean	Standard Deviation	Min	Max
Number of Premature Deaths	83	1108.735	244.203	601	1799

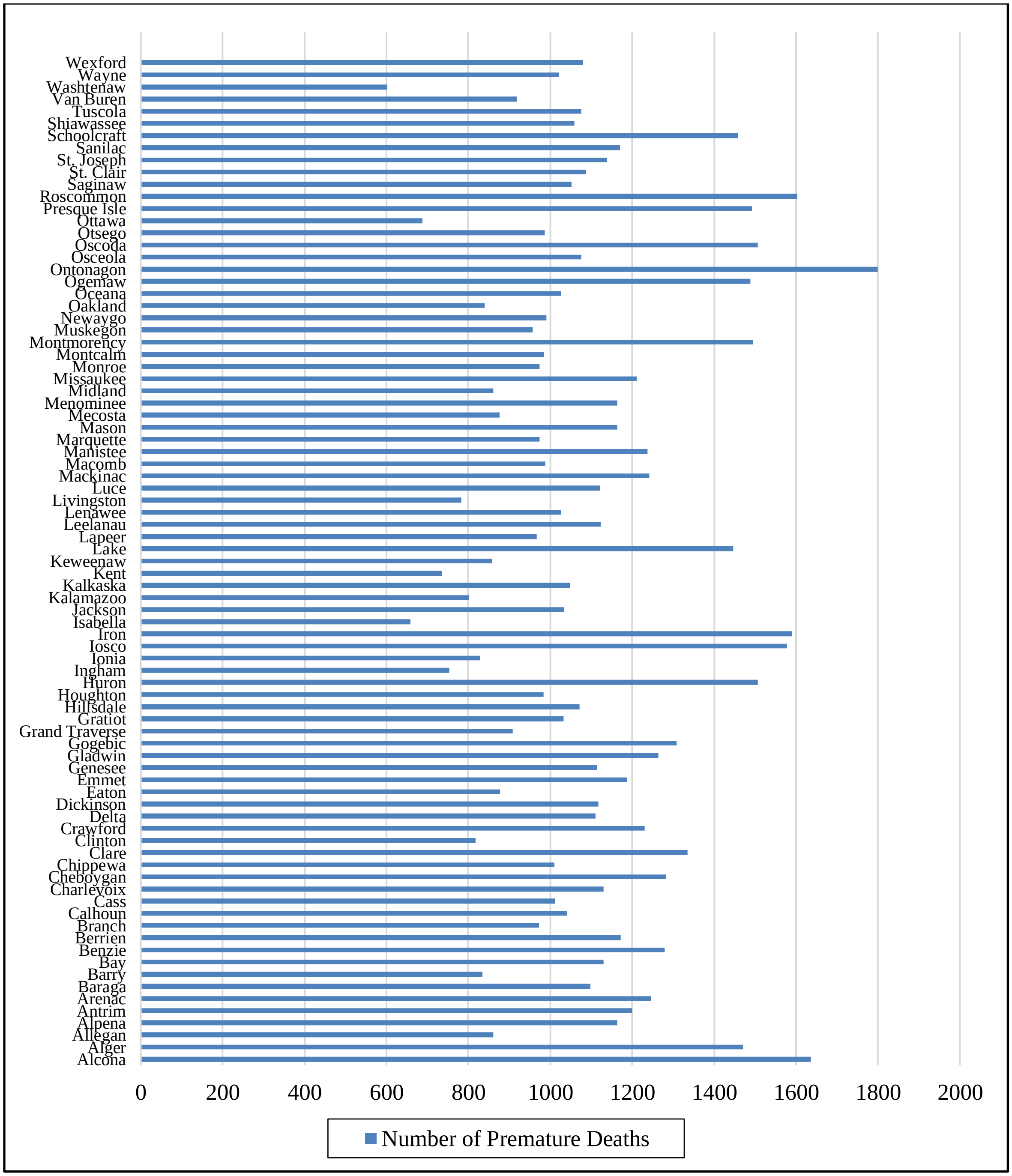

Figure 9: Graphical representation of the data for number of premature deaths by counties in Michigan

Chapter 4 Application of Transportation and Health Tool in Michigan

The Transportation and Health Tool (THT) is developed by the United States Department of Transportation (USDOT) and Centers for Disease Control and Prevention (CDC) to provide an easy determination of the health impacts of the transportation system. The tool developed by the USDOT and CDC encompasses the data for transportation and health indicators; it shows how transportation system affects the active transportation, safety, air quality, and connectivity. This resource also provides information that can give natural understanding for links between transportation and human health and recognition to policies that can improve health by transportation planning.

The tool collects the data for all the different indicators that are incorporated into the tool. Indicators in this research are the points that show the performance of an entity in the specified area. The measurement of how transportation affects the human health with issues such as active transportation , safety , air quality and connectivity are also depicted by these indicators in the tool. The THT used by the USDOT deals with different states, metropolitan areas, and urbanized areas. The THT used during research was focused on the Michigan case. A tool using the same methodology as of the THT by USDOT was prepared for Michigan State by county-level, and all the indicators were scored further.

4.1 Indicator selection procedure

The transportation and health tool has 14 indicators for the state, metropolitan and urbanized areas. The selection of the indicators for the tool was one of the most critical parts of the tool development. The selection of the THT indicators involved the USDOT, CDC, and American Public Health Association (APHA).

With suggestions guidance and research from all the three organizations involved, APHA conducted an intensified process to recognize, assess, and process the indicators. Indicators refer to the factors that are included in the THT. The purpose of these indicators would be to identify contributors from transportation which can impact health. The indicators were considered to be selected from the following factors. Figure 10 represents overview of strategies, indicators, and data sources in Transportation and Health Tool.

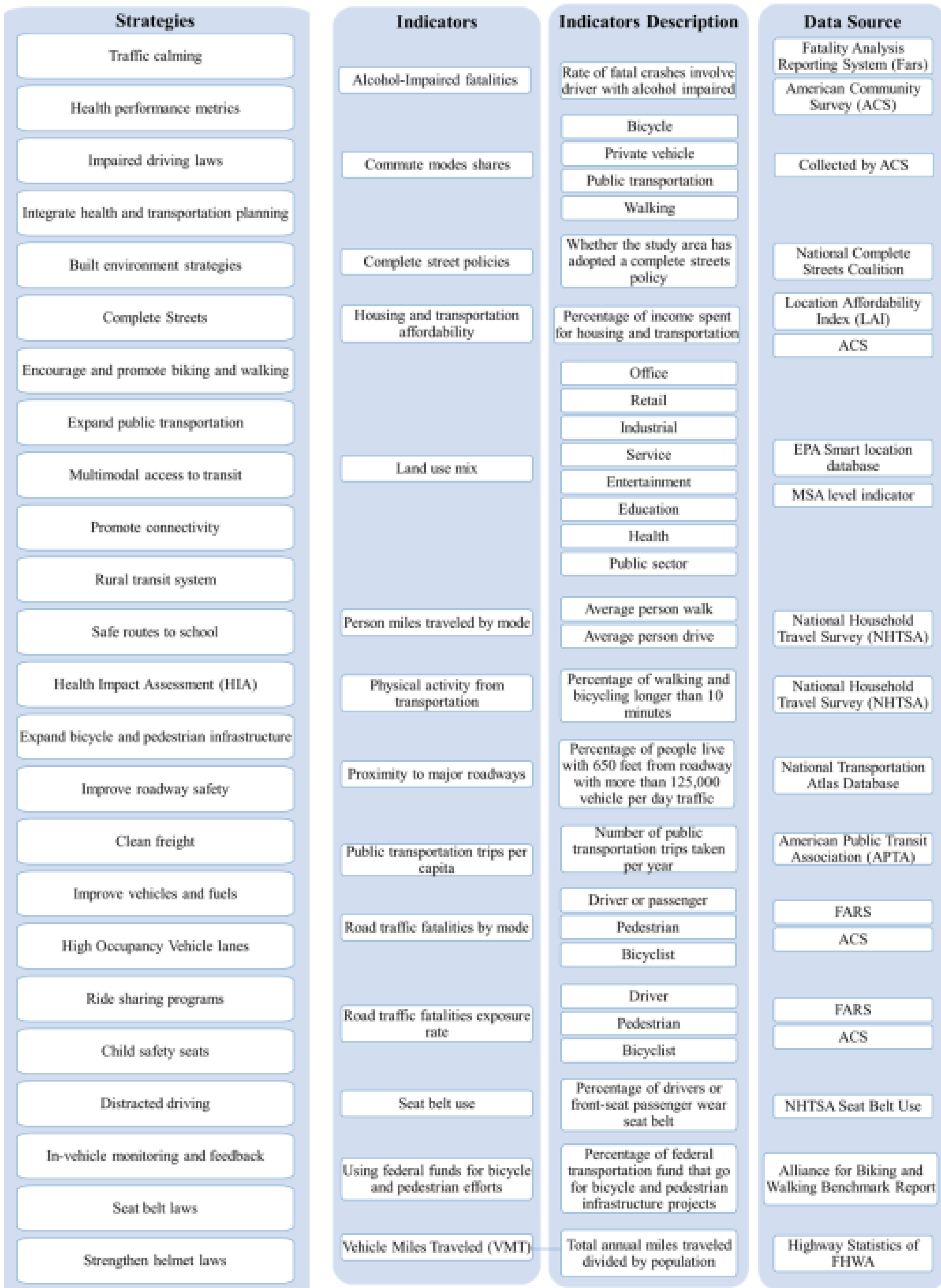

Figure 10: Strategies, indicators, and data sources in Transportation and Health Tool

Physical activity, air quality, traffic injuries or fatalities, commute modes, vehicle miles traveled, complete streets policies, safe routes to school, and transportation infrastructure investment. The indicators were intended to be derived out of the factors mentioned above as those factors are considered to be the ones impacting the transportation system and health to a notable extent. It's suggested that the transportation and health literature supports the indicators extensively. The data is said to show a further connection between transportation and health for the states, metropolitan areas, and urbanized areas.

The focus was to review the indicators for counties in Michigan and see if the significance is the same in this case. The data connection between transportation and health as mentioned earlier in the THT is attempted to be derived for county-level. A total of 11 elements were selected for the Michigan case due to data constraints. The elements are further explained and evaluated.

4.2 Transportation and health tool scoring methodology

Data was collected for all the indicators of the Michigan counties, and the scoring on a scale of 0-100 was done, significantly higher values depict better health. The scores were created by deriving the Z-Scores for all the indicators. The Z-score was calculated by using the difference between the value of the indicator for the particular county and the mean value of all counties for the respective indicator which is further divided by the standard deviation.

Calculating the Standard Score (Z-Score)

Standard Score, $z = \frac{X - \mu}{\sigma}$

μ = Mean

X = Score or Value

σ = Standard Deviation.

Z-Scores are proven to derive the best results when the data is normally distributed. The data was adjusted in such a way that the outliers are constrained so that the variation in data for individual indicators on a county is minimized. The final Z-Scores were adjusted so that the results showed the values for all the indicators as the higher, the better. Lastly, the Z-Scores are were converted into percentile values to get the final scores for all regions.

There are maps used in the THT to represent the behavior of each community on the particular indicator. The map shows different counties in Michigan with their respective score range represented by the colors. Different counties were scored on a scale of 0-100, and the scores on the map are described in the increments of 20, to group counties with similar behavior in one category. A score in the range of 80-100 shows that county has a better health performance in regards to the particular indicator, in comparison to the other counties. Simultaneously, as the scores decline with the color change, the health performance of that indicator for the counties aggravates.

Note: The higher the score, the better the health performance of the county on any particular indicator.

4.3 Indicator data and discussions

Alcohol related driving fatalities: This indicator computes the road traffic fatalities involving an inebriated individual. Alcohol-impaired driving is defined as the deaths caused by motor vehicle crashes that involve a person with a blood alcohol concentration of at least 0.08 g/dL.

The map shows different Michigan counties with their respective score range represented by the colors. The counties were scored on a scale of 0-100, and the scores on the map are described in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that the county is a better health performer on the particular indicator when compared with the other counties. The higher score suggests fewer cases of alcohol-related driving fatalities within that specific county and as the scores decrease the alcohol-related driving fatalities increase. Therefore, as the scores decline with the color change, the health performance of the indicator for the counties aggravates.

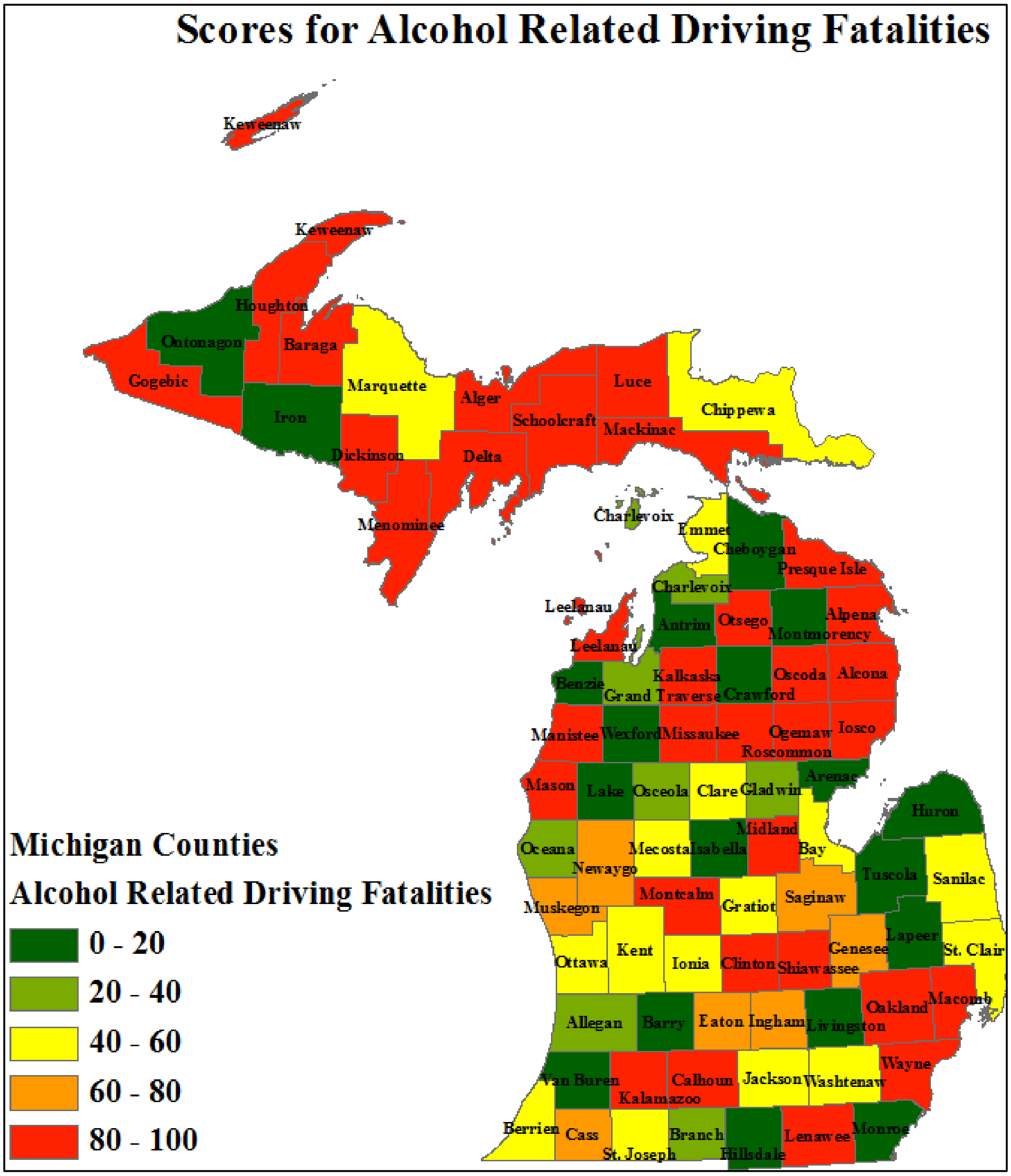

Figure 11: Scores for alcohol related driving fatalities

The data was obtained from Michigan State Police Criminal Justice Information Center, Crash Statistics. The data was collected in 2014.

Discussions on number of alcohol related driving fatalities: Driving a vehicle under the influence impedes the capability of an individual's ability to drive safely. The people in the vehicle as well as on the streets are considered to be at risk. This indicator directs the link between transportation and adverse health outcomes. This measure supports the policies and laws against alcohol-impaired driving.

Shults et al. (2002), stated that policies against drunk driving, strict enforcement, and prevention strategies could be administered to minimize the fatalities from alcohol-related crashes. These policies and requirements have the tendency to decrease the alcohol-related deaths and injuries. Strategies and countermeasures that are adopted by different states and cities have provided evidence which depicts lower rates of reported crashes due to alcohol involvement. These countermeasures and strategies have to lower the BAC limits, providing a license to only graduated drivers and mandatory alcohol assessments and rehabilitation for the alcohol-impaired offender.

Wechsler and Nelson (2010), suggested that fortifying the enforcement and initiating different policies to brace the minimum legal drinking age are potential approaches that can diminish alcohol-related injuries and fatalities among young adults.

Commute mode shares: This indicator measures the amount of individuals that commute to work by either Walking, Bicycling, Public Transit or Private Vehicle.
The map represents the commute mode walked to work. Similarly, the maps for commute mode biked, commute mode public transit and commute mode automobile users are presented in the appendix.

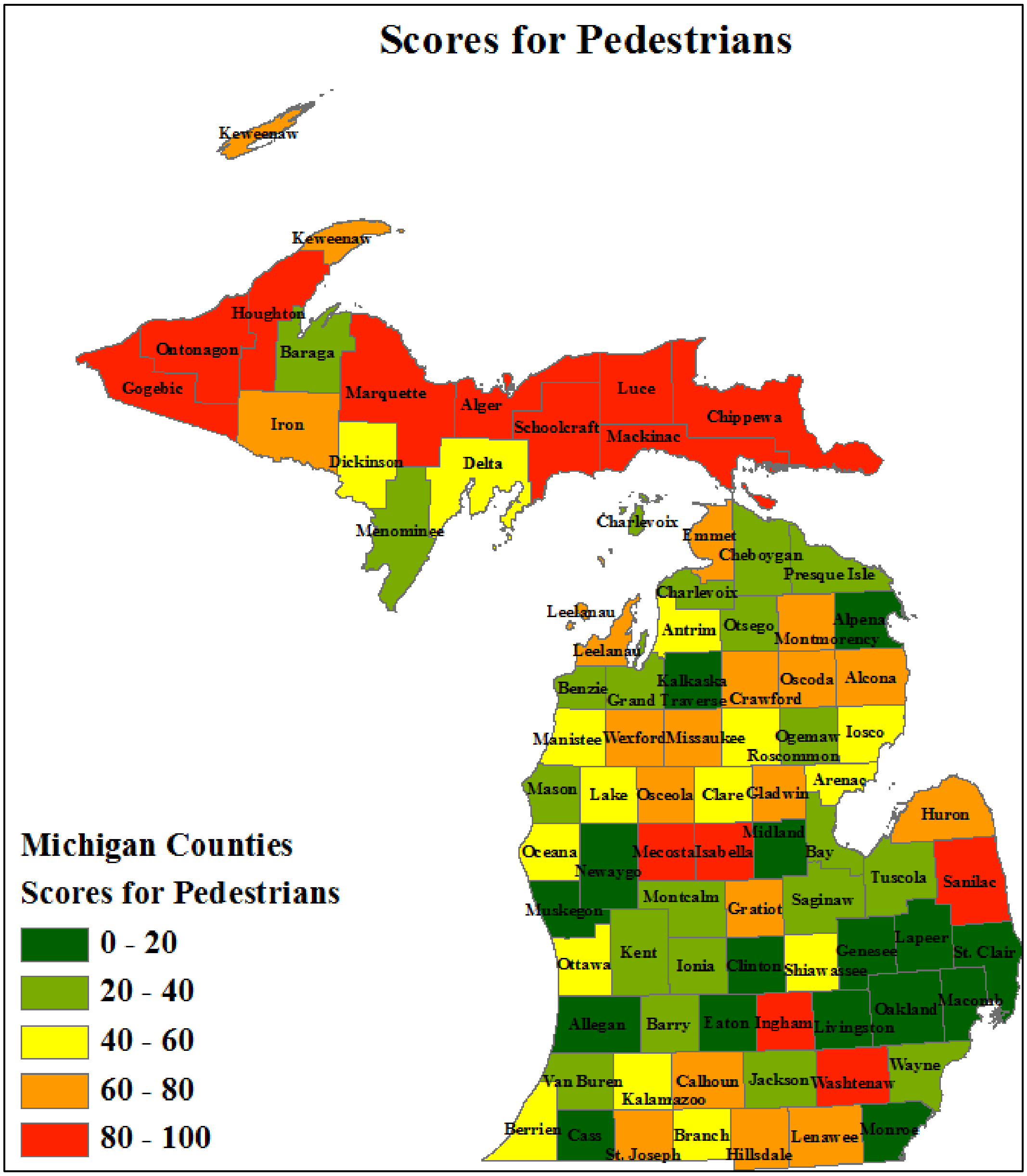

Figure 12: Scores for pedestrians

The data was obtained from American Community Survey of U.S Census Bureau. The data was collected in 2013. The map shows different Michigan counties with their respective score range for pedestrians, represented by the colors. The data was normalized to 100,000 population, and then scoring procedures were implemented. Different counties were scored on a scale of 0-100, and the scores on the map are represented in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that the county is a better health performer on the particular indicator when compared with the other counties. More individuals are adapting active transportation resulting in better health. Therefore, the higher the number of pedestrians, the higher the score. Simultaneously, as the scores decline with the color change, the health performance of that indicator for the counties aggravates.

Discussions on the commute modes: The commute modes are classified into four types that are represented separately. As discussed in the literature review section above, commute modes are one of the major aspects that decide how healthy community is. Commute modes demonstrate how infrastructure, land-use, transportation patterns and socioeconomic factors impel the mode choice behavior. Reduction of motorized transport and increasing the active modes palliates the harmful effects of motorized transport on the environment. (Xia et al., 2013).

Detailed advantages of active transportation on human health and adverse effects of motorized transport are explicitly discussed and verified in the literature review section. The obtained information from the commute mode data can be further used in discussing and ameliorating the transportation infrastructure, complete street policies, and safe routes to schools, prospectively creating better health outcomes for a community. Pucher et al. (2010), stated that incorporating changes in the commute mode patterns have evidence of changes in travel behavior.

Housing and transportation costs: This indicator materializes the share of income an average household spends on housing and transportation. They are considered to be the two most important factors that influence the expenses in a community.

The data for this entity was obtained from The Department of Housing and Urban Development Location Affordability Index (LAI). This data uses the housing costs from American Community Survey, and the transportation costs obtained from the values based on land use mix, commute mode patterns and also the socioeconomic factors. The data was readily available at the LAI website for the county-level. The data for households with the median income for the region was selected for this indicator. The map shows different Michigan counties with their respective score range represented by the colors. Different counties were scored on a scale of 0-100, and the scores on the map are described in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that the county is better at health performance on the particular indicator when compared with the other counties. Counties with higher housing and transportation cost tended to have better infrastructure and built environment features which contribute towards better health. Simultaneously, as the scores decline with the color change, the health performance of that indicator for the counties aggravates.

Discussions on housing and transportation costs: The cost of housing is considered as one of the most substantial expenses for the majority of the households. Transportation costs being second to it, makes housing and transportation cost the most influential parameters in determining the economy of a community.

These costs also demonstrate the characteristics of the built environment. It is stated by the U.S. Department of Housing and Urban Development in 2013 that housing that requires not more than 30% of the household income is considered as affordable housing. The transportation costs are not incorporated into the affordable housing parameter.

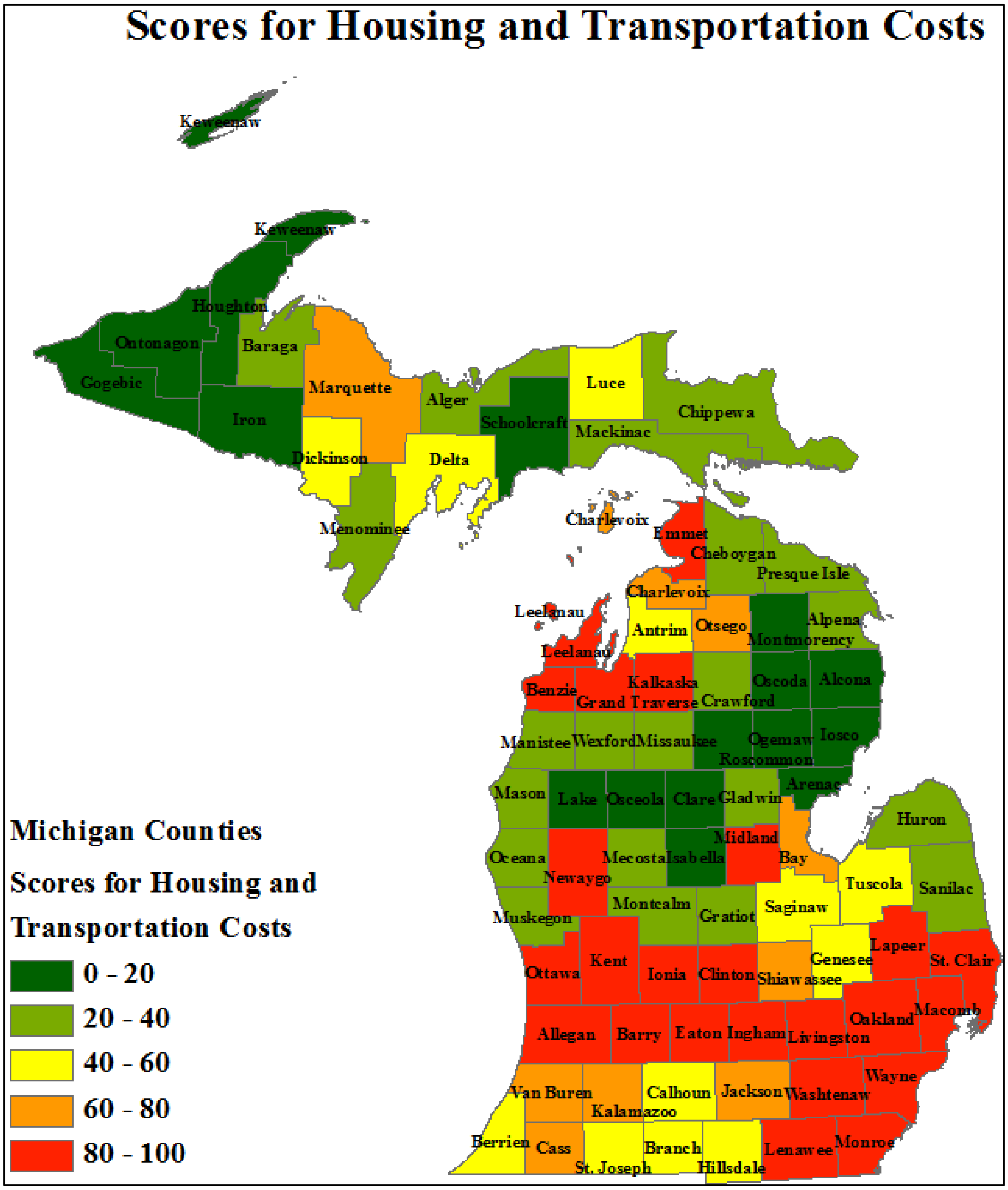

Figure 13: Scores for housing and transportation costs

Sustainable Cities Institute (2012), stated that affordability significantly means the cost of accommodation associated with the cost of transportation. The primary trend is that the communities that are pedestrian, bicycle, and public transit friendly, provide its resident's easy access to goods and services, with less dependence on motorized transport. The behavior of the active commuters' saves time and costs, as well as it is sustainable (Center for Neighborhood

Technology). The housing costs of these neighborhoods are assumed to be higher when compared with neighborhoods with less access, therefore resulting in residents with low-income abandoning these communities to subsist in affordable neighborhoods which does not have the benefits of the well-built environment.

Physical activity from transportation: This indicator provides the link between active transportation and physical activity which is considered as a major factor linking transportation and health. It measures the trips made for 10 minutes and longer by a pedestrian. The data is obtained from American Community Survey of U.S Census Bureau. The data was collected in 2014. One challenge faced was that the data available was for the working population commuting to work by active transportation modes. The data was available by travel times to work which made it facile to process.

The data was further normalized to 100,000 population to make the data balanced for all the counties. The data was later scored using the scoring procedures as mentioned further. The data is represented for walking associated with physical activity. The map represents the physical activity from transportation walking. The map shows different Michigan counties with their respective score range represented by the colors. The data was normalized to 100,000 population, and then scoring procedures were implemented.

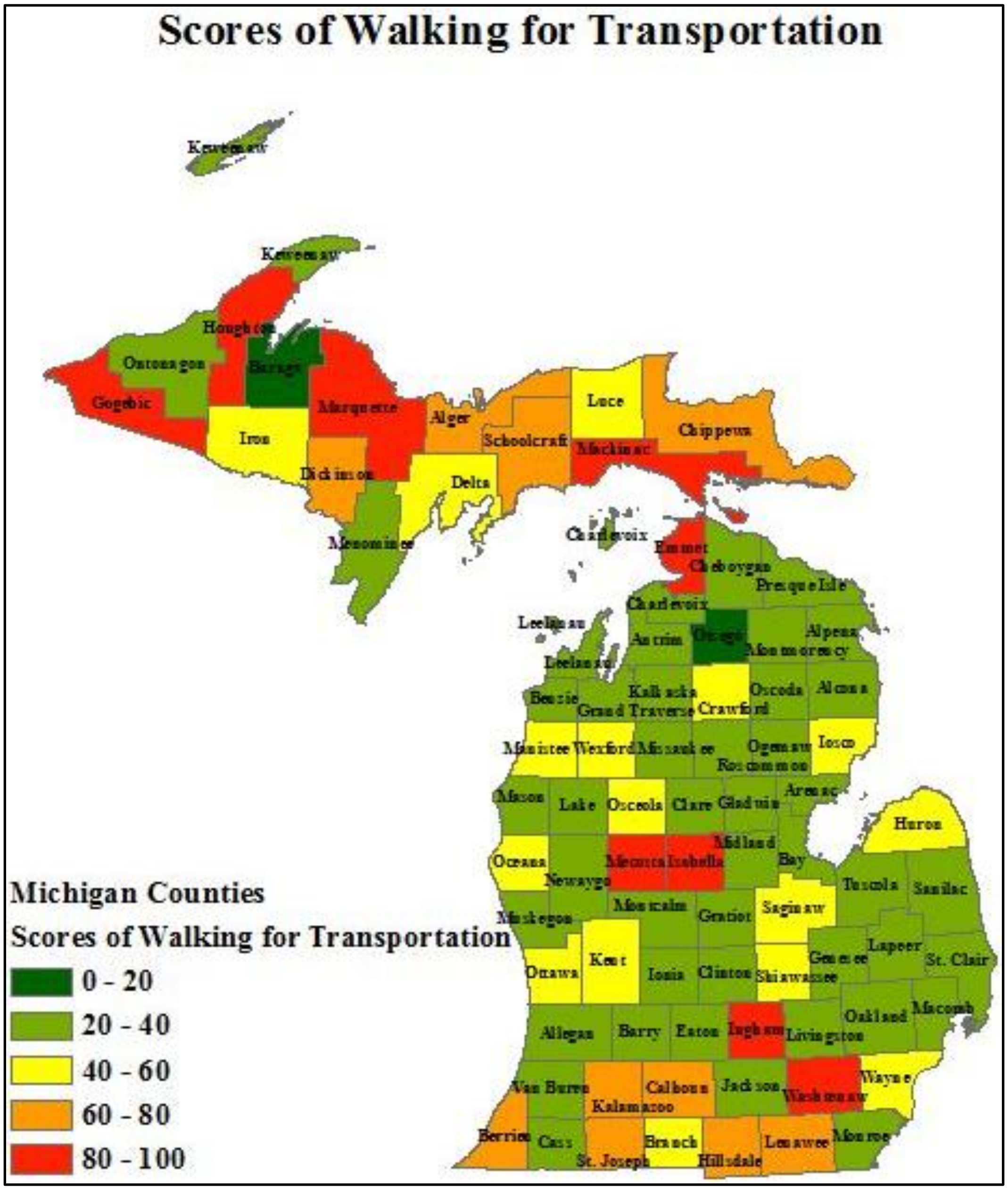

Figure 14: Scores of walking for transportation

Different counties were scored on a scale of 0-100, and the scores on the map are represented in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that more individuals that tend to ride bicycles in those respective counties, and it could result in better health outcome. Simultaneously, as the scores decline with the color change, the health performance of that indicator for the counties aggravates.

Discussions on physical activity from transportation: Active mode of transportation is considered as the most beneficial way to commute, and it also accounts for routine physical activity. The details about health benefits of physical activity have already been documented in the literature review section. Details about the needs and criteria of physical activity are discussed in the literature review. Analysis to prove the assumptions are provided in later sections of this research. The transportation infrastructure is usually focused on motorized transport which deludes the opportunities for motorized travel. The mode change behavior from motorized to active transportation can be obtained by reducing the motorized dependency by providing reasonable access to active modes. This indicator can be helpful in decision making towards the implementation of policies that support alternative modes of transportation by incorporating changes in the built environment.

Land use mix: Land use mix is the general term defining how land in a community is used to provide a mix of a variety of entities. This indicator tends to convey the relation of built environment with commute modes, which in turn account to human health.

The data was collected from the Environmental Protection Agencies Smart Location Database. The indicator measures the diversity of eight different employment types to depict the land use mix in a block group on a scale of 0-1. Each census block has its population and diversity proportion. The population weighted diversity for each census block in each county was obtained. Once the share of each census block was obtained, they were overlapped with the Michigan counties showing the overall land use mix or population weighted diversity of that county. The data was available in dbf format and is extracted using ARCGIS tools. The data was further calculated using a population-weighted average for all the Michigan counties. It was scored and represented on the scale of 0-100. The map shows different Michigan counties with their respective score range represented by the colors. The data was normalized to 100,000 population, and then scoring procedures were implemented. Different counties were scored on a scale of 0-100, and the scores on the map are represented in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that the county is better at health performance on land use mix when compared with the other counties. Simultaneously, as the scores decline with the color change, the land use mix of the counties aggravates.

Discussions on land use mix: Land use mix is always linked to physical activity and human health. The substantiality on the link between them has been questioned, but according to recent studies by (Saelens, Handy, 2008), the link is justified.

The research states that active modes of transportation have been linked significantly with land use densities and also the distance to goods and services is connected with land use mix. Analysis has resulted in correlations between land use mix, accessibility and intersection density with physical activity. (Ewing, Cervero, 2010)

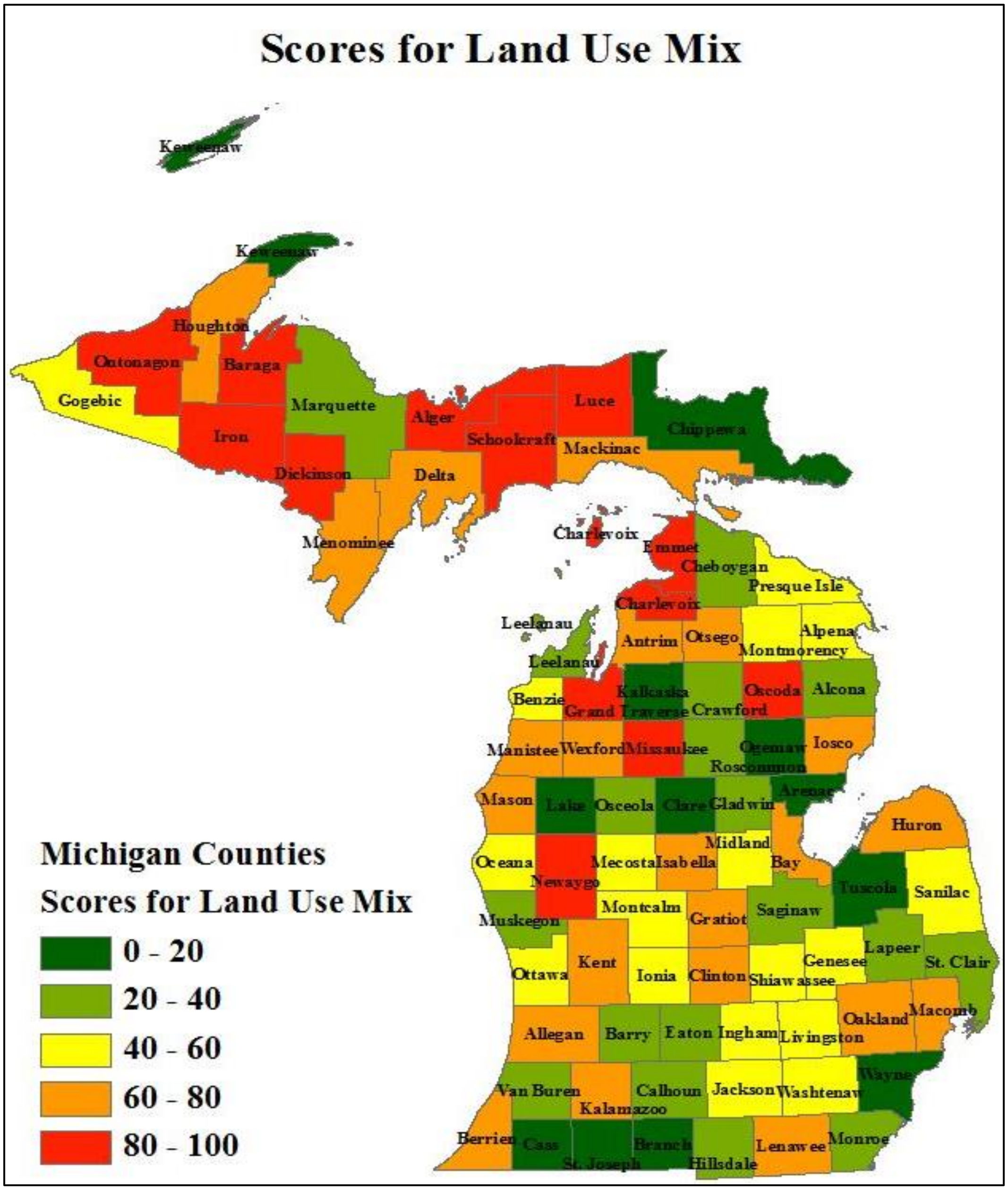

Figure 15: Scores for land use mix

There is further evidence from studies that communities with higher density, better accessibility, and high land use mix proportions tend to have a higher number of pedestrians and bicyclists when compared to low density and poorly connected and accessible neighborhoods. Therefore, accessibility and land use densities are also critical parameters other than socioeconomic and demographic parameters concerning physical activity (Saelens, Sallis, Frank, 2003). The information from land use mix can be helpful in analyzing and determining the changes in the built environment which can support physical activity, enhance safety, and air quality.

Proximity to major roadways: This indicator exhibits the amount of people who live within a 200-meter proximity of the road which has AADT more than 12500. The data was processed in ARCGIS using shape files from Michigan State Police and also Census Data. The data was collected after conducting a geospatial analysis by census block.

All the census blocks within the Michigan State are plotted and the roads with AADT more than 12500 are selected. A 200-meter buffer is drawn along all the roads that have an AADT of more than 12500, and for the census blocks that are partially intersected by the buffer, the area within the block group is considered. The AADT of 12500 was selected to represent the population that lives within the proximity of major roadways. This indicator clearly states that the closer the population is to the major roads, the more the adverse health effects of transportation on the population. The AADT of 12500 is not significantly high, but the figure is considered as the data was definite and the intention is just to show the trend of different communities that stay close to major roadways.

A county-level analysis was performed as the data from census block was overlapped with the counties and proximity of roads of different counties were obtained. The data was further processed, and the analysis was done for 100,000 population to capture the trend of different counties.

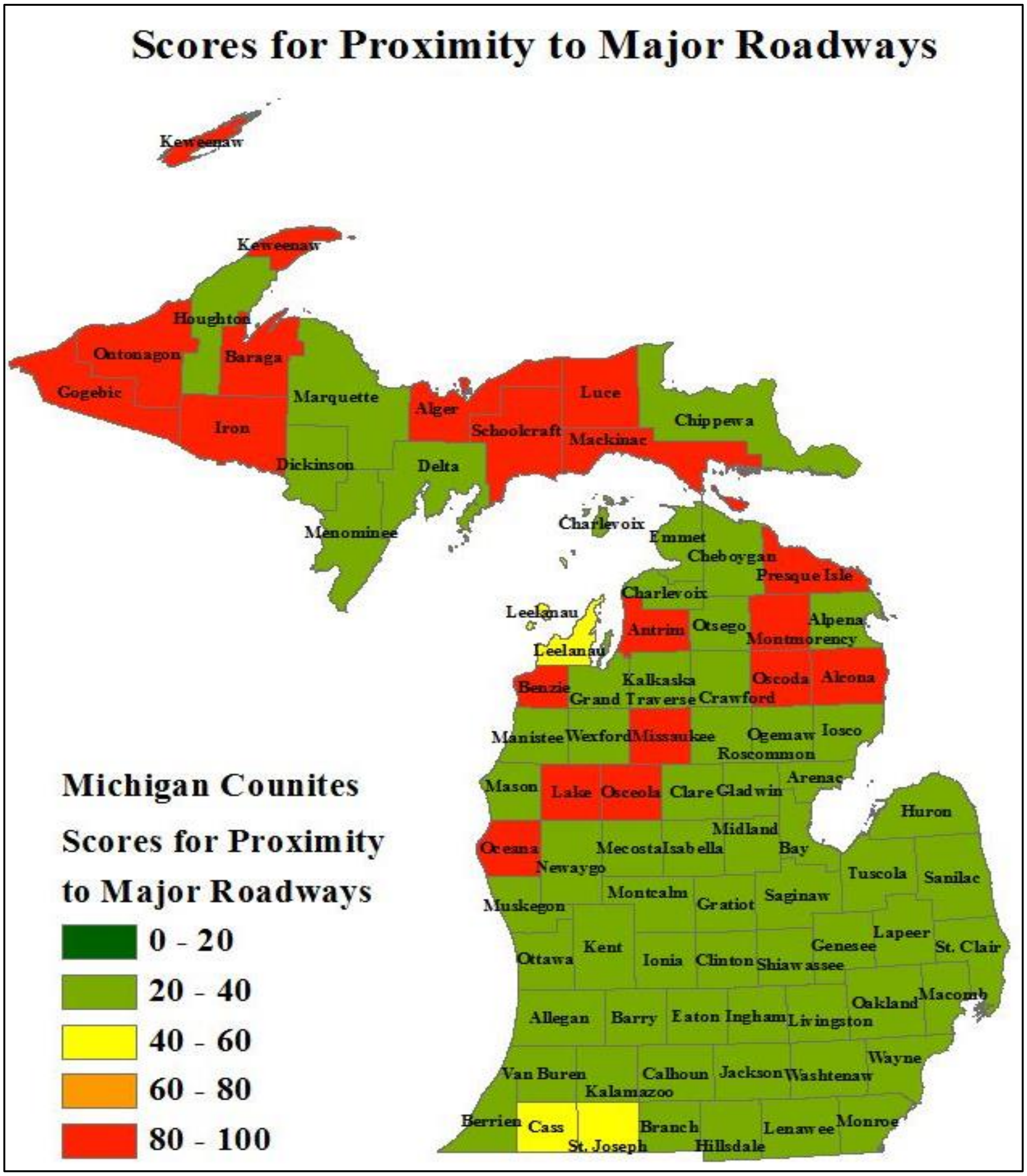

Figure 16: Scores for proximity to major roadways

For this indicator, the lower the population within the proximity is better for health. Once the data was processed and organized, the scoring measures were implemented. The map shows different Michigan counties with their respective score range represented by the colors. The counties were scored on a scale of 0-100, and the scores on the map are described in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that there is less proximity to major roadways, which is considered to be a better health feature. Simultaneously, as the score declines with the color change, the proximity to major roads increases and tends to have adverse effects on human health

Discussions on proximity to major roadways: The CDC stated that more than 11 million individuals in the United States live within a 150 meters proximity to major highways. (Boehmer et al., 2013). Residing in proximity to the major roadways result in exposure to air pollution, which is further associated with respiratory ailments like asthma, cardiovascular issues, etc., resulting in premature death. (National Heart, Lung, and Blood Institute National Asthma Education and Prevention Program, 2007; Health Effects Institute, 2010). A study by Karner et al., 2010) stated that expanding residency from major highways by more than 150 meters can result in 50% less exposure to pollutants for the residents. Therefore, residing further away from major roadways can prove beneficial to health in many ways.

Public transit passengers: This indicator quantifies the amount of public transit users in the different Michigan counties. The data for Public Transportation Passengers was obtained in 2014, from the Michigan Public Transit Facts. The data was available on agency levels, so it was further aggregated and processed for all the Michigan counties. The American Public Transportation Association stated the various benefits of public transportation, ranging from an increase in physical activity, safety, and accessibility to lowering the levels of air pollution.

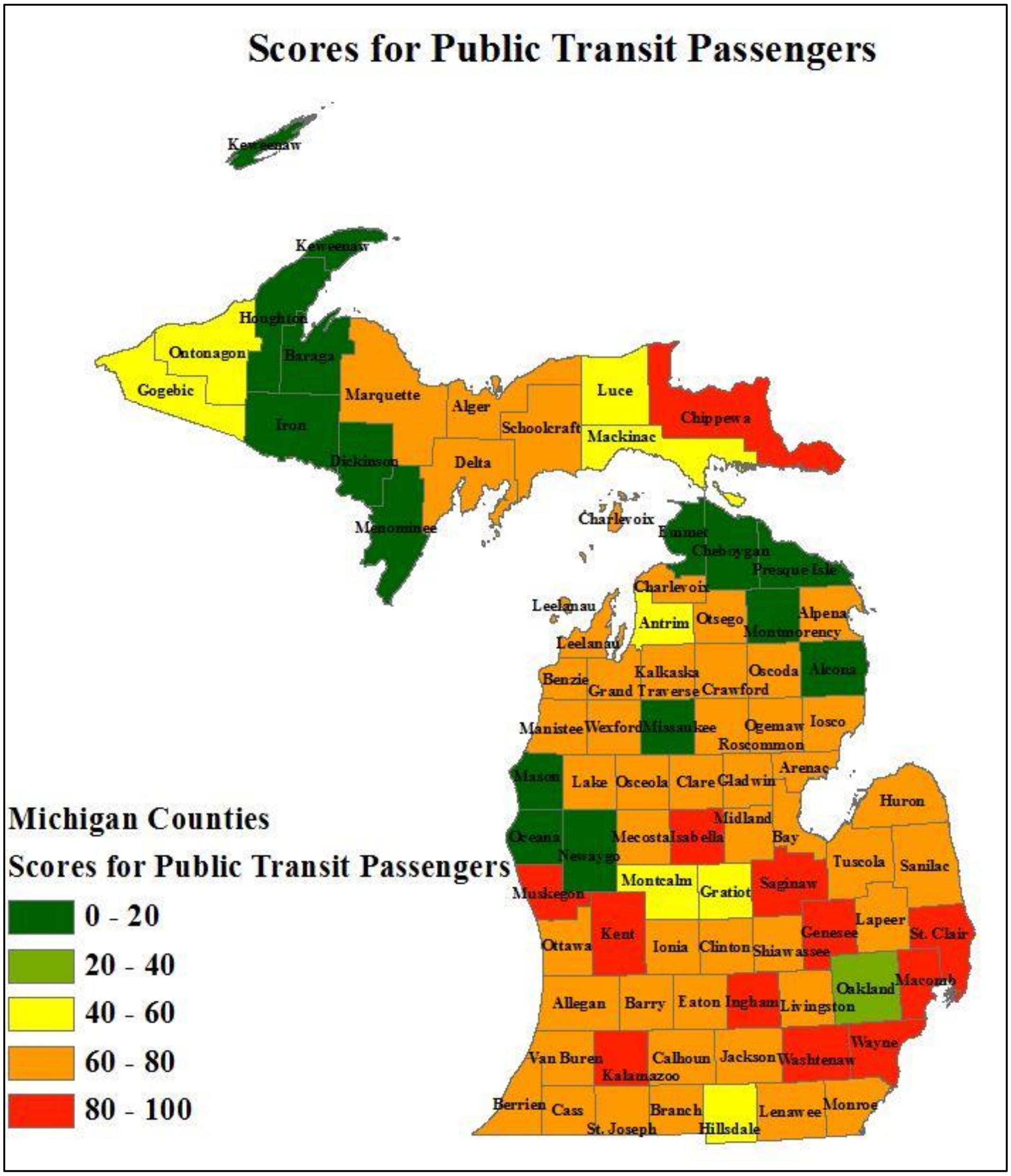

Figure 17: Scores for public transit passengers

The map shows the different Michigan counties with their respective score range represented by the colors. The data was normalized to 100,000 population, and then scoring procedures were implemented. Different counties were scored on a scale of 0-100, and the scores on the map are represented in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that the county has more public transit passengers when compared to other counties. Moreover, as the scores decline with the color change, the public transit passengers' decrease which tends indicate that the health of the county on public transit passengers aggravates.

Discussions on public transit passengers: A Health Impact Assessment study by (Gorman et al., 2003) stated that increased expenditure on public transportation benefits human health and depletes social inequalities. Carlson and Howard (2010) indicated that further and constant research should be performed to analyze the potential of policies that promote the use of public transportation. The CDC affirmed that dilating the scope for safety and accessibility to alternative transportation can meld health endeavoring choices into the transportation policy. This can further prevent various diseases and deaths, and can further improve the environmental and socioeconomic conditions of a community. (CDC 2010).

Road traffic injuries and fatalities by mode: This measures the traffic-related injuries and deaths. The measurement incorporates data from three different commute modes being: Pedestrian crashes, Bicyclist crashes, and Motorized crashes. The data was obtained from the Michigan State Police Office of Highway and Safety Planning, Crash Statistics. The data was collected for the years 2010-2014.

The map represents the motorized injuries and fatalities. It shows different Michigan counties with their respective score range represented by the colors. The data was normalized to 100,000 population, and then scoring procedures were implemented. Different counties were scored on a scale of 0-100, and the scores on the map are represented in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that the county is a better at health performance on the particular indicator when compared with the other counties. The counties with higher scores mean that they have fewer injuries and fatalities compared to the counties with lower scores. Therefore, as the scores decline with the color change, the health performance of the counties on injuries and fatalities dwindles.

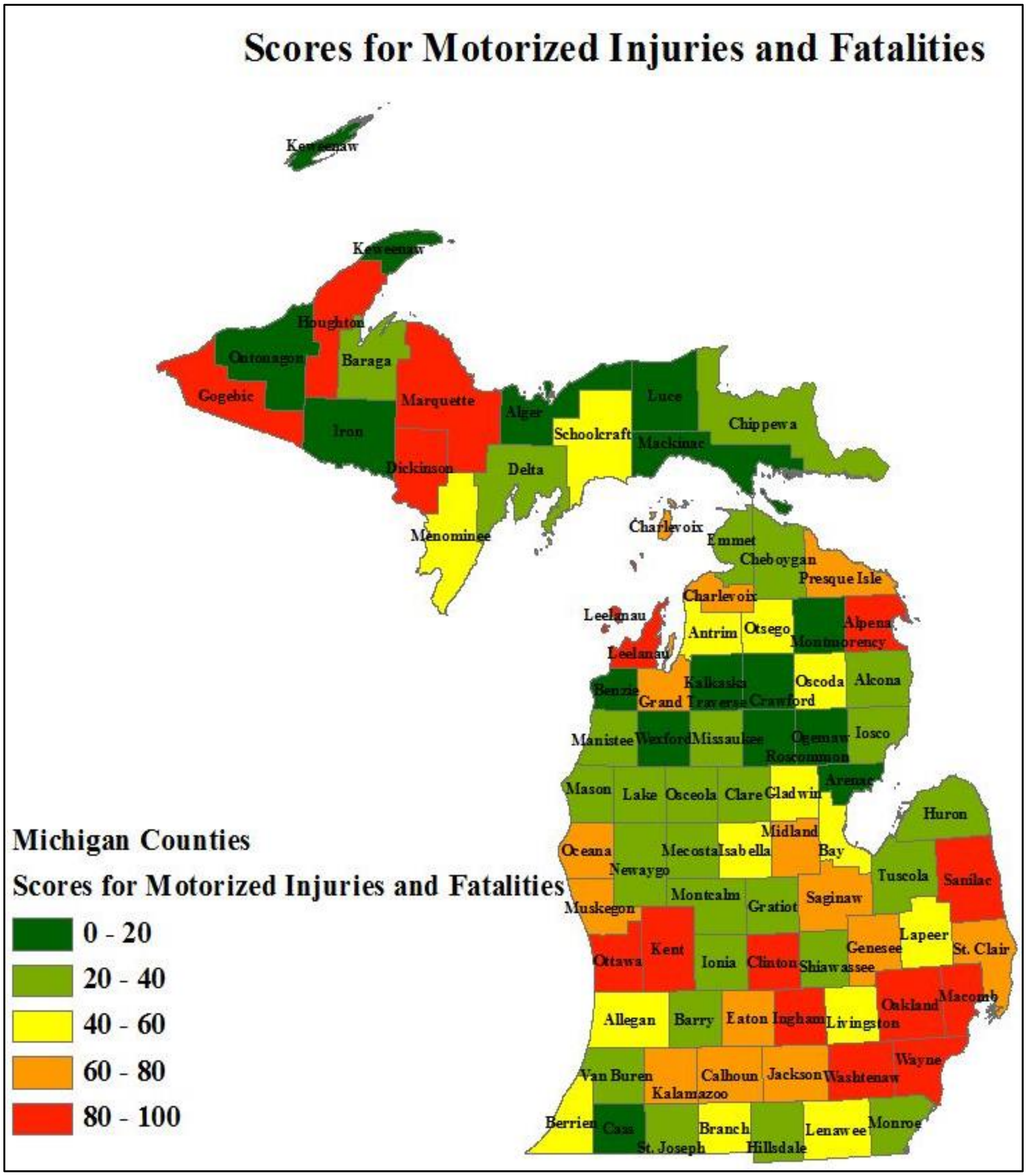

Figure 18: Scores for motorized injuries and fatalities

The maps representing the pedestrian and bicyclist injuries and fatalities are present in the appendix.

Discussions on road traffic injuries and fatalities by mode: Traffic crashes and fatalities are directly related to transportation and human health. This measure depicts the safety of the community and neighborhoods, which helps when determining which safety policies to implement for the area. Traffic accidents account for injuries, fatalities, and economic concerns. The factors relating to road traffic fatalities include safety of driving, road condition, driver behavior, and miles traveled on a given vehicle. Increase vehicle miles traveled may account for an increase in the number of crashes. There is a general assumption that increase in commuters would probably increase the number of crashes and fatalities irrespective of the mode. Road traffic fatalities by mode can be a viable indicator to represent the safety of different commute modes.

The THT can be used to determine the relationship between various modes of transportation and their safety, which can help in deriving the health state. Road traffic fatalities can be avoided by making changes in the built environment, incorporating safety- related laws, and by implementing enforcement.

Road traffic injuries and fatalities exposure rate by mode: This indicator measures the risk of a pedestrian, bicyclist, and motorist being involved in a traffic crash. The exposure rate was calculated by diving the road traffic injuries and fatalities per 100,000 population, by the respective commute mode for 100,000 population. For instance, the injuries and deaths exposure rate for pedestrians was calculated by diving the pedestrian fatalities per 100,000 population, by the commute mode walked for 100,000 population, and simultaneously for the bicyclist and motorized transportation.

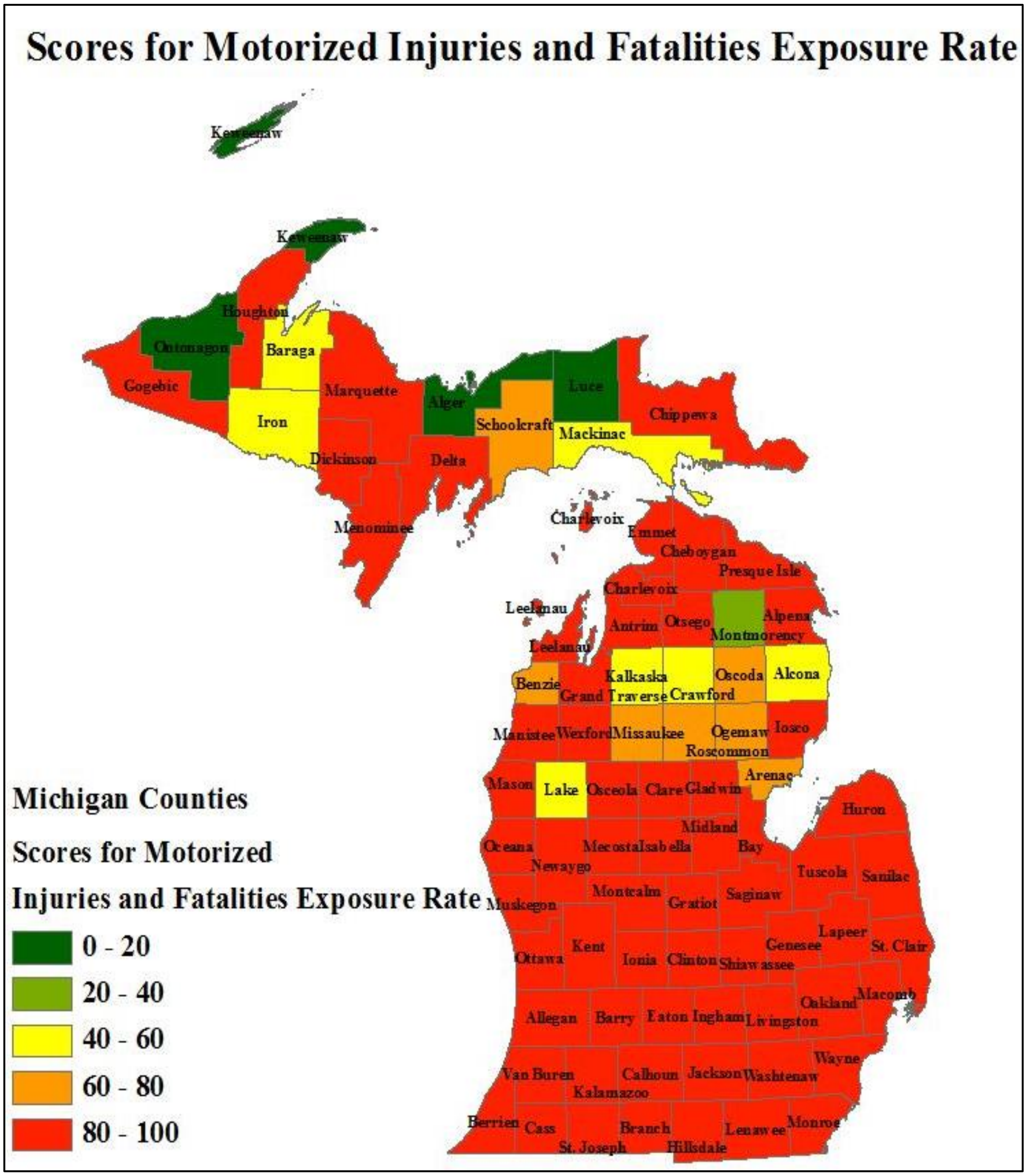

Figure 19: Scores for motorized injuries and fatalities exposure rate

A restriction to the calculation was that the commute mode data was only available for a set of commuters, i.e., the workers commuting to work, whereas the fatalities were for the total population. The commute mode share is more likely to belittle the actual rates of active transportation as it is only for the workers. The exposure rate was calculated by first normalizing all the data to 100,000 population. The data on crashes and fatalities were obtained from the

Michigan State Police Office of Highway and Safety Planning, Crash Statistics. The data was collected for the years 2010-2014.

The map represents the motorized injuries and fatalities exposure rate. It shows the different Michigan counties with their respective score range represented by the colors. The data was normalized to 100,000 population, and then scoring procedures were implemented. Different counties were scored on a scale of 0-100, and the scores on the map are represented in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that the county is a better at health performance concerning the road traffic injuries and fatalities exposure rates when compared with the other counties. Simultaneously, as the scores decline with the color change, the health performance of this indicator drops as it tends to project higher exposure to road traffic injuries and fatalities. The maps for pedestrian and bicyclist injuries and fatalities exposure rate are in the appendix.

Discussions on road traffic injuries and fatalities exposure rates by mode: The relation between transportation and human health are linked to road deaths to a certain extent. Road traffic fatalities by mode are not the only factor that is related to the health risks of each mode of commuting. This indicator deals with the exposure to the risk of death by mode of transport. Pedestrian and bicyclist possess a higher risk of attaining fatal injuries if involved in a crash. (Naumann et al., 2010). Despite taking preventive measures, individuals with different age groups and gender have increased the risk of injury due to crash. (Beck, Dellinger, O'Neil, 2007). Older adults have increased the susceptibility of fatality from a crash as they are less recoupable if involved in a high-intensity injury crash (Insurance Institute for Highway Safety, 2013). (Jacobsen, Racioppi, Rutter, (2009) stated that perception of risk of injury and fatality is a barrier to active transportation.

This provides a crucial link between public health from transportation safety. The data provides identification and comprehension of the improvements on the safety pertaining to transportation for all modes. This data can justify the discrepancy between different ways of travel and also can provide recommendations for improvements in safety. Potentially making a difference in commute patterns. (Pulugurtha, Desai, Pulugurtha, 2010; Chen et al., 2013) Suggested that traffic calming studies, pedestrian countdown signal, are useful in increasing the pedestrian's participation. The pedestrian, bicyclist and motorist plans could be developed using this data as a source of risks measure for each mode, to improve the safety. (Jones et al., 2010).

Seat belt usage: This measure calculates the percentage of drivers and front-seat passengers that use the seatbelt while in a vehicle. The seat belt is considered to be one of the safety elements while commuting in a motorized vehicle. The data was obtained from a report prepared for the Office of Highway and Safety Planning by Wayne State University Transportation Research Group. Data was available for only selected counties. Therefore, the counties which the data is unavailable are represented in the lowest score range. The data was collected in 2012.

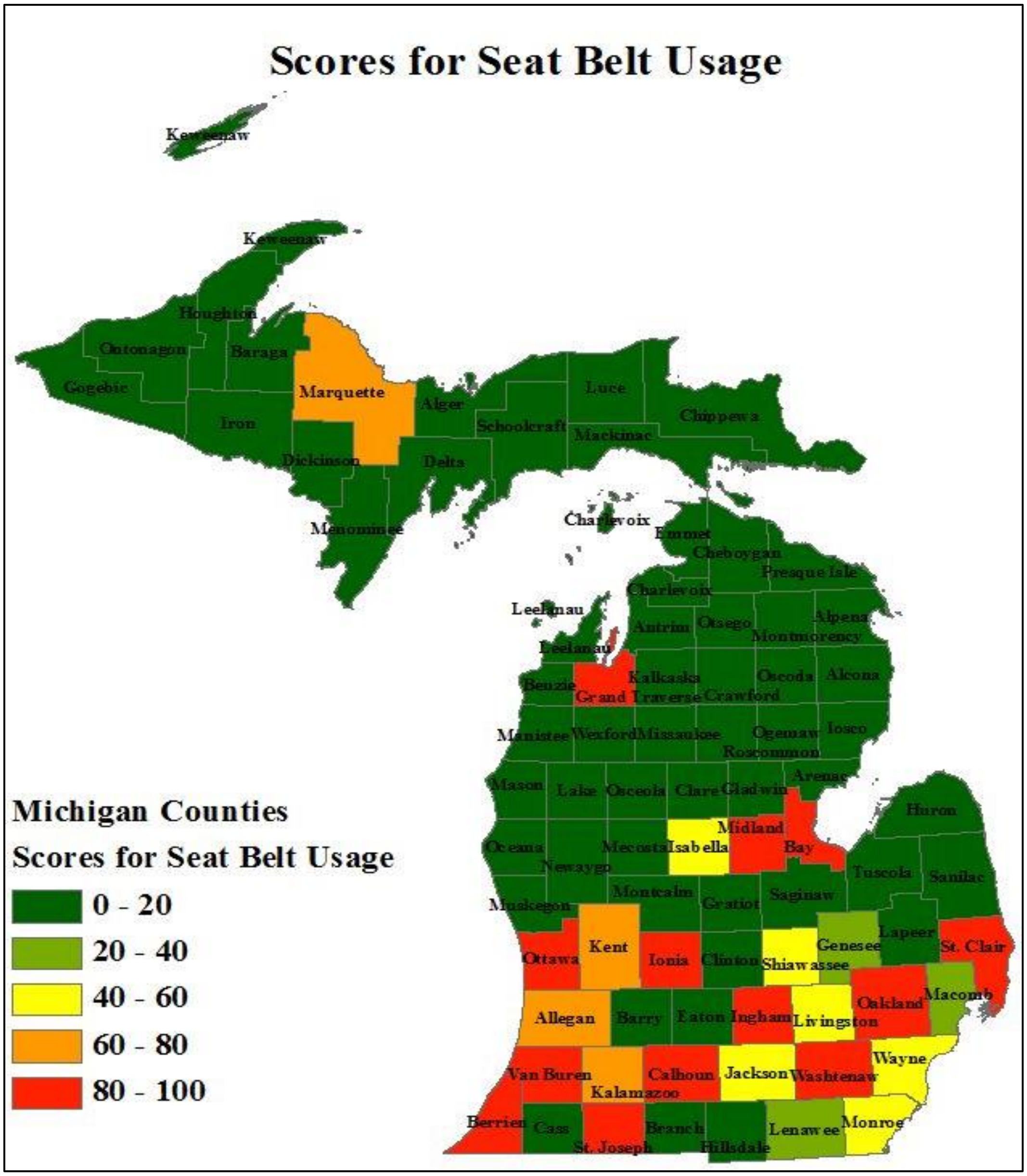

Figure 20: Scores for seat belt usage

The maps for seat belt usage shows the different Michigan counties with their respective score range represented by the colors. The data for seat belt usage was obtained in percentage and was further scored using the measures defined in the scoring methodology. Different counties were scored on a scale of 0-100, and the scores on the map are represented in the increments of 20, to group counties with similar behavior in one category. The scores in the range 0-20 depict that the data was unavailable for the respective counties. The score in the range of 80-100 represents that the county is better at health performance pertaining to this indicator when compared to the other counties. Simultaneously, as the scores decline with the color change, the health performance of this indicator for the counties aggravates.

Discussions on seat belt usage: The use of seat belts can minimize the risk of a fatality or a fatal injury in a high-intensity crash. All the states adopted the law for seat belt usage in the United States, but the terms of the law vary throughout the different states. Seat belt usage has been proven as an additional safety measure to automobile users. Therefore, it is documented as one of the primary indicators linked with transportation. Various researchers show the effectiveness of seat belt usage in preventing the motorized injuries and fatalities. (Hijar et al., 2010) The enforcement study on the relation of road traffic injury laws suggested that the seat belt laws were the most enforced laws, whereas speeding laws were the least enforced. Seat belt laws are classified as primary and secondary. Fundamental rules authorize the officials of ticketing if seat belt laws are not obeyed, whereas secondary laws enforce the ticketing only if the seat belt is not used while another traffic offense is cited. Studies reveal that seat belt uses are higher in states where primary laws are implemented when compared to the secondary laws.

Further evidence indicates that teenaged drivers are less likely to use seat belts in the states that impose the secondary law when emulated to the states that use the primary law. (Garcia-Espana, Winston, Durbin, 2012). Health outcomes can be enhanced by attaining certain policies and strategies that embody the evidence of the connection amidst public health and transportation. The medications actualized should be accessed carefully by the public health officials to obtain their effectiveness and also to fortify attempts to diminish motorized injuries and fatalities

Vehicle miles traveled per capita: Vehicle miles traveled per capita computes which the total annual miles of vehicle travel within a county, divided by the population of the county. The data for VMT was collected from Michigan Department of Transport Annual Vehicle Miles Travelled statistics in 2014. The data was selected on the county-level. The population data was collected from the U.S Census Bureau.

The map shows different Michigan counties with their respective score range represented by the colors. The data was normalized to 100,000 population, and then scoring procedures were implemented. Different counties were scored on a scale of 0-100, and the scores on the map are represented in the increments of 20, to group counties with similar behavior in one category. The score in the range of 80-100 represents that the county is a better at health performance pertaining to this indicator when compared with other counties.

Discussions on the vehicle miles traveled per capita: The vehicle miles traveled are inversely related to air quality. It is assumed that a decrease in the VMT can result in better air quality. The difference the VMT makes in determining the air quality depends on the type of vehicle and the area characteristics. (Johnson, 2006). The increase in the VMT is also linked with the inactive behavior of individuals. Studies by (Change Lab Solutions, 2007; U.S. EPA, 2013) show that the lower the VMT in a community, the higher are the active transportation rates, and also the population density increases with a decrease in VMT.

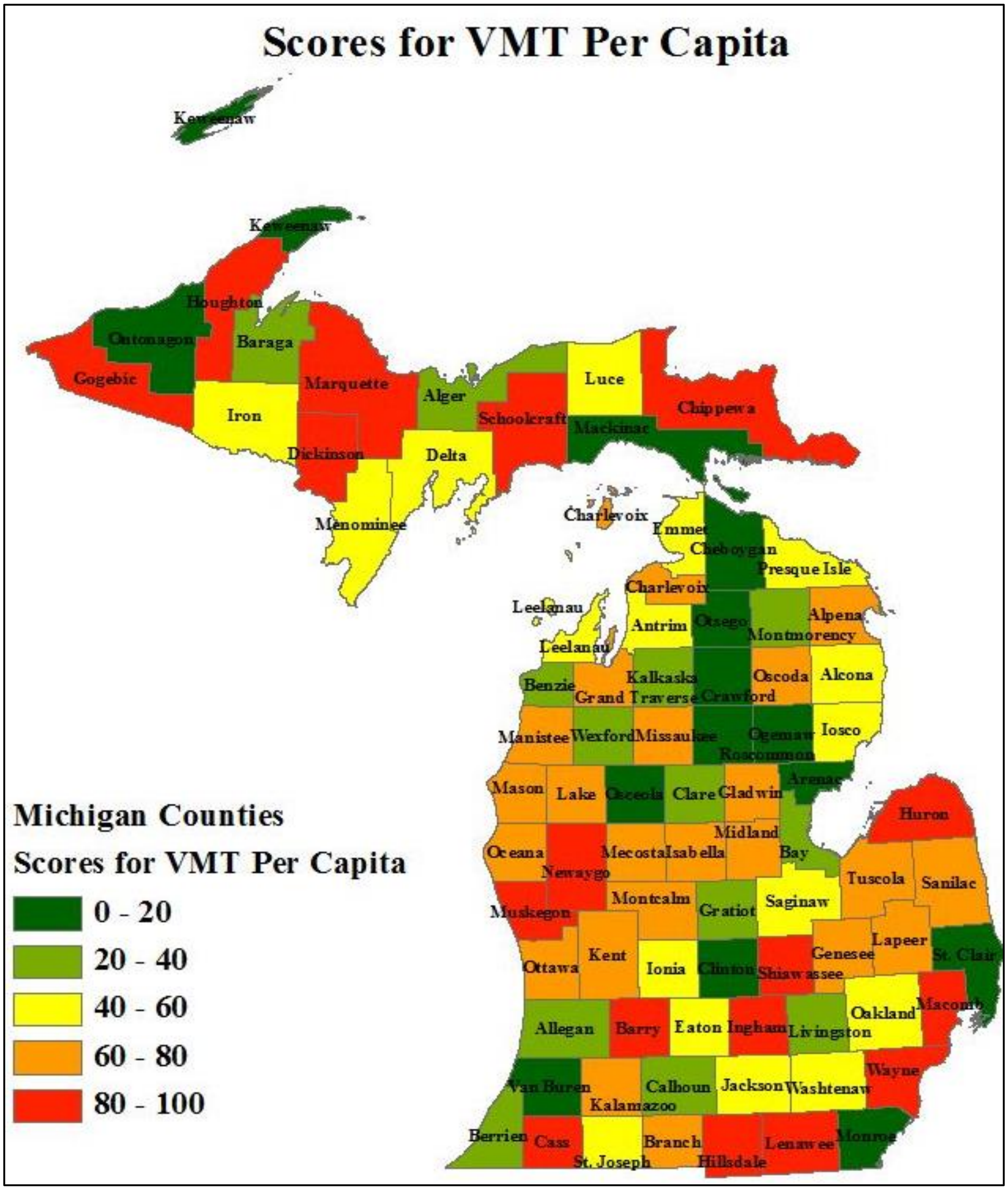

Figure 21: Scores for vehicle miles traveled per capita

Enhancing the built environment forms and the accessibility for active modes of transportation is expected to reduce the VMT to a feasible extent (Carlson and Howard, 2010). VMT data is also considered helpful in determining the policies and strategies to improve public health outcomes linked to physical activity, safety, and air quality.

Transportation and health tool conclusions

The THT gives an exclusive proposition as to what factors need to be considered when determining the link between transportation and human health. Different indicators in the THT depict different assumptions and tries to link elements from transportation which can variably influence the health of the community.

The THT does not have any statistical relation that links the transportation indicators to health.

From the evidence of past literature and some statistical reports on crashes and mode use behavior, many assumptions had been complied.

The data of the components show how different geographical areas perform on the particular index. This can result in determining the health impacts of this field. It would be better if the components from the health side were included in THT. Then a significant relation between different components could predict the health impacts quintessentially.

Chapter 5 Relations between Transportation and Health

5.1 Correlation analysis for factors and relations derived from literature and previous studies

There are different transportation, socioeconomic, and health indicators which are correlated to each other. Components from each of the systems influence variables in the other. This segment of the thesis reflects different elements from all the classifications, and will correlate findings among them. Manual correlations from earlier studies were obtained. They were further processed using various statistics to see the pattern of how the diverse components tend to correlate with one another. Various analysis and assumptions have been made but not in a comprehensive way. The statistical analysis used in this study, however, infer a comprehensive statistical logic behind the assumptions and also indicate how multiple factors correspond to one another.

The data on the factors from the Michigan counties were imported in Stata, and the correlation test was progressed for all the elements derived from literature review. The relationships were analyzed to see if they satisfied the assumed relations, to incorporate them further into the relationship model. The components appearing to have a conceivable relationship were further illustrated. The correlation analysis before modeling was performed to decipher the relations proclaimed from the literature reviews. The correlation test was performed with data for the Michigan counties, and the significance level was set to 85%. Evident factors and their relations from the literature and past studies were observed, and conclusions were made. The correlation test analyzed the results from Stata, which are represented and described below. The graphs depict the trend of the relations between various factors.

5.1.1 Correlation analysis between commute modes and health factors

This section describes the illustration and discusses the results from the correlation test between commute modes and health indicators.

The assumed link from previous studies suggested that an increase in the number of people commuting by walking may result in the decrease of the number of individuals with adult obesity and hypertension. The results of the correlation test stated that the assumption was significant at 85%. Also, the link between the number of people commuting by walking and the number of pedestrian injuries and fatalities was intended to be derived. The results termed to be insignificant and are tabulated in Table 13.

Studies and assumptions stated that an increase in the number of people commuting by bicycling in a community could help increasing physical activity, which further decreases the number of individuals with adult obesity. As the correlation test was progressed, the correlation was significant at 85%. There are also assumptions that increase in physical activity from bicycling can help in reducing the number of individuals with hypertension while increasing the bicyclist injuries and fatalities. The results of these correlation tests were insignificant and are tabulated in Table 13.

The results for the correlation of the number of people commuting by public transit with the number of individuals with adult obesity and hypertension were observed to be significant at 85%. Therefore, increasing usage of public transit can result in lower obesity and hypertension rates. A correlation test was also performed between the number of people commuting by public transit and the number of pedestrian injuries and fatalities. The assumption is that increase in public transit usage increases the number of people walking which may increase the pedestrian injuries and fatalities. The results of the correlation test are observed to be significant at 85% and are tabulated in Table 13.

The number of people commuting using automobiles is linked with adult obesity and hypertension. The results of the correlations termed are to verify the literature that the increase in automobile usage tends to increase adult obesity and hypertension. The results were significant at 85%. The use of automobiles is also linked with an increase in motorized injuries and fatalities. In the case of this correlation test, the results were insignificant and are tabulated in Table 13.

Table 13: Correlation test results of commute modes with health factors.

	Number of Individuals with Adult Obesity	Number of Individuals with Hypertension	Number of Pedestrian Injuries and Fatalities	Number of Bicyclist Injuries and Fatalities	Number of Motorized Injuries and Fatalities
Number of People Commuting by Walking	-0.2148*	-0.3692*	0.0898	-	-
Number of People Commuting by Biking	-0.1602*	-0.0237	-	-0.0532	-
Number of People Commuting by Public Transit	-0.3297*	-0.2635*	0.4061*	-	-
Number of People Commuting by Automobiles	0.3219*	0.2567*	-	-	-0.1006

Note: * represents the coefficient of the correlations that termed to be significant at 85%.

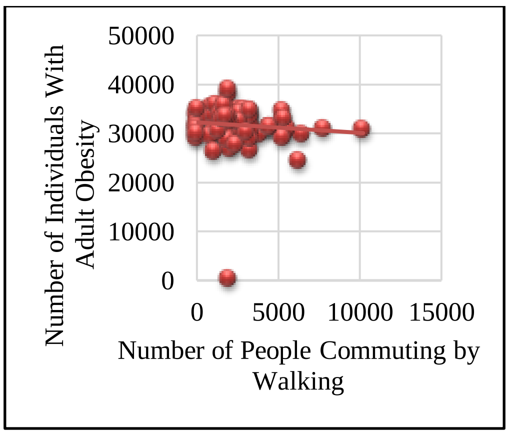

Figure 22: Graphical representation and trend of the relation between adult obesity and pedestrian

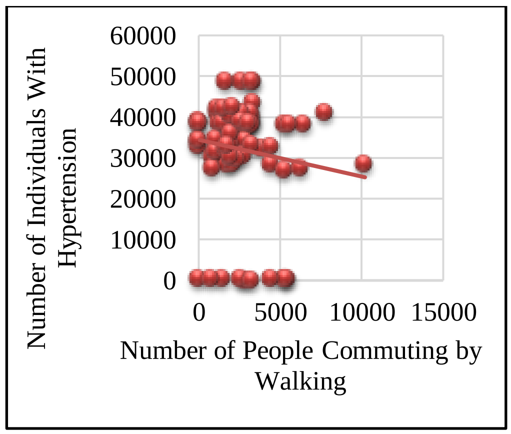

Figure 23: Graphical representation and trend of the relation between hypertension and pedestrians

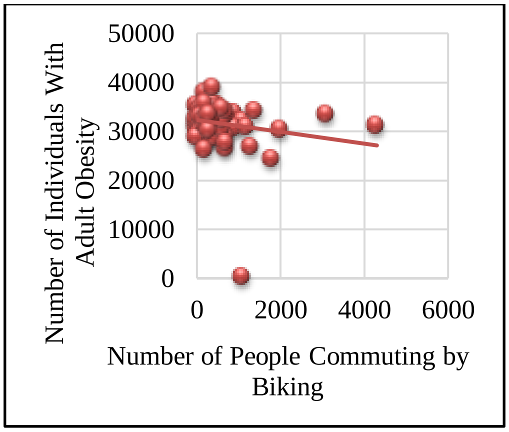

Figure 24: Graphical representation and trend of the relation between adult obesity and bicyclist

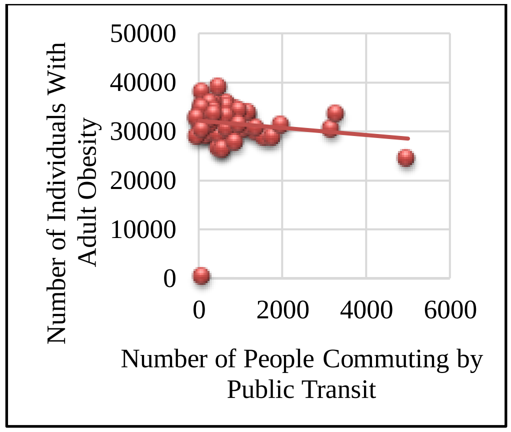

Figure 25: Graphical representation and trend of the relation between adult obesity and public transit users

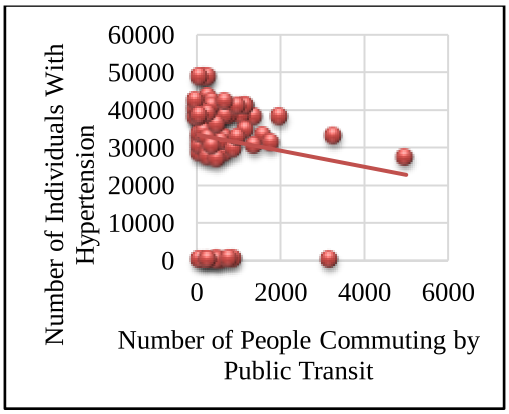

Figure 26: Graphical representation and trend of the relation between hypertension and public transit users

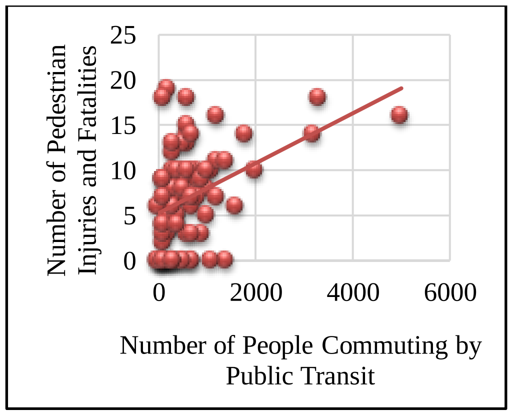

Figure 27: Graphical representation and trend of the relation between pedestrian injuries and fatalities and public transit users

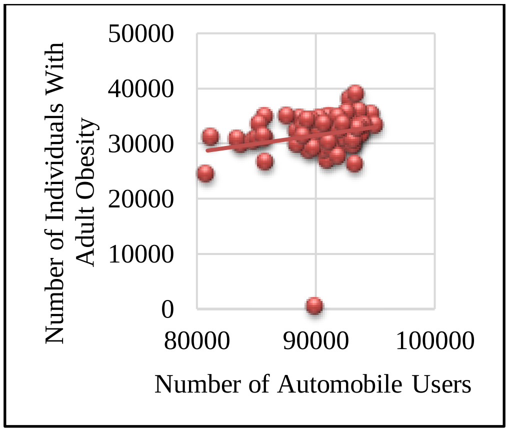

Figure 28: Graphical representation and trend of the relation between adult obesity and automobile users

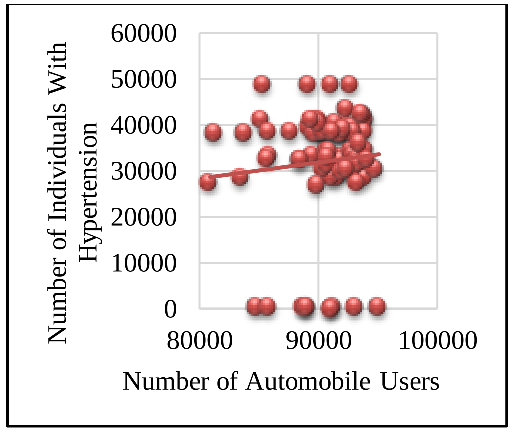

Figure 29: Graphical representation and trend of the relation between hypertension and automobile users

5.1.2 Correlation analysis between socioeconomic factors with transportation and health factors

This section elaborates on the illustration and discusses the results of the correlation tests between socioeconomic and health factors. Studies suggested that an increase in the number of unemployed individuals could lead to the decrease in commuting. The assumption is that an increase in the number of unemployed individuals tends to decrease the number of people commuting by walking and bicycling. A correlation test was progressed, and the results were insignificant at 85%. The results of the correlation test between the number of unemployed individuals with the number of people commuting by public transit and the automobile were significant at 85%. The coefficients of the correlation are tabulated in

	Number of People Commuting by Walking	Number of People Commuting by Biking	Number of People Commuting by Public Transit	Number of People Commuting by Automobiles
Number of Unemployed Individuals	0.0752	0.0679	-0.2359*	-0.1769*
Number of Individuals Below Poverty Line	0.3598*	0.0722	0.0832	-0.1825*
	Number of Individuals	Number of Individuals	Number of Individuals	Number of Individuals

	With Adult Obesity	With Hypertension	With Diabetes	With Heart Diseases
Number of Unemployed Individuals	0.1701*	0.2724*	0.6655*	0.5054*
Number of Individuals Below Poverty Line	0.3448*	0.2425*	0.2633*	0.3212*

Studies and assumptions further stated that unemployment could also result in physical inactivity, which can further lead to different types of health conditions. A correlation of unemployment with different diseases was intended to be derived. The result of the correlation between the number of unemployed individuals and health conditions like adult obesity, hypertension, diabetes and heart disease were significant at 85%, and the coefficients of the correlation tests tabulated in

	Number of People Commuting by Walking	Number of People Commuting by Biking	Number of People Commuting by Public Transit	Number of People Commuting by Automobiles
Number of Unemployed Individuals	0.0752	0.0679	-0.2359*	-0.1769*
Number of Individuals Below Poverty Line	0.3598*	0.0722	0.0832	-0.1825*
	Number of Individuals With Adult Obesity	Number of Individuals With Hypertension	Number of Individuals With Diabetes	Number of Individuals With Heart Diseases
Number of Unemployed Individuals	0.1701*	0.2724*	0.6655*	0.5054*
Number of Individuals Below Poverty Line	0.3448*	0.2425*	0.2633*	0.3212*

An increase in the number of individuals below the poverty line increases the number of people commuting by walking, due to affordability. The link suggests that an increase in poverty level would decrease automobile usage. A correlation test was progressed between the number of individuals below the poverty line and the number of people commuting by walking and automobiles. The results of the correlation were significant at 85%, and the coefficients are tabulated in

	Number of People Commuting by Walking	Number of People Commuting by Biking	Number of People Commuting by Public Transit	Number of People Commuting by Automobiles
Number of Unemployed Individuals	0.0752	0.0679	-0.2359*	-0.1769*
Number of Individuals Below Poverty Line	0.3598*	0.0722	0.0832	-0.1825*
	Number of Individuals With Adult Obesity	Number of Individuals With Hypertension	Number of Individuals With Diabetes	Number of Individuals With Heart Diseases
Number of Unemployed Individuals	0.1701*	0.2724*	0.6655*	0.5054*
Number of Individuals Below Poverty Line	0.3448*	0.2425*	0.2633*	0.3212*

. A correlation test was progressed to derive the correlation between the number of individuals below the poverty line and the number of people commuting by bicycling and public transit. The results of the correlation were insignificant, and the coefficients are tabulated in

	Number of People Commuting by Walking	Number of People Commuting by Biking	Number of People Commuting by Public Transit	Number of People Commuting by Automobiles
Number of Unemployed Individuals	0.0752	0.0679	-0.2359*	-0.1769*
Number of Individuals Below Poverty Line	0.3598*	0.0722	0.0832	-0.1825*
	Number of Individuals With Adult Obesity	Number of Individuals With Hypertension	Number of Individuals With Diabetes	Number of Individuals With Heart Diseases
Number of Unemployed Individuals	0.1701*	0.2724*	0.6655*	0.5054*
Number of Individuals Below Poverty Line	0.3448*	0.2425*	0.2633*	0.3212*

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The poverty level is also linked with health conditions. There is an assumption that increase in the number of individuals below the poverty line enhances the risks of different health conditions. A correlation test was progressed between the number of individuals below the poverty line and health conditions. The results of the correlation test of the number of individuals below the poverty line with adult obesity, hypertension, diabetes and heart disease were significant at 85%, and the coefficients are tabulated in

	Number of People Commuting by Walking	Number of People Commuting by Biking	Number of People Commuting by Public Transit	Number of People Commuting by Automobiles
Number of Unemployed Individuals	0.0752	0.0679	-0.2359*	-0.1769*
Number of Individuals Below Poverty Line	0.3598*	0.0722	0.0832	-0.1825*
	Number of Individuals With Adult Obesity	Number of Individuals With Hypertension	Number of Individuals With Diabetes	Number of Individuals With Heart Diseases
Number of Unemployed Individuals	0.1701*	0.2724*	0.6655*	0.5054*
Number of Individuals Below Poverty Line	0.3448*	0.2425*	0.2633*	0.3212*

.

Table 14: Correlation of socioeconomic factors with transportation and health factors

	Number of People Commuting by Walking	Number of People Commuting by Biking	Number of People Commuting by Public Transit	Number of People Commuting by Automobiles
Number of Unemployed Individuals	0.0752	0.0679	-0.2359*	-0.1769*
Number of Individuals Below Poverty Line	0.3598*	0.0722	0.0832	-0.1825*
	Number of Individuals With Adult Obesity	Number of Individuals With Hypertension	Number of Individuals With Diabetes	Number of Individuals With Heart Diseases
Number of Unemployed Individuals	0.1701*	0.2724*	0.6655*	0.5054*
Number of Individuals Below Poverty Line	0.3448*	0.2425*	0.2633*	0.3212*

Note: * represents the coefficient of the correlations that termed to be significant at 85%.

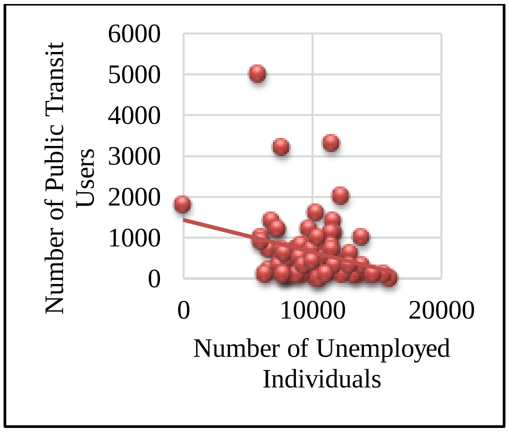

Figure 30: Graphical representation and trend of the relation between public transit users and unemployment rate

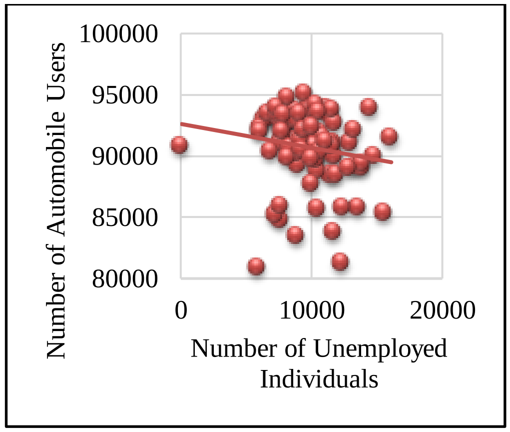

Figure 31: Graphical representation and trend of the relation between automobile users and unemployment rate

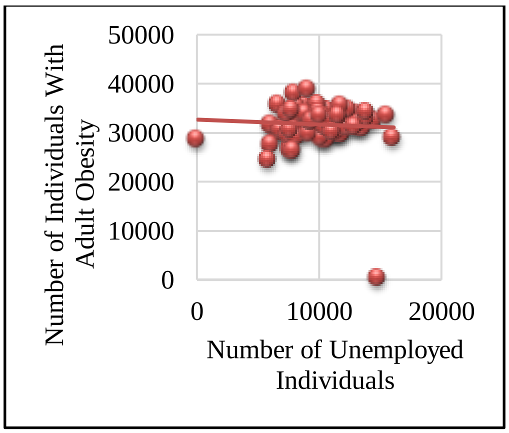

Figure 32: Graphical representation and trend of the relation between adult obesity and unemployment rate

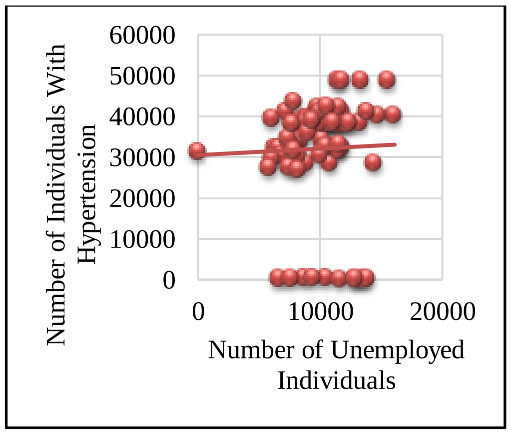

Figure 33: Graphical representation and trend of the relation between hypertension and unemployment rate

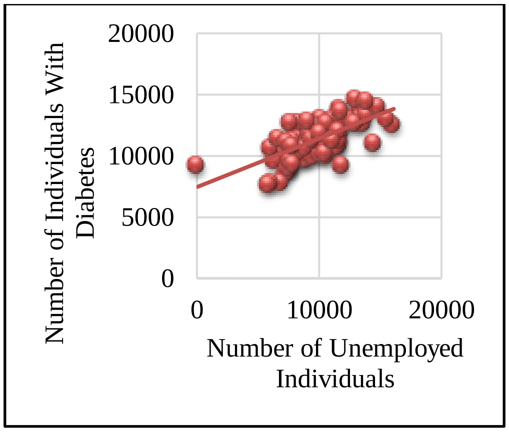

Figure 34: Graphical representation and trend of the relation between diabetes and unemployment rate

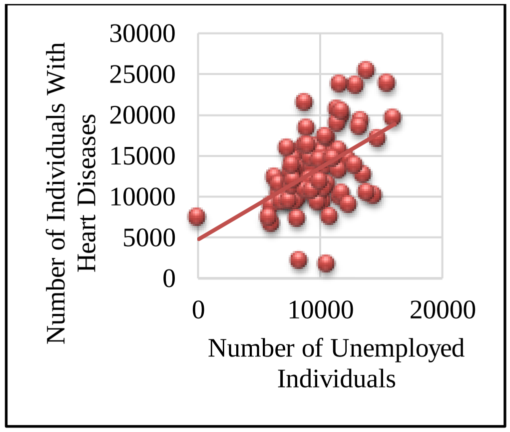

Figure 35: Graphical representation and trend of the relation between heart disease and unemployment rate

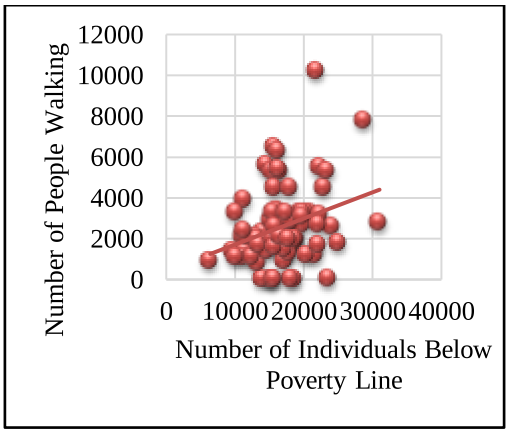

Figure 36: Graphical representation and trend of the relation between pedestrian and poverty level

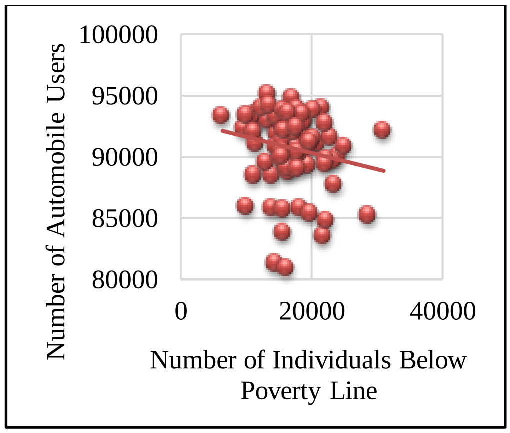

Figure 37: Graphical representation and trend of the relation between automobile users and poverty level

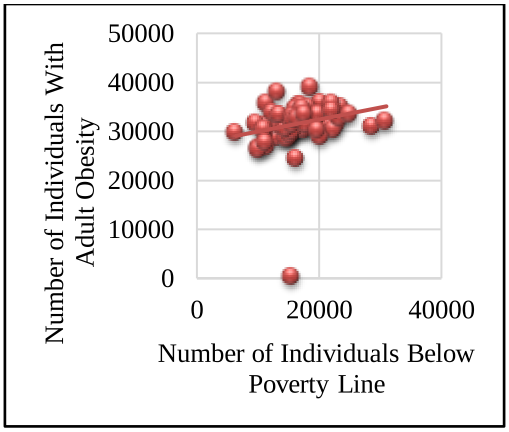

Figure 38: Graphical representation and trend of the relation between adult obesity and poverty level

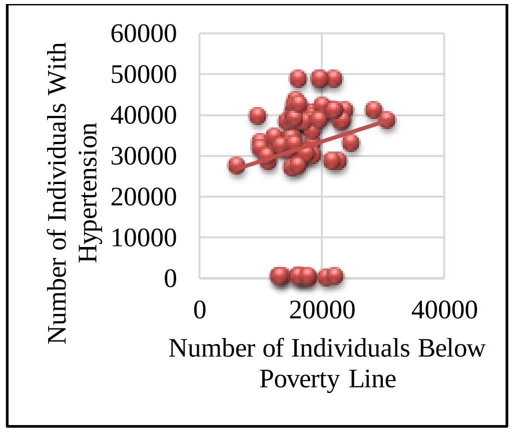

Figure 39: Graphical representation and trend of the relation between hypertension and poverty level

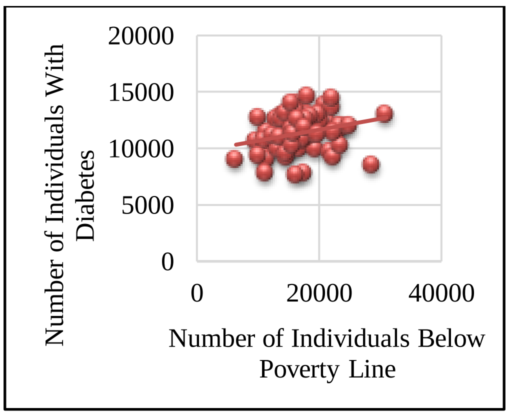

Figure 40: Graphical representation and trend of the relation between diabetes and poverty level

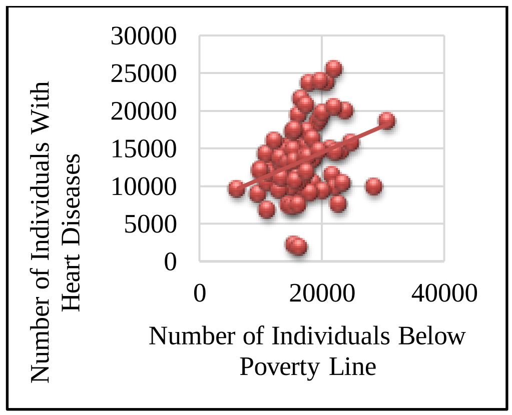

Figure 41: Graphical representation and trend of the relation between heart disease and poverty level

5.1.3 Correlation analysis between health factors and health outcomes

This section elaborates on the illustration and discusses the results from the correlation test between health indicators and health outcomes.

The health literature suggested that an increase in a particular health condition would result in other health disparities. Therefore, the number of individuals with adult obesity were linked to individuals with other diseases like hypertension, diabetes and heart disease and all the correlations when tested were significant at 85%. This evidence justifies the literature with the coefficients tabulated in Table 15.

There are assumptions from studies which stated that an increase in hypertension could result in other health conditions and mortality. The correlation test was progressed to determine the relation between the number of individuals with hypertension, diabetes, heart disease and premature death. All the associations resulted in being significant at 85%. The evidence of this correlation further justifies the literature with the coefficients tabulated in Table 15.

Diabetes is also linked to heart disease and premature death. The increase in diabetes tends to increase the risk of heart disease and premature death. A correlation test was progressed, and the relations were significant at 85%. The coefficients of the correlation are tabulated in Table 15.

An increase in the number of individuals diagnosed with heart diseases is assumed to have an increased risk of premature death. A correlation was progressed, and the relation was significant at 85%. The coefficients of the correlation are tabulated in Table 15.

Table 15: Correlation test results of health factors and health outcomes

	Number of Individuals With Hypertension	Number of Individuals With Diabetes	Number of Individuals With Heart Diseases	Number of Premature Deaths
Number of Individuals With Adult Obesity	0.3940*	0.4246*	0.3080*	-
Number of Individuals With Hypertension	-	0.4531*	0.5496*	0.3701*
Number of Individuals With Diabetes	-	-	0.5715*	0.7077*
Number of Individuals With Heart Diseases	-	-	-	0.6042*

Note: * represents the coefficient of the correlations that termed to be significant at 85%.

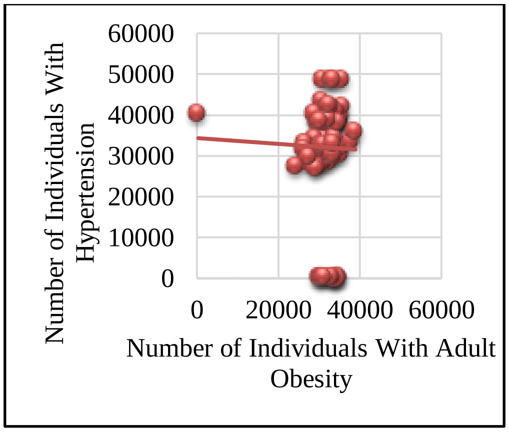

Figure 42: Graphical representation and trend of the relation between hypertension and adult obesity

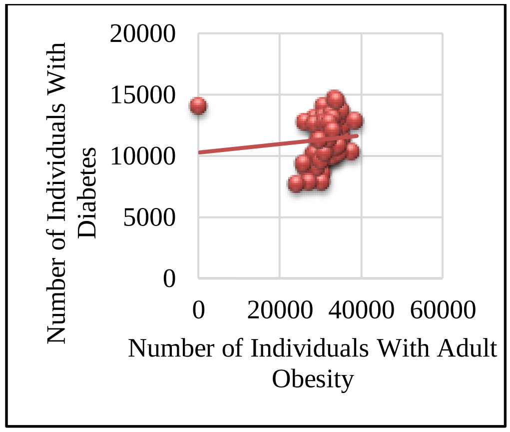

Figure 43: Graphical representation and trend of the relation between diabetes and adult obesity

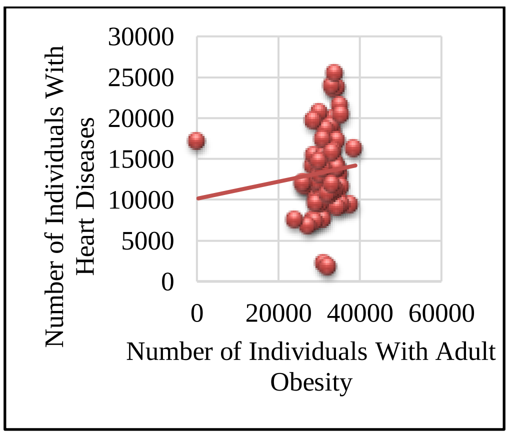

Figure 44: Graphical representation and trend of the relation between heart disease and adult obesity

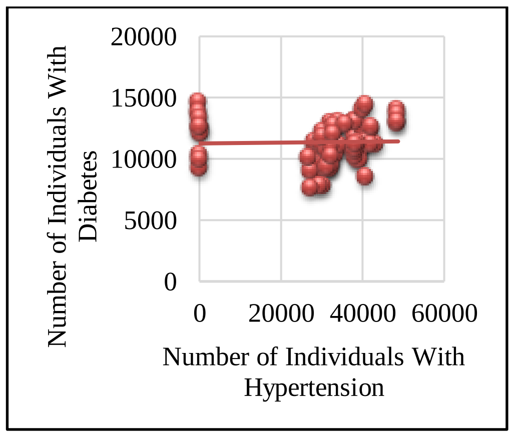

Figure 45: Graphical representation and trend of the relation between diabetes and hypertension

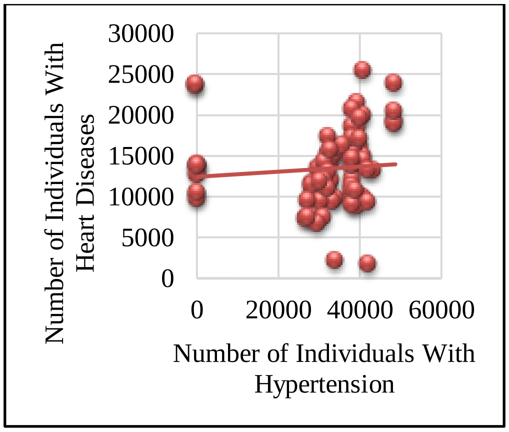

Figure 46: Graphical representation and trend of the relation between heart disease and hypertension

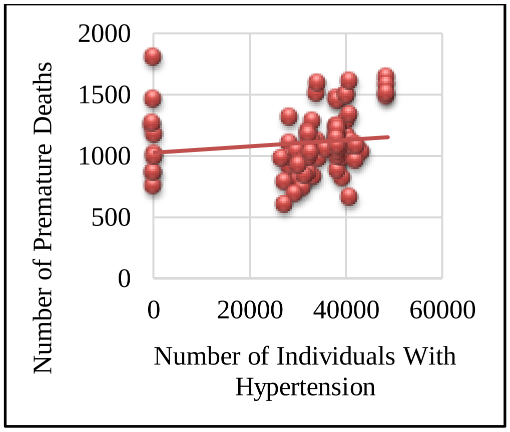

Figure 47: Graphical representation and trend of the relation between premature death and hypertension

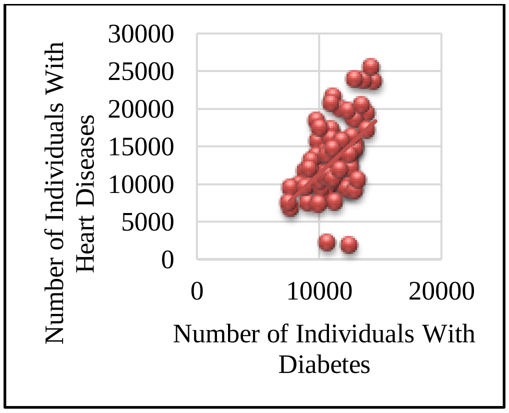

Figure 48: Graphical representation and trend of the relation between diabetes and heart disease

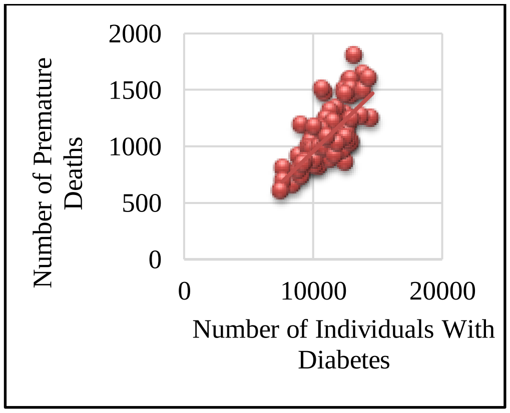

Figure 49: Graphical representation and trend of the relation between diabetes and premature death

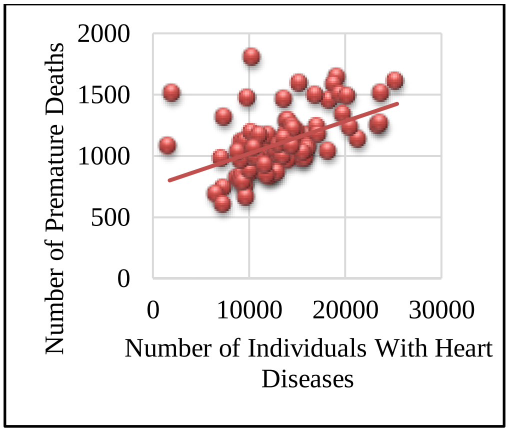

Figure 50: Graphical representation and trend of the relation between heart disease and premature death

5.1.4 Correlation test results of injuries and fatalities with final health outcome

This section elaborates on the illustration and discusses the results from the correlation test between injuries and fatalities from crashes and health outcomes.

Previous studies suggested that an increase in traffic related crashes, injuries, and deaths also constitute to premature death. The correlation was progressed between Injuries and deaths from crashes with premature deaths. The result for the correlation of pedestrian, bicyclist and motorized injuries and fatalities with premature deaths were significant at 85%, with the coefficients tabulated in Table 16. However, the relations between pedestrian and bicyclist injuries and fatalities with premature deaths does not correspond to the relationships derived from literature.

Table 16: Correlation test result of injuries and fatalities with premature death

	Pre-Mature Death
Pedestrian Injuries & Fatalities	-0.3060
Bike Injuries & Fatalities	-0.3946
Motorized Injuries & Fatalities	0.3784*

Note: * represents the coefficient of the correlations that termed to be significant at 85%.

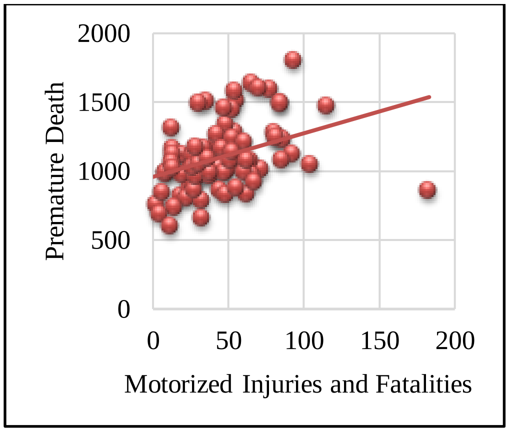

Figure 51: Graphical representation and trend of the relation between premature death and motorized injuries and fatalities

5.2 Modeling and analysis of transportation and health indicators

5.2.1 Modeling all the correlations and factors derived from correlation test

A modeling approach using multinomial linear regression is processed further to investigate the magnitude of the correlation between various factors. The intention was to obtain the significance and coefficients of all the relationships. Once the correlation test is processed, all the correlations that tend to be significant are summarized. These correlations are further processed using the multinomial linear regression technique to see the magnitude of different influence factors have on each other. The multinomial linear regression is employed in Stata to perform the examination of the relation of all individual components with multiple factors. Several components that are dependent on other components are part of the analysis. Multinomial linear regression is used to derive the correlation and dependency of different independent factors on one dependent factor. Contingent on the influence of the grouped multiple independent factors with one dependent factor, different models are derived. The relations of the components insignificant during the multinomial linear regression; they were excluded from the model.

At first, the relation of socioeconomic factors with commute modes was modeled depending on the results obtained from the correlation test. The commute patterns were treated as dependent variables, whereas the social and economic factors were treated as independent variables. Three different models were obtained to determine the links between commute patterns, social and economic factors, which are further explained.

Another analysis was performed on the components from transportation and socioeconomic backgrounds having a relation with health factors. The health factors were treated as the dependent variables in the analysis and the transportation, and socioeconomic factors are treated as independent variables. Two different models were processed using multinomial linear regression to obtain the coefficients and significance of the relations.

Further, an analysis of the influence of socioeconomic and health factors on different health outcomes was modeled. The health outcomes were treated as the dependent variables. While the health factors, social and economic factors were considered the independent variables. Two additional models were generated using the same multinomial regression to obtain the influence on health outcomes, which is further discussed.

Finally, the relations between health outcomes and mortality were modeled using the multinomial linear regression technique to obtain the influence of health outcomes on premature death with coefficients and significance. The final model depicts the end of the correlations with the association of health outcomes to premature death, which was considered the final output link in the study.

Table 17: Results of the multinomial linear regression analysis

	Dependent Factors (Y)							
Independent Factors (X)	Pedestrians (Y1)	Public Transit Users (Y2)	Automobile Users (Y3)	Adult Obesity (Y4)	Hypertension (Y5)	Diabetes (Y6)	Heart Disease (Y7)	Premature Death (Y8)
Poverty Level (X1)	Coeff: 0.14 T-Stat: 3.47 Sig: 99%		Coeff: -0.13 T-Stat: -1.67 Sig: 90%	Coeff: 0.29 T-Stat: 4.90 Sig: 99%	Coeff: 0.49 T-Stat: 3.62 Sig: 99%			
Unemployment (X2)	-	Coeff: -0.07 T-Stat: -2.18 Sig: 95%			Coeff: 0.34 T-Stat: 1.47 Sig: 90%	Coeff: 0.37 T-Stat: 7.44 Sig: 99%	Coeff: 0.44 T-Stat: 2.21 Sig: 95%	

Pedestrians (X3)	-			Coeff: -0.48 T-Stat: -3.13 Sig: 99%	Coeff: -1.57 T-Stat: -4.78 Sig: 99%			
Public Transit Users (X4)	-			Coeff: -0.97 T-Stat: -3.09 Sig: 99%	Coeff: -1.01 T-Stat: -1.45 Sig: 90%			
Adult Obesity (X5)	-					Coeff: 0.15 T-Stat: 3.11 Sig: 99%		
Hypertension (X6)	-					Coeff: 0.05 T-Stat: 2.44 Sig: 95%	Coeff: 0.29 T-Stat: 4.06 Sig: 99%	
Diabetes (X7)	-						Coeff: 0.65 T-Stat: 2.01 Sig: 95%	Coeff: 0.08 T-Stat: 5.96 Sig: 99%
Heart Disease (X8)	-							Coeff: 0.17 T-Stat: 3.28 Sig: 99%
Constant	488.75	1428.036	92963.6	29091.7	29554.41	742.57	-8499.821	-96.654
R-Squared	0.13	0.057	0.0333	0.3313	0.3475	0.57	0.4661	0.5601

5.2.2 Results of the models and discussions

Based on the multinomial linear regression analyses, the following results and models are derived and explained.

Model 1:

The model below depicts how the number of people commuting by walking is dependent on other independent factors by attaining statistical measures.

$Y1 = 488.75 + 0.14X1$

Y1 = Number of People Commuting by Walking

X1 = Number of Individuals below Poverty Line.

The results of the regression model state that an increase in the number of individuals below the poverty line by 10% increases the number of people walking for commuting by 1.4%. The results of the correlation were significant at 99% and are tabulated in Table 17.

Factors like affordability and accessibility compel individuals in neighborhoods with higher poverty level to adopt walking for commuting. Therefore, the intent from transportation should be towards better active commuting, irrespective of the socioeconomic status of the community. The safety and accessibility of pedestrians are the prime focus in a society with higher poverty level. Transportation factors in relation to socioeconomic factors are not the only variables that affect human health.

Model 2:

This model depicts how number of people commuting by public transit are dependent on other independent factors by attaining statistical measures

$Y2 = 1428.03 - 0.07X2$

Y2 = Number of People Commuting by Public Transit,

X2 = Number of Unemployed Individuals.

The results of this regression model state that an increase in the number of unemployed individuals by 10%, decreases the number of people commuting using public transit by 0.7%. The results of the correlation were significant at 95% and are tabulated in Table 17.

The use of public transportation is dependent on employment to a certain extent, and this analysis proves the relation. The literature and the earlier correlation test suggests that the number of people commuting by public transit increases with a decrease in the rate of unemployment. Therefore, the consideration should be towards promoting physical activity for commuting.

Model 3:

This model portrays how the number of people commuting by automobiles is reliant on other independent factors by acquiring statistical measures.

$$Y3 = 92963.6 - 0.13X1$$

Y3 = Number of People Commuting by Automobiles,

X1 = Number of Individuals Below Poverty Line.

The results of this regression model state that an increase in the number of individuals' below the poverty line by 10%, decreases the number of people commuting using automobiles by 1.3%. The correlation is significant at 90%, and the results are tabulated in Table 17.

The correlation test states that an increase in the poverty level would decrease the use of automobiles. The increase in the number of individuals below the poverty line would reduce the use of automobiles, with affordability in context. The intent of transportation system should be towards better active commuting opportunities irrespective of the economic conditions of the community. The decrease in the use of automobiles would promote better health, with a mode shift to active commuting. Safety of commuters is another concern which must be noted.

Model 4:

This model shows how the number of individuals with adult obesity is reliant on other independent factors by obtaining statistical measures.

$$Y4 = 29091.7 + 0.29X1 - 0.48X3 - 0.97X4$$

Y4 = Number of Individuals with Adult Obesity;

X1 = Number of Individuals Below Poverty Line,

X3 = Number of People Commuting by Walking,

X4 = Number of People Commuting by Public Transit.

The following are the results of model 4:

An increase in the number of individuals below the poverty line by 10%, has an increase in the number of people with adult obesity by 2.9%. The results of this correlation are significant at 99% and are tabulated in Table 17.

The increase in the number of people walking by 10%, has a decrease in the number of individuals with obesity by 4.8%. The results of this correlation are also significant at 99% and are tabulated in Table 17.

The results of the correlation between the number of public transit users and the number of individuals with adult obesity state that an increase in the number of public transit users by 10%, decreases the number of individuals with adult obesity by 9.7%. This result is also significant at 99% and is tabulated in Table 17.

The results for all the relations states that increase in the poverty level would increase health disparities. The intent should be towards increasing physical activity from transportation, and the most feasible way to do that is active commuting. Transportation factors are not the only ones that influence the health conditions. Therefore, variables such as nutrition, lack of physical activity for general purposes, etc., which are not a part of this study may also result in health disparities for the individuals below the poverty level.

Model 5:

This model shows how the number of individuals with hypertension is dependent on other independent factors by obtaining statistical measures.

$$Y5 = 29554.41 + 0.49X1 + 0.34X2 - 1.57X3 - 1.01X4$$

Y5 = Number of Individuals with Hypertension,

X1 = Number of Individuals below Poverty Line,

X2 = Number of Unemployed Individuals,

X3 = Number of People Commuting by Walking,

X4 = Number of People Commuting by Public Transit.

The results of model 5:

An increase in the number of individuals below the poverty line by 10%, increases the number of people with hypertension by 4.9%. The relation tends to be significant at 99% with the results tabulated in Table 17.

The increase in the number of unemployed individuals by 10%, increases the number of people with hypertension by 3.4%, with the significance at 90% and the results tabulated in Table 17.

The results also state that an increase in the number of people walking by 10%, decreases the number of individuals with hypertension by 15%, with the significance at 99% and the results tabulated in Table 17.

The increase in the number of public transit users by 10%, decreases the number of individuals with hypertension by 10.1%, with the significant at 90%, and the results are tabulated in Table 17.

The increase in the unemployment and poverty level of different communities correspond with adverse health from socioeconomic factors. The results can relate to the facts that better socioeconomic status tends to provide better modes and means of active transportation, which in turn results in better health. As it is already known that transportation factors are not the only ones that influence health through socioeconomic variables, it is also the nutrition, physical activity from other purposes that can affect health for communities with high unemployment and poverty level.

The results of this model state that an increase in pedestrians and public transit users can decrease hypertension. This factor clearly relates to the physical activity from transportation. Therefore, as noted earlier, the focus of transportation policymakers should be towards providing easy, accessible, and affordable active modes and infrastructure for transportation.

Model 6:

This model shows how the number of individuals with diabetes is reliant on other independent factors by acquiring statistical measures.

$Y6 = 742.57 + 0.37X2 + 0.15 X5 + 0.05 X6$

Y6 = Number of Individuals with Diabetes;

X2 = Number of Unemployed Individuals;

X5 = Number of Individuals with Adult Obesity;

X6 = Number of Individuals with Hypertension.

The result of this model state the following:

The increase in the number of individuals' unemployed by 10% increases the number of individuals with diabetes by 3.7%. The relation is significant at 99%, and the results are tabulated in Table 17.

The increase in the number of individuals with adult obesity by 10%, increases the number of people with diabetes by 1.5%. The significance of the relation is at 99%, and the results are tabulated in Table 17.

An increase in the number of individuals with hypertension by 10%, increases the number of individuals with diabetes by 0.5%. The relation is significant at 95%, and the results are tabulated in Table 17.

The results of the model persuade towards physical activity through active commuting, for the reduction of the associated health risks. Therefore, the risk of diabetes can be reduced by preventing adult obesity and hypertension which can be avoided by active commuting. The measures that need to be considered for active commuting have already been discussed.

Socioeconomic factors are one of the constituents to many chronic diseases, with diabetes being one of them. Unemployment is one of the prime social and economic factors that affects various health conditions. Unemployment is a social and economic factor that may lead to increased health risks. The relation between unemployment and diabetes tends to depict the same relationship as unemployment results in less physical activity and active commuting thereby increasing the risk of diabetes.

Model 7:

This model shows how numbers of individuals with heart disease are reliant on other independent factors by acquiring statistical measures

$$Y7 = -8499.821 + 0.44X2 + 0.29X6 + 0.65\,X7$$

Y7= Number of Individuals with Heart Disease;

X2 = Number of Unemployed Individuals,

X6 = Number of Individuals with Hypertension;

X7 = Number of Individuals with Diabetes

Results of Model 7 are as follows:

The increase in the number of unemployed individuals by 10%, increases the number of individuals at risk for heart disease by 4.4%. The relation is significant at 95%, and the results are tabulated in Table 17.

The increase in the number of individuals with hypertension by 10%, increases in the number of individuals at risk for heart disease by 2.9%. The relation tends to be significant at 99%, and the results are tabulated in Table 17.

The increase in the number of individuals with diabetes by 10%, increases the number of individuals at risk for heart disease by 6.5%. Also, the relation is significant at 95%, and the results are tabulated in Table 17.

Unemployment may increase the risk to heart disease. The relation in the multinomial linear regression suggests that unemployment is one of the contributing factors to heart disease, due to unemployed individuals typically are more sedentary. Therefore, to prevent the risk of heart disease from unemployment, physical activity, and active commuting is to be promoted among all socioeconomic groups.

The analysis also relates hypertension and diabetes with heart diseases and the result states that decrease in the number of individuals with hypertension and diabetes can decrease the number of individuals with heart disease. Therefore, measures of better health from transportation as discussed earlier are to be considered to avoid hypertension and diabetes, which further follows up to heart disease.

Model 8:

This model shows how the number of premature deaths is dependent on various independent factors by acquiring statistical measures.

$Y8 = -96.65 + 0.08\, X7 + 0.17\, X8$

Y8 = Number of Premature Deaths;

X7 Number of Individuals with Diabetes;

X8 = Number of Individuals with Heart Disease.

The increase in the number of individuals with diabetes by 10%, increases the number of premature deaths by 0.8%. The results are also significant at 99% and are tabulated in Table 17.

The increase in some individuals with heart diseases by 10%, increases the number of premature deaths by 1.7%. The relation is significant at 99%, and the results are tabulated in Table 17.

Certain health conditions are related to premature death or early mortality. Reducing the risk of diabetes can decrease the risk of premature death, as illustrated in the model. Physical activity is considered to be the prime factor in this study, and it is one of the root causes of all the health conditions relating to premature death. Physical activity from active transportation is of primary focus in this analysis. Heart Disease is another significant factor relating to premature death. Therefore, similar to other factors causing premature death, measures should be taken to prevent heart diseases to avoid the preventable risks of premature death.

The influence of transportation factors on route to premature death may not be huge but as the results of the study state; transportation elements do have some relations with health conditions that tend to cause premature death. The influence of these factors can be diminished by adopting measure of better health through transportation.

This thesis helps determine how elements from transportation, socioeconomic and health backgrounds connect to mortality. The process of multinomial linear regression determined how the different social and economic factors affect transportation and human health variables. The relations between transportation variables and health factors may result in health outcomes that can cause premature death.

Chapter 6 Conclusion and Recommendations

6.1 Conclusions

The THT was used to provide evidence on what factors related to transportation affect health and what is the conduct of those factors in different Michigan counties. The analysis of the THT in Michigan case provided a better understating on what various factors are to be considered by stakeholders for improvement, depending on their scores. A few suggestions on how some considerations can be incorporated in the THT are also addressed.

The objective of this study was to provide a relation of how different transportation and socioeconomic factors affect human health. The study considered all the assumptions from literature and some basic descriptive studies. They were progressed to derive factors that are sagacious. The study further revealed the correlation of different factors with their significance and the impact on the other factor when linked and analyzed. The result of the analysis provided evidence that elements from transportation and socioeconomic backgrounds have an effect on human health. Studies suggested that transportation infrastructure is not the only factor that is responsible for promoting active modes of transportation. The convenience, features, equity, and connectivity, are some factors which can be focused on to promote the adoption of positive commute patterns.

The challenge is to stimulate healthy and sustainable transport alternatives to prevent the adverse effects of transport systems on human health. A certain way which can be adopted is to ensure that health issues the focus when changes in the transport systems are being made. The reason for this issue not being thoroughly regarded is the lack of analytical tools and data to justify the assumptions as of to what extent and significance transportation system impact human health.

This study provides evidence of how elements from different backgrounds have an adverse influence on each other. Recommendations on different treatment measures that can be undertaken to resolve the queries are further discussed. Promoting the health aspects of transportation not only benefits the community and individuals but also the stakeholders as the concerns such as air pollution from motorized transport, traffic congestion, crashes involving motorized transport and their detrimental health effects can be mitigated.

6.2 Recommendations

The approach should be towards identifying policies that promote the use of cohesive evaluation, supervising the progress and accounting to social and environmental costs which help in the identification of the strategies with considerable benefits. For instance, the complete streets policy can be incorporated into the areas which rank low in different aspects of the transportation system, but a few other considerations should be considered with the adaptation of the new policy. Accessibility and commuting distance is another factor which relates to walking and bicycling. If the ride/bike facilities are well connected, the probability of opting for active transportation mode increases. Apart from land use mix, the livability and lifestyle variables also constitute to mode choice behavior. Therefore, the focus of the transportation system should be towards improving connectivity and accessibility to destinations.

The use of active transportation may increase the risk of traffic-related injuries and fatalities and also health atrocities from air pollution, but the health benefits of this mode are significantly substantial. Transportation policymakers must focus on safe built environment that can promote active transportation. A balanced transport network which incorporates alternative transportation facilities in addition to motorized transportation services can be more efficient and cost-effective. Therefore, every community should consider adopting stable infrastructure with well-designed multimodal commute system that may provide betterment from transportation issues like, safety and air quality to promote better health. Considering and integrating health behavior when planning the transportation system and its goals and objectives gives a cutting edge over the current health issues from transportation.

The increase in the safety of transportation may result in people adopting varying modes by reducing injuries linked to motorized crashes. Improving the air quality by setting new standards for emissions and promoting hybrid and Zev’s may result in benefits from the transportation system. Enhancing the connectivity of public transportation and making it economical can also improve active transportation. The discussion and recommendations correspond to an improvement in the transportation network as it further helps in better health outcomes. Though transportation factors are not the only variables that affect health, other considerations are important which have been discussed in detail in studies with health literature.

6.3 Limitations

This study correlated the relations to the best possible extent, but due to the lack of data and other fundamental issues, the relationships in the model are bounded. For instance, there are some restrictions on the data set that the commute mode data was only for workers. These limitations can be addressed in future studies if data is available for all commuters. The later part of the study is entirely data driven; my perceptions are solely based on literature and statistics.

The air pollution effects of transportation had to be remitted from this study as the data was unavailable. Many factors were proposed to have correlations, but the lack of statistical significance between them resulted in their effacing from the model and analysis. Some results stated that communities with low poverty levels had higher pedestrians and less automobile usage, but the health status of those communities is still deprived. The reason for this may be other factors like nutrition, physical activity for leisure purpose, which is not incorporated in this study due to data restrictions.

This study can be further improved by integrating the infrastructure data and evaluating the behavior of the commuters on it. The data on air pollution can also be incorporated, and the emissions and its health effects can also be determined. This study shows relations among few parameters. An extended study with an addition in the data set can further result in the significance of the parameters that turned out to be insignificant in this study.

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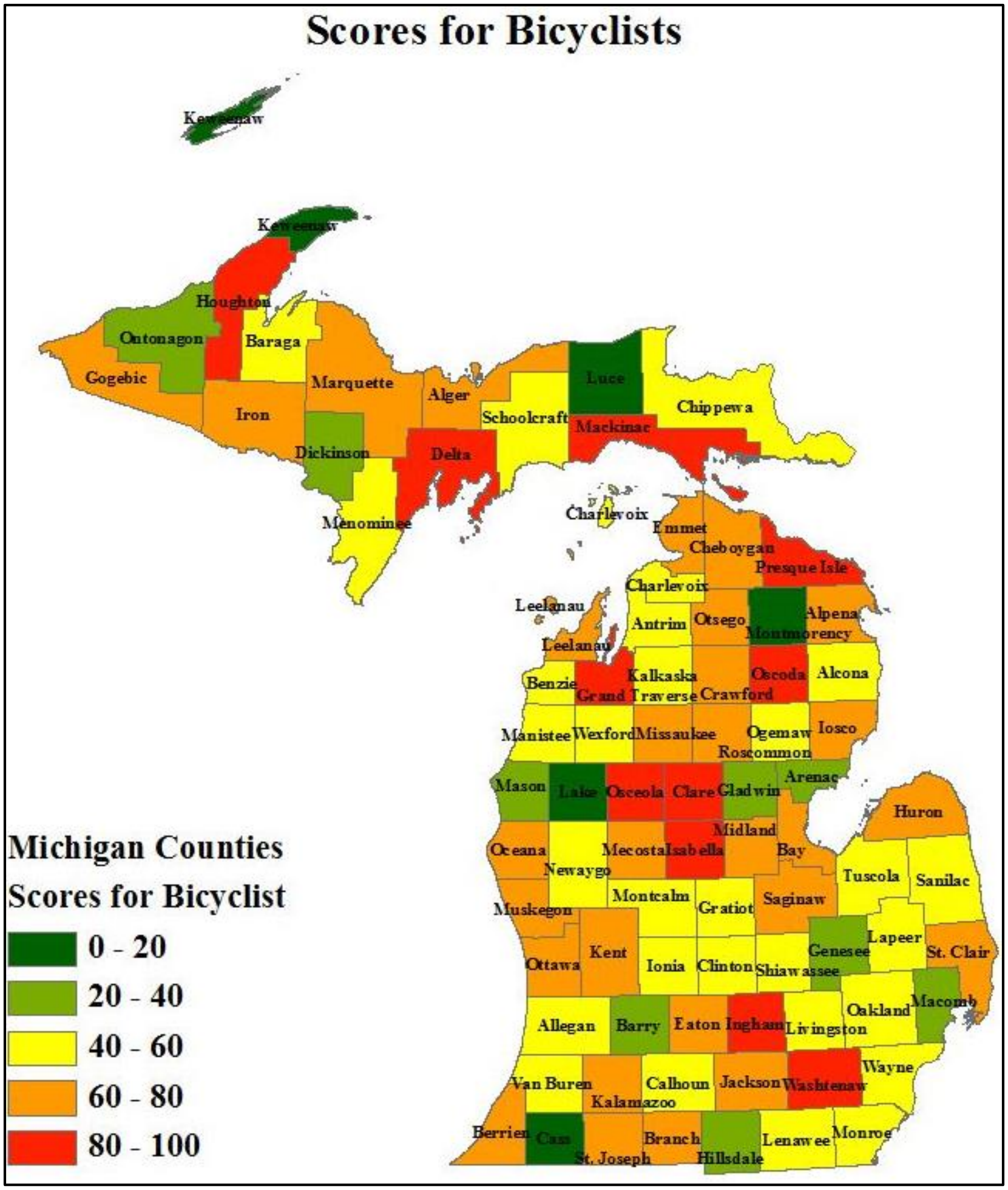
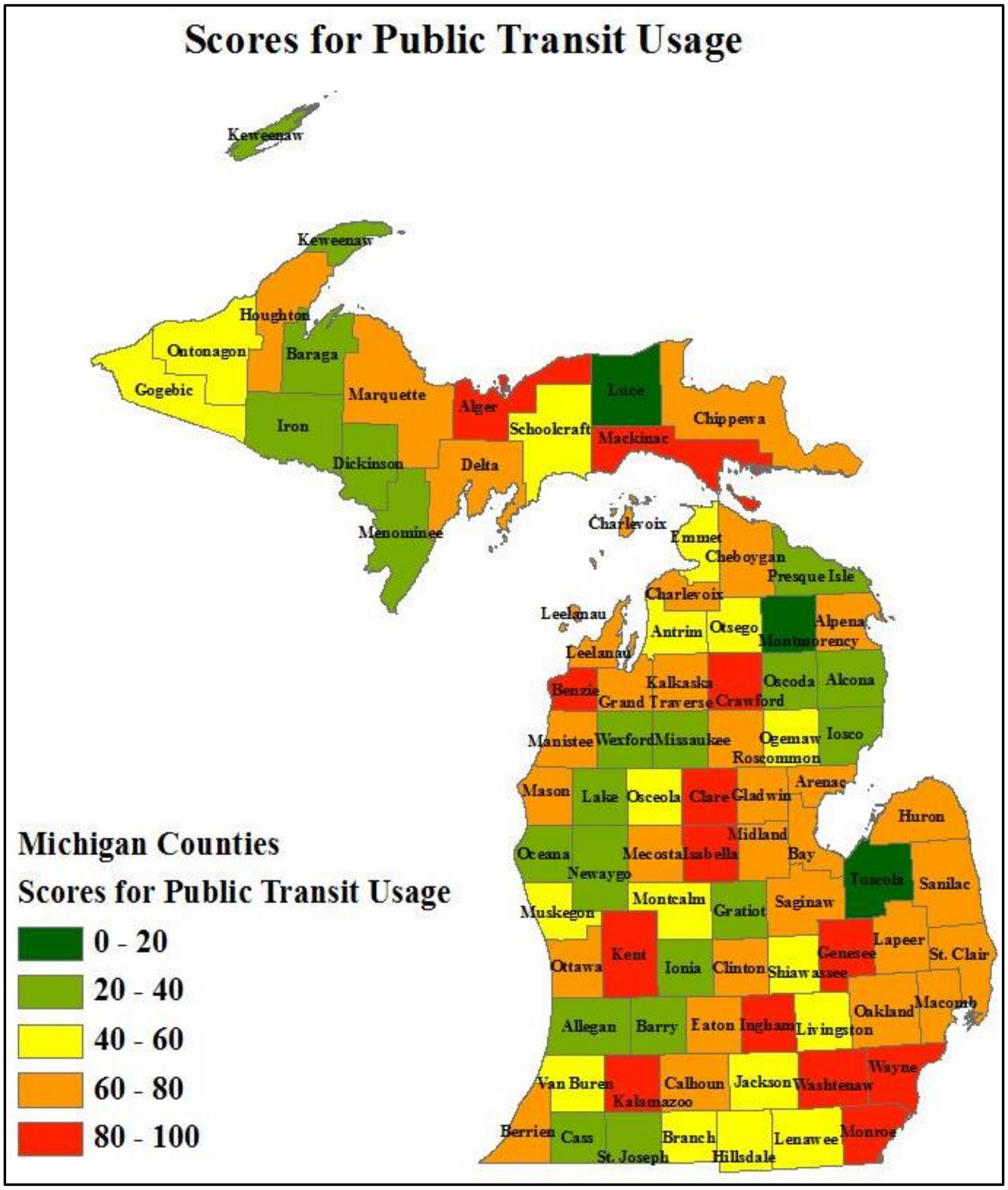
APPENDIX

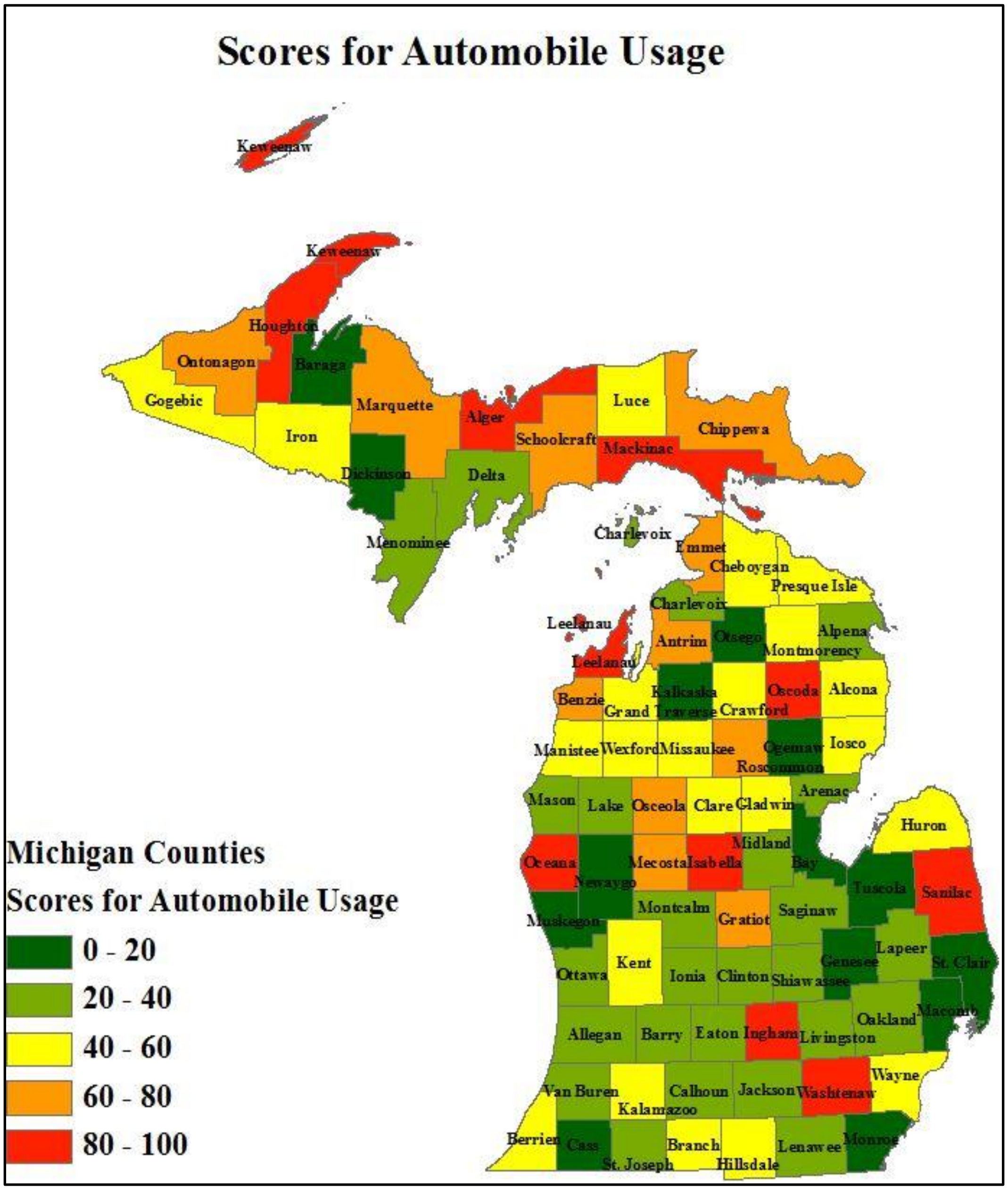
Appendix 1: Map from THT (Michigan case) representing scores for commute mode biked



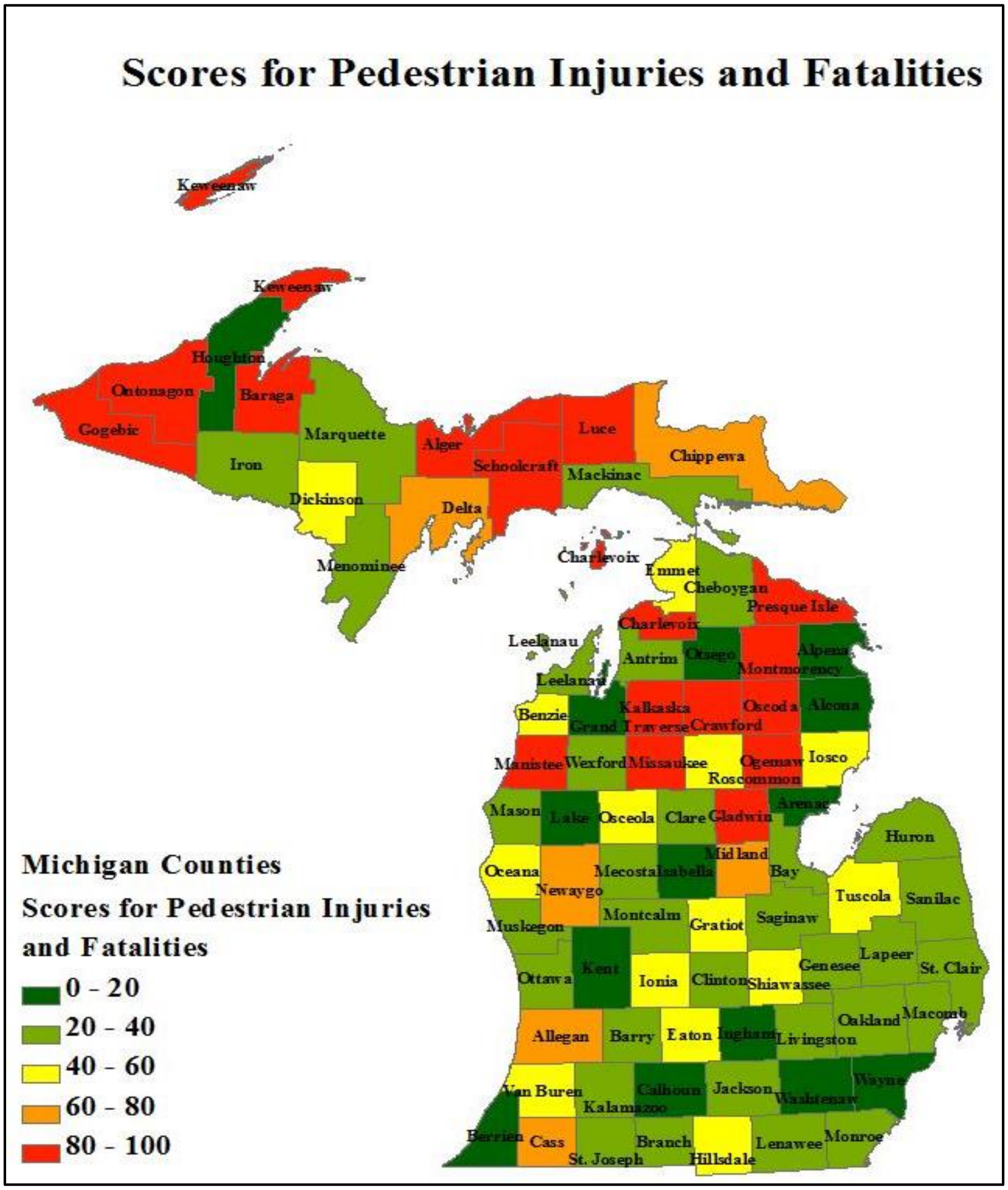
Appendix 2: Map from THT (Michigan case) representing scores for public transit usage



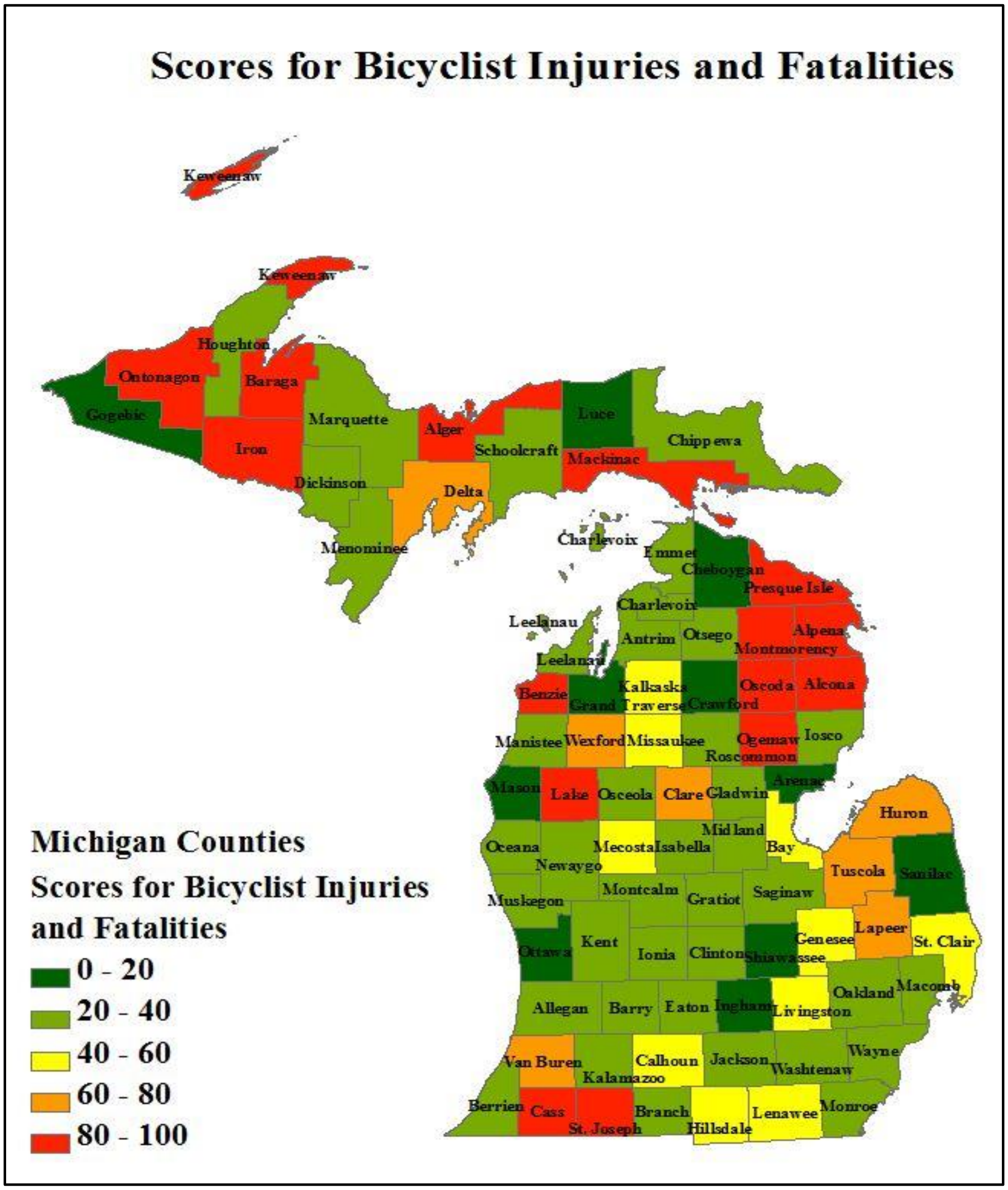
Appendix 3: Map from THT (Michigan case) representing scores for automobile usage



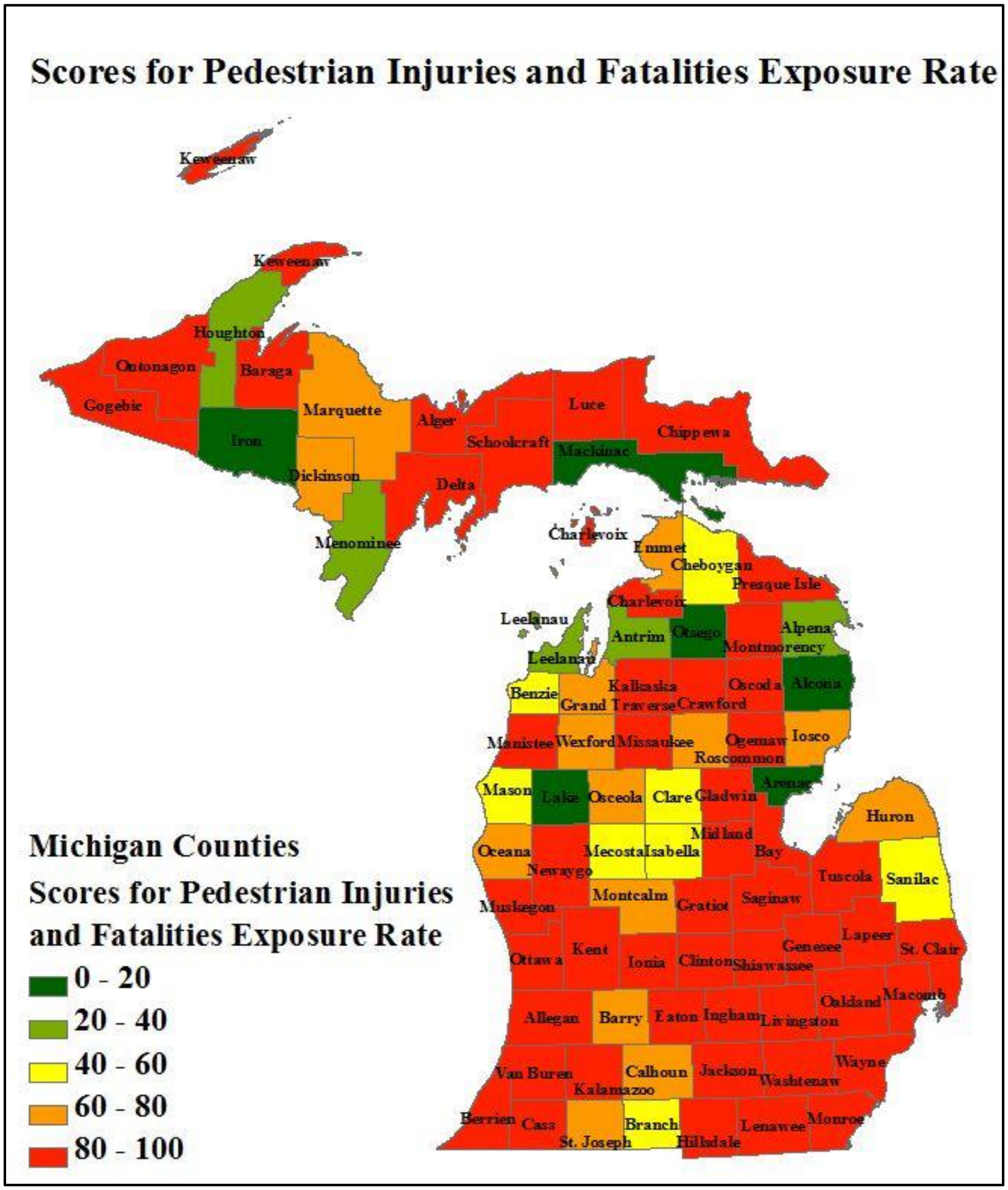
Appendix 5: Map from THT (Michigan case) representing scores for pedestrian injuries and fatalities



Appendix 6: Map from THT (Michigan case) representing scores for bicyclist injuries and fatalities


Scores for Bicyclist Injuries and Fatalities
Michigan Counties
Scores for Bicyclist Injuries and Fatalities
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
Keweenaw
Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Alger
Luce
Chippewa
Iron
Schoolcraft
Mackinac
Dickinson
Delta
Menominee
Charlevoix
Emmet
Cheboygan
Presque Isle
Charlevoix
Leelanau
Antrim
Otsego
Alpena
Montmorency
Leelanau
Kalkaska
Oscoda
Alcona
Benzie
Grand Traverse
Crawford
Manistee
Wexford
Missaukee
Ogemaw
Iosco
Roscommon
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Huron
Midland
Oceana
Mecosta
Isabella
Bay
Newaygo
Tuscola
Sanilac
Montcalm
Gratiot
Saginaw
Muskegon
Genesee
Lapeer
St. Clair
Ottawa
Kent
Ionia
Clinton
Shiawassee
Oakland
Macomb
Allegan
Barry
Eaton
Ingham
Livingston
Wayne
Van Buren
Calhoun
Jackson
Washtenaw
Kalamazoo
Berrien
Cass
Branch
Lenawee
Monroe
St. Joseph
Hillsdale

Appendix 7: Map from THT (Michigan case) representing scores for pedestrian injuries and fatalities exposure rate



Appendix 7: Map from THT (Michigan case) representing scores for bicyclist injuries and fatalities exposure rate