JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION AND PURDUE UNIVERSITY

Economic Effect of Active Transportation Features and the Association Between the Healthcare Industry and Transportation

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16. Abstract

The goal of this project is to help INDOT determine the economic effects of active transportation features, the impact of transportation infrastructure on the healthcare industry, and to explore a potential relationship between active transportation and healthcare. To capture the details thoroughly, the analysis was done at a macro and micro level. We identified relevant attributes based on existing studies and captured the county-level data for these attributes from public sources. A regression analysis was performed at the macro-level to understand relationships and trends. In the micro-view, the analysis aimed to investigate the impact of active transportation investments on business growth and the impact of transportation investments on trip patterns and healthcare growth at a granular level of ZIP Code Tabulation Areas (ZCTAs). Large-scale datasets were analyzed to extract key metrics, which were tested for changes due to investments in the region. A Difference in Differences (DID) model was used to analyze causal effects, and trends of individual ZCTAs were analyzed against their corresponding demographics. Insights were developed and recommendations were made to INDOT based on the analysis regarding macro trends and factors impacting the transportation features. Practical recommendations for transportation investments and their corresponding effects were provided to INDOT based on the micro analyses.

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NOTICE

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COVER IMAGE

Zirkel, K. C. (2018, April 2). *New bike lanes in Roger Williams Park, installed June 2017. Northbound car traffic on the far left, and separate lanes for runners, and cyclists. Roger Williams Park, Providence, Rhode Island* [Photograph]. Wikimedia. https://commons.wikimedia.org/wiki/File:Bike_and_pedestrian_lanes_in_Roger_Williams_Park.jpg#/media/File:Bike_and_pedestrian_lanes_in_Roger_Williams_Park.jpg

EXECUTIVE SUMMARY

Introduction

The goal of this project is to enable the Indiana Department of Transportation (INDOT) to determine the economic effects of active transportation features, to determine the impact of the overall transportation infrastructure on the healthcare industry, and to explore a potential relationship between active transportation and healthcare. To capture the details thoroughly, the analysis was done at a macro and micro level. For the macro view, we identified relevant attributes based on research studies and captured county-level data for these attributes from public sources. A regression analysis was performed at the macro-level to understand relationships and trends.

In the micro-view, the analysis aimed to investigate the impact of active transportation (AT) investments on business growth and the impact on trip patterns and healthcare growth at a granular level of ZIP Code Tabulation Areas (ZCTAs). Large-scale datasets were analyzed to extract key metrics, which were tested for changes due to investments in the region. A Difference in Differences (DID) model was used to analyze causal effects, and trends of individual ZCTAs were analyzed against their corresponding demographics. Practical recommendations for transportation investments and their impact were provided to INDOT based on these analyses.

A detailed literature review was performed, as highlighted in Sections 2.1 and 2.2 of the report, to understand the current status of active transportation and the footprint of the healthcare industry in Indiana. Several studies were reviewed to understand the actions of other Departments of Transportation (DOTs) and state agencies where active transportation has improved the state economy and transportation infrastructure has boosted the healthcare industry.

Findings

Using the data collected, a regression analysis was performed to identify and establish the relationship between active transportation and the county's economy. The analysis was performed using various active transportation metrics (trail miles, number of trails, active transportation investment, etc.) against economic metrics (GDP, employment, number of firms, etc.). A relationship was identified between these metrices that presents the economic impact of active transportation features. The results in Section 5.1.2 of the report indicate that there are several benefits to having active transportation features in manufacturing, finance, and real estate industries, implying that a strong economic relationship exists between these industries and active transportation.

This study utilized passive datasets and causal analysis models to examine changes in business growth and trip patterns resulting from active transportation investments at a spatially granular level of ZCTAs. The results in Section 5.2 show that active transportation had a positive impact on the growth of healthcare, education, and hospitality and recreation industries, particularly in low-income regions. Bike lanes were found to have the highest growth impact on healthcare and education services in low-income and middle-income areas, while trails were found to have the highest growth impact on hospitality and recreation and professional, scientific, and technical services in low-income areas.

Regression analysis was also performed to understand the relationship between the transportation features and the healthcare industry. The analysis was performed using various transportation metrics (trail miles, transportation investment, road miles, etc.) against the economic metrics (employee payroll, number of firms, ambulatory service locations, etc.). The results indicate that improved transportation infrastructure enables ease of access to healthcare, and that the healthcare industry is driven mostly by population and thus infrastructure development should be focused on populous regions, as highlighted in Section 5.1.7 of the report.

We analyzed the impact of overall transportation investments on healthcare business growth, usage of healthcare facilities, and trip patterns at a spatially granular level of ZCTAs. Our findings indicate that healthcare businesses tend to be more beneficial in terms of growth due to increased overall transportation investments in high-income areas, while non-local visitors primarily drive the impact of these investments on healthcare facility usage in low and middle-income areas. We also observed that trip generation during morning rush hours was generally higher in the suburban areas of several cities in Indiana.

Implementation

Based on the results obtained, we conclude that there are economic benefits, in addition to other benefits, of active transportation and it would be beneficial for INDOT to invest in active transportation specifically to boost the real estate industry at the macro level. The study also suggests investing in active transportation in the regions where the GDP and population are high because of a higher potential for further improvement.

We observe that, at the micro level, investments in active transportation had varying effects on different industries. The net change in healthcare and education-based establishments showed positive associations with lower population density, higher median income, and active transportation investment costs, which suggests that active transportation investments can enhance economic development in less densely populated and higher-income areas. Additionally, the type of active transportation investment significantly influenced the changes. For instance, bike lanes were associated with increased service-based establishments, while trails had a negative impact. Understanding these nuances are crucial for informed policy decisions regarding active transportation investments and their potential economic benefits in various sectors.

Furthermore, the findings reveal that transportation investments have significant effects on trip generation, both in terms of overall trips and during morning rush hours. Transportation investments have a positive impact on healthcare utilization, with increased visits to healthcare-related points of interest in rural and suburban areas, especially around Evansville, South Bend, and Gary. Healthcare establishment changes, particularly in small healthcare businesses, also vary with transportation investments, which indicate that tailored strategies are necessary for different income regions. These findings suggest that transportation investments can enhance access to healthcare services and promote economic growth, especially in underserved areas. However, the unique characteristics of each region need to be carefully considered in policy planning to maximize their impact.

In summary, this study provides a data driven approach that elaborates on the economic benefits of active transportation, establishes the relationship between overall transportation infrastructure and the healthcare industry, and also explores the relationship between active transportation and the healthcare industry. This report is instrumental for INDOT to understand important transportation-related impacts on the economy and can be used as a basis for further investigations that enable INDOT to implement actions in correspondence with these results.

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1. INTRODUCTION

1.1 Link Between Active Transportation and Thriving Businesses

1.1.1 General Introduction

According to Indiana Department of Transportation's Bicycle and Pedestrian Program (INDOT, 2022) currently has more than 3,268 miles of trails and bikeways. INDOT, under the *Indiana Department of Natural Resources (DNR) plan, Hoosiers on the Move: The Indiana State Trails, Greenways and Bikeways Plan* undertaken in 2006, set a goal to build a trail within 7.5 miles (or 15 minutes) of all Indiana residents by 2016. This goal was realized in 2013 with 97.9% of all Indiana residents living within 7.5 miles of a trail and 93.2% living within five miles of a trail. In addition, nearly 1,000 miles of State Visionary Trails were built in the state. Indiana boasts several longest rail-trails that amplify tourism, healthy lifestyle, and economic development, not just limited to around the trails but to surrounding communities as well, among other benefits.

INDOT plans to continue its commitment to advancing and promoting multimodal and active transportation planning, keeping pace with the nation as US sees a $45 million grant for the 2023 fiscal year, followed by up to $200 million a year for the next 5 years under the Active Transportation Infrastructure Investment Program which is a part of Consolidated Appropriations Act (Wilson, 2022).

Several studies have suggested the importance of active transportation features on economic competitiveness at both local and state levels. This study aims to explore the economic effects of active transportation in terms of the growth in industries across Indiana. The study will be carried out at a macro and micro level to investigate how active transportation is linked to a region's economic viability. The study is expected to recommend INDOT how it can plan and develop the active transportation infrastructure in the state such that it boosts the state's economic viability and makes Indiana economically competitive.

1.1.2 Macro-View

Phase 1 focused on preparing a macro view using a scenario-based approach through 2050. The team performed literature review by referring to the material and studies related to active transportation and its impact on a region's economic viability, at a macro level. The team then performed benchmarking by reviewing the active transportation status in other states and exploring how it is related to those state's economy. The team collected data regarding active transportation inventory through the corresponding state's, industry locations, supply chain capabilities, etc. Using this data, the team analyzed the current status of active transportation in Indiana in terms of trail miles, number of trails, ongoing projects, active transportation investment, etc. Once the team established the current scenario of active transportation in Indiana, the team explored its influence on the state economy and specific industries. The team performed linear regression analysis to identify the relationship between economic and active transportation parameters. The effects of active transportation features on a region's economic viability are presented as results based on the analysis for INDOT's review.

1.1.3 Micro-View

Phase 2 of the analysis aimed to investigate the impact of active transportation investments on business growth at a granular level of ZIP Code Tabulation Areas (ZCTAs). The team conducted a thorough review of datasets related to active transportation and businesses and performed data cleaning and preprocessing to identify useful information and patterns. The team analyzed data to gain insights and identify causal relationships between active transportation investments and business growth. Various causal inference modeling frameworks were reviewed, and the most suitable model was selected to assess the increase in the number of industry establishments. Factors considered included active transportation investments across different industries and types of transportation such as sidewalks, bike lanes, and trails. The results were analyzed based on population density, unemployment rates, urbanization, and income levels to determine patterns and overall changes in business growth. The study focused on ZCTAs and involved both low-income and high-income regions.

1.2 Connection Between Transportation Investments and Healthcare Businesses

1.2.1 General Introduction

The United States has the highest spending on healthcare—18.3% of GDP in 2021. U.S. national healthcare spending, which stood at $4.3 trillion in 2021 ($12,914/person), is expected to reach $6.2 trillion by 2028 according to Centers for Medicare and Medicaid Services and reach nearly $12 trillion by 2040, about 26% of GDP, according to research by Deloitte (Insider Intelligence, 2021).

According to U.S. News based on 2019 data, Indiana is ranked #32 in the U.S. for healthcare availability which includes attributes like healthcare access, healthcare quality, public health (USNews, 2020). Indiana's population has a median age of 37.8 years in 2023 and ranks 16th in the country (Worldpopulationreview, n.d.). Despite Indiana having a higher rank in median age, 16.4% of Indiana population in 2022 was 65 years and over according to U.S. Census Bureau (n.d.).

It is important for Indiana to not overlook the importance of the healthcare industry, especially after the pandemic and create an opportunity to become the highest ranked state in healthcare. This study takes up that challenge and addresses how INDOT, through transportation, can increase the presence of healthcare industry in Indiana.

1.2.2 Macro-View on a County Level

Phase 1 focused on performing the analysis at the macro, or county, level. The main objective was to explore how improvements to transportation infrastructure can attract the healthcare industry and enable it to grow in Indiana. This involved identifying county specific healthcare metrics like healthcare employee payroll, healthcare Medicare reimbursements, number of healthcare firms, number of ambulatory services, etc. and transportation metrics like roadway miles, county miles, local miles, trail miles and determining the potential underlying relationship between transportation infrastructure and healthcare industry. This analysis at the macro level was performed through regression analysis of the identified attributes. The team also performed literature review of studies that explored this relationship. Conclusions and recommendations about the impact of transportation infrastructure on healthcare industry are presented for INDOT's perusal based on the analysis.

1.2.3 Micro-View of ZCTAs

Phase 2 of the analysis aimed to examine the impact of transportation investments on trip patterns and healthcare growth at a fine-grained level of ZCTAs. To achieve this, large-scale datasets containing information about trip patterns and healthcare facilities were analyzed, and key metrics were extracted. These metrics included trips generated in the whole dataset, trips generated during morning peak hours, number of people visiting healthcare facilities, number of people visiting healthcare facilities from outside the ZCTA, number of healthcare businesses, and number of small healthcare businesses. These metrics were extracted for multiple years and tested for changes due to transportation investments in the region. To analyze the causal effects of transportation investments, a Difference in Differences (DID) model was used. Changes in trip patterns and healthcare facility usage and growth due to transportation investments were observed for the whole state and for individual ZCTAs. The trends of individual ZCTAs were analyzed against their corresponding demographics, and differences between impacts in low and high-income regions were also reported. The results were assessed, and practical recommendations for transportation investments and their corresponding effects were provided to INDOT.

1.3 Relationship Between Active Transportation and the Healthcare Industry

In addition to the study's two objectives, as described above, impact of active transportation features on a region's economic viability and identify the relationship between overall transportation and the state's healthcare industry, services, and access, the study also aims to evaluate whether a relationship exists between the economic impact of active transportation features on the healthcare industry, services, and access.

This section provides an introductory description of the study, briefly discussing the problem statement, objectives, methodology, analysis, and the results for INDOT.

2. LITERATURE REVIEW AND BENCHMARKING

2.1 Active Transportation

There are several benefits of active transportation—economic, environmental, health, etc. Among many, we are exploring the economic benefits. These economic benefits include lower transportation costs, increased property values, savings from reduced wear and tear to roads and infrastructure and reduced local congestion.

Reduction in local congestion is a key benefit that INDOT can use to its advantage (Castillo, 2019). Low congestion enables traffic to move quickly and thereby reduces any delay faced by motorists and prevents loss of productivity. This is especially attractive to industries as this allows them to move their goods around easily. The benefits are amplified for the retail industry that commits to quick delivery, utilizing the last mile stretch to make them happen. In addition to the direct benefits to industries, the reduced congestion also benefits the critical services in the city (law enforcement, emergencies, etc.). The ease of congestion near critical locations (hospitals, schools, fire stations, police stations) makes the city and thereby the state attractive to the industries, thus adding to the state's advantage and making it more competitive.

According to rails to trails, one of the key benefits of active transportation is fostering economic health (Indiana Department of Natural Resources, n.d.b.). Active transportation improves the quality of life and creates a dynamic, physically active, and connected community that prompts small business development. As more and more people consider active transportation to be a key feature of the community, increased investment in active transportation attracts corporate investment that in turn attracts a talented and highly educated workforce.

Transportation and Real Estate: The Next Frontier, a project by Urban Land Institute, explores the relationship between walking, bicycling, and real estate (Urban Land Institute, 2016). This report refers to the Urban Land Institute's *America in 2015* report and the U.S. Census to highlight that accessibility to walking and bicycling are top priorities for more than 50% of U.S. residents when considering where to live and active transportation has become the fastest growing form of transportation. The report also states that the U.S. Census data showed that the number of people who traveled to work by bike increased roughly 62% between 2000 and 2014. The report provides four ways in which bike lanes and active transportation boost economic growth that are detailed below.

With the growing city population, vehicle congestion becomes a challenge that can be resolved by investing in active transportation infrastructure and developing bike and pedestrian paths. This would boost the surrounding real estate value. This is supported by a 2014 study conducted by the Indiana University Public Policy Institute on Indianapolis Cultural Trail. Since the opening of the trail in 2008, the value or properties surrounding the trail increased by 148%. Other such cases can be found in Dallas, Texas and Radnor, Pennsylvania, as well as many other cities across the U.S.

The availability and access to the trails and bike lanes attracts talented workers to the city, thereby helping the companies grow their footprint. This is due to the increasing popularity and the health benefits of physical activity that more people are taking into consideration.

The increase in presence of active transportation features would attract more residents to use the features and thereby improving their health and productivity. In addition to reducing the healthcare costs due to staying healthy and fit, increased productivity would also boost the regional economy, enabling the companies to grow more.

A well-connected active transportation infrastructure encourages residents to use the pedestrian path and bike lanes more often, thereby increasing the number of trips taken to retail stores. This results in an increase in sales volume and hence boosts growth of the retail sector in the region. Increased usage of active transportation features also reduces vehicle trips and thereby the usage and need for parking spots. This increases the availability of parking for bikes and thereby allows more traffic into retail establishments and increases their visibility.

2.1.1 Ohio's Active Transportation Plan

Ohio Department of Transportation (ODOT) launched the state's first statewide bicycle and pedestrian plan—*Walk.Bike.Ohio Policy Plan*, in 2021 following a public engagement survey conducted in 2019 and inputs from local governments and other state agencies (Center for Environmental Excellence, 2021). This framework aims to advance statewide development of active transportation over the next 5 years through improving mobility, safety, and quality of life by implementing policies in walking and bicycling infrastructure, maintenance standards, and programs.

According to the survey, 1 in every 10 Ohio households does not own or have access to a motor vehicle. This makes active transportation a basic need for these residents. Ohio also noticed a decline in the number of 16- and 17-year-old drivers by 16.83% from 2016 to 2020. In addition, the population over 65 in Ohio continued to grow. Both of these demographics would be heavily dependent on active transportation and transit.

As part of development of the plan, an economic analysis was completed that suggested that existing trips by foot or bike would save Ohio residents $12.7 billion in transportation and environmental costs over the next 20 years. Additionally, an increase in walking and biking by over 1% could save $5 billion over the next two decades. In addition to the economic benefits, the effort to prepare the plan also determined that a well-connected active transportation network would improve the Ohio residents' overall health, reducing obesity and physical inactivity.

The Mid-Ohio Regional Planning Commission (MORPC) developed a 2016–2040 Active Transportation Plan which has been revised to 2020–2050 Active Transportation Plan that helps with the planning and implementation of pedestrian, bicycle, and transit infrastructure related projects in the region, among many others (MORPC, 2020). Increased safety, improved level of comfort, expanded connectivity, and increased access to active transportation are some of the goals of this plan.

According to the plan developed, several action plans are drafted to achieve the goals of the plan. These action plans involve encouraging and promoting active transportation infrastructure development plans (MORPC, 2020).

2.1.2 New Hampshire Department of Transportation–NHDOT

The *New Hampshire DOT Statewide Pedestrian & Bicycle Transportation Plan and Economic Impact Study* explores the hypothesis that "Pedestrian and bicycle infrastructure in New Hampshire generates financial benefits and contributes to the statewide economy in several ways" (The League of American Bicyclists, n.d.). The study suggests that pedestrian and bicycle infrastructure supports the state economy by creating construction-related jobs, supporting bicycle and pedestrian-oriented businesses, attracting tourism spending, and providing value for adjacent residential properties. The analysis was divided into five parts that are discussed in detail.

1. *Economic impacts of capital investment:* An average investment of $11 million per year from 2016 to 2018 by the New Hampshire Department of Transportation on pedestrian and bicycle infrastructure projects has resulted in over 130 jobs. After including the impacts associated with supplier purchases and employee spending, the investment has resulted in $8.5 million in labor income and $21 million in business sales in the state's economy.
2. *Economic contribution of pedestrian and bicycle-oriented businesses:* Pedestrian and bicycle-oriented businesses in New Hampshire contribute significantly to the state's economy. The businesses in this category are responsible for 240 direct jobs and an estimated $35.4 million in annual sales. When supplier purchases and employee spending are factored in, the economic impact of these

businesses increases substantially. They are responsible for an estimated 335 jobs and $48.7 million in sales. This suggests that supporting these businesses can have a positive impact on the overall economy of New Hampshire.

3. *Economic impacts of bicycle tourism:* In 2018, an estimated 200,000 out-of-state visitors came to New Hampshire for bicycle tourism, with an estimated $28 million spent overall. Accommodations and food and beverage were the top spending categories, and bicycle tourism supported 269 jobs and over $8 million in labor income. Including the additional impacts associated with supplier purchases and employee spending, bicycle tourism contributed to the state's economy by supporting nearly 400 jobs, $14 million in labor income, almost $24 million in value added, and over $43 million in business sales.
4. *Benefits of non-motorized travel:* Savings of $2.1 billion (or an average of $105 million per year) in transportation, environmental, and health costs is estimated for the residents of New Hampshire over the next 20 years by existing pedestrian and bicycle trips that replace motorized vehicle trips. Cost savings for households, congestion reduction, roadway maintenance, and reduced collisions are some of the benefits of transportation. Reduction in vehicle miles travelled helps save New Hampshire residents $1.9 billion in transportation costs over a 20-year period. In addition, it prevents 1 million metric tons of greenhouse gas and criteria pollutant emissions ($70.1 million mitigation savings), and an estimated $176.0 million in healthcare cost savings.
5. *Property values:* In addition to quantitative benefits, pedestrian and bicycle facilities also provide qualitative benefits such as quality-of-life, which can make a community more desirable to live in. Higher property values are expected over time, with this increased desirability.

2.1.3 Home Sales Near Two Massachusetts Rail Trails

The study, conducted by American Trails (Penna, 2018), collected information like number of properties sold, average listing price, average sale price, ratio of sale to list, number of days on the market, etc. for various properties near trails and not so near to trails to understand the impact of trails on real estate.

The article discusses the increasing desirability of homes located near rail trails and how it affects their sale price and time on the market. The results show that houses near the trail sell for higher than the asking price and in about half the time that general inventory houses take to sell.

The ratio of sale price to list price favored homes near rail trails in some counties in Massachusetts. The study analyzed home-sale data for seven eastern Massachusetts towns for the period from June to September 2005. Averaging over all the home sales in the seven towns, the ratio of sale to list price favors homes near rail trails by 99.3% as compared to 98.1% for other home sales. For all the towns in Massachusetts together, the homes near rail trails were on the market for an average of 29.3 days compared to other homes that were listed on the market for 50.4 days, which is a difference of three weeks. The data for the sale of houses near the rail trails strongly suggest the assertion that rail trails improve the quality of life and thereby are favorable.

2.1.4 Takeaways

Based on literature review, it is determined that there are several benefits of active transportation. While a substantial investment is required for the development of active transportation infrastructure, the benefits overcome the cost. This is realized from the benchmarking analysis performed. Active transportation can be seen to have multi-fold benefits such as reduction of congestion, increased economic activity in several industries through direct and indirect impact, increased attractiveness for homebuyers and thereby property prices. Thus, this section helps comprehend the several benefits of active transportation features and helps to identify the specific benefits that can be realized for INDOT. It also guides the further analysis by suggesting what parameters and metrics should be considered.

2.2 Healthcare Industry

The economic standpoint of an industry is represented by the gross domestic product (GDP) metric and how much the corresponding industry sector is contributing to the overall GDP of the country. Gross Domestic Product (GDP), which totals spending on all final products and services bought by individuals, firms, governments, and foreigners in a country, is a measure of economic activity. Each of the five categories of expenditures—healthcare, housing, food, education, and all other goods and services—measures the final demand for that particular goods and services.

While studying the trends of contribution of healthcare industry and transportation industry to the overall US GDP, the publishers recommend key highlights with the parameters that influence the individual industry sector's contribution (Bureau of Transportation Statistics, n.d.). The trends of contribution of different industry sectors as a percentage of US GDP is depicted in Figure 2.1.

Spending on transportation (the amount of GDP that may be ascribed to the demand for transportation) is lower than spending on every other sector except education. Transportation still proves to be the most crucial industry sector to drive the economy of the region. For instance, transportation provides firms with the raw materials they need to make their products. Further, transportation provides the infrastructure to facilitate the movement of raw materials, goods, and services to all the industrial value chains. Based on this excerpt, we believe transportation does play a critical role in providing better means of support in terms of infrastructure, emergency movements, strategic location identification for healthcare industry.

In order to promote and preserve health, prevent, and manage diseases, and work toward health equity for all Americans, access to healthcare is essential.

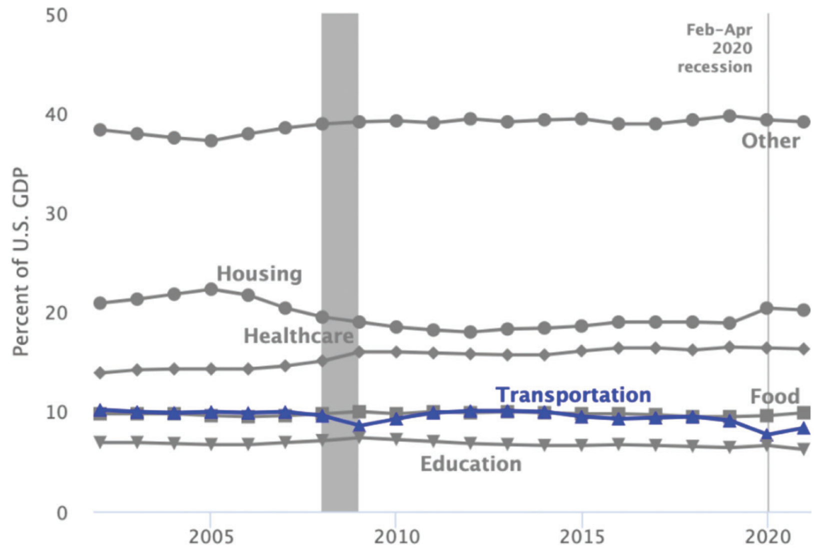


Figure 2.1 Industry wise contribution as a percent of US GDP over the years.

Additionally, access is significantly influenced by transportation. It has been described as crucial to the wellbeing of society. Effective transportation guarantees members of a community access to healthcare services and facilitates access to other important locations and services. Local communities have a responsibility to provide that mobility for their citizens in order to improve their health outcomes and increase access to a variety of neighborhood amenities.

No matter where they live—in the city, the suburbs, or the country—people's capacity to get healthcare is influenced by the accessibility of transportation. Lack of access to reliable transportation causes people to miss medical appointments, which delays the delivery of medical interventions and may result in worse health outcomes. This is one of the many reasons the price of healthcare is growing.

According to research, improved access to healthcare will result in more patient encounters and lower no-show rates, as well as increased use of health services and likely better health outcomes. Furthermore, easy access to transportation can reduce the need for additional hospital stays and result in overall cost savings.

The number of patients who are directly impacted by a lack of transportation cannot be documented from the data at hand. The percentage of patients who cite transportation as a barrier to receiving medical care ranges from 10% to 50%, according to a study (National Academies of Sciences, Engineering, and Medicine, 2021).

Transportation demands that affect access to healthcare have been recognized as being more prevalent among certain demographics. This includes: the elderly, people with disabilities, low-income people, people without their own vehicles, veterans who use the Department of Veteran Affairs (VA) healthcare system, people with chronic illnesses, and people who live in remote rural locations are some of these.

The lack of communication, information sharing, and coordination between the healthcare and transportation sectors, which otherwise might work to improve transportation access, is one of the main obstacles to increasing transportation access to healthcare. Other obstacles include long travel distances to access healthcare.

Based on studies and analysis by many researchers in the medical goods and services, there have been identified states with the highest demand for healthcare professionals. These are the states which lack the designated number of healthcare professionals to cater to the healthcare needs of the growing population in the respective states: California is ranked 1, followed by New York at rank 2. Indiana is ranked 7th most in need of more healthcare professionals (Stone, 2022).

There are more than twenty counties in Indiana that are medically underserved and have restricted access to the complete spectrum of healthcare services. Twenty more counties have populations that are medically underserved, which means that certain communities lack access to healthcare due to factors like their location and financial situation. The state of Indiana also has increasing healthcare demands as a result of a combination of an aging workforce, a growing population, and aging demographics. Indiana anticipates having 817 fewer doctors than necessary by 2030 (Petterson et al., 2013).

In the Figure 2.2, by 2030, Indiana would require 817 more primary care doctors (PCP), or a 20% increase over the 3,906 PCPs that were currently in practice in the state as of 2010. The current population to PCP ratio is 1,659:1, which is higher than the 1,463:1 national average. The prediction for 2030 places the Midwest generally above the recommended number of PCP, and the United States overall below the recommended quantity. Thirty-five percent, 286 PCPs, of Indiana's increased requirement for PCPs is attributable to higher usage brought on by aging, 48% (398

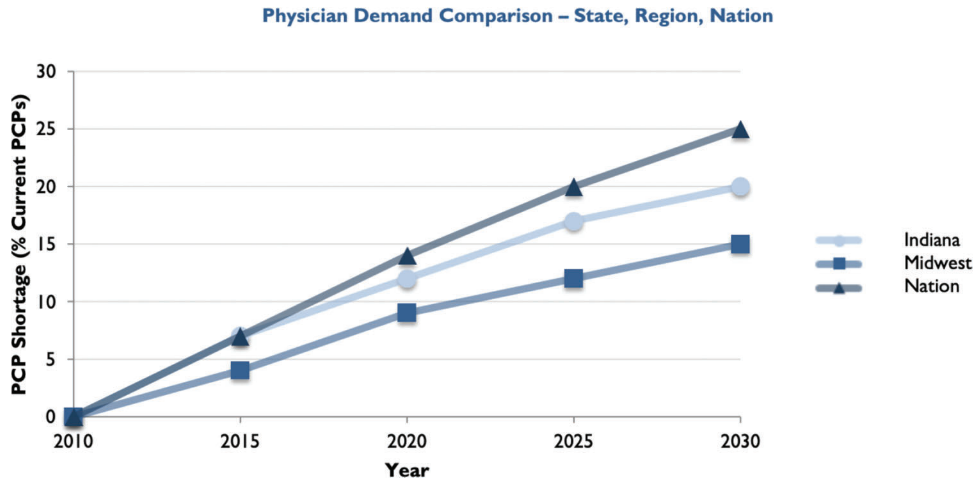


Figure 2.2 Physician demand in Indiana vs. other states and the US nation as a whole.

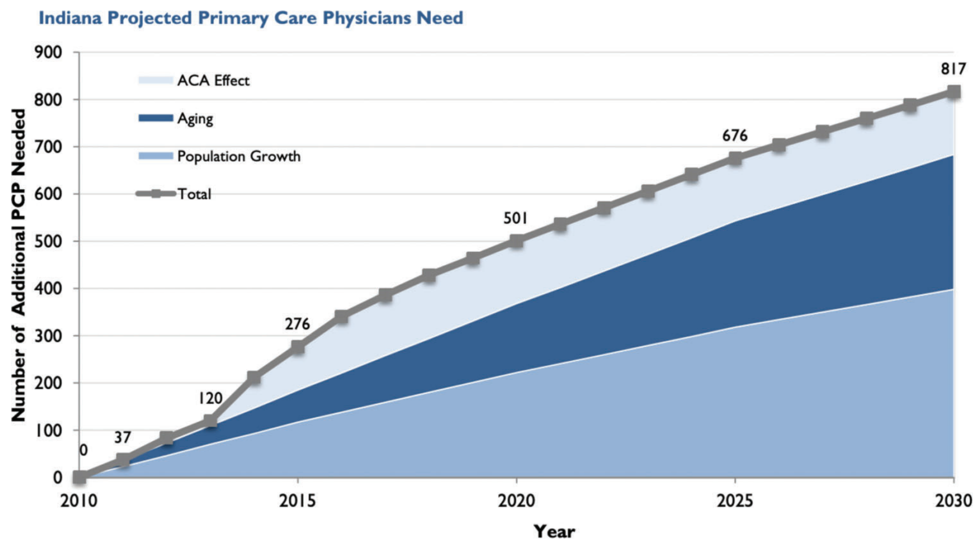


Figure 2.3 Indiana primary care physicians trend projection.

PCPs) is attributable to population expansion, and 16% (133 PCPs) is attributable to an increase in insured people as a result of the Affordable Care Act (ACA).

Figure 2.3 clearly explains the various factors that lead to the identified problem of deficiency of healthcare professionals. Out of all the factors—aging and population growth are the critical factors that provide a leading statement that healthcare industry has a direct correlation with population and the demographics of the population growth.

2.2.1 Takeaways

From the literature review and benchmarking, it is concluded that population has a very high impact on the presence of healthcare industry in a region. This inference helps advance this study where a relationship between population and overall transportation can facilitate determining the relationship between overall transportation and healthcare industry. Thus, this section helps understand the variables that need to be used to establish the impact of transportation on healthcare and how it helps INDOT in planning.

3. DATA COLLECTION

3.1 Datasets

3.1.1 Macro-View (Datasets for Transportation, HealthCare, and Economics)

3.1.1.1 Active transportation and economic datasets. Based on literature review and benchmarking, the team identified economic parameters (such as GDP, employment, and population) and active transportation parameters (number of trails, trail length (miles)). The data for these parameters was collected at a county-level which was then used to explore and analyze the economic impact of active transportation.

This data was collected on a historical basis to understand the trend and outline the potential relationship between active transportation and economic attributes. We also reviewed some miscellaneous data like urbanization to correlate certain groups of counties.

We collected the employment data from U.S. Census Bureau which was used to explore the correlation between employment and trail miles (US Census Bureau, 2023d). The data was collected for 2019 and 2020 for the analysis (refer to Table A.1 for sample data). The population data was also obtained from U.S. Census Bureau (2023c) at the county level for the years 2019 and 2020 (refer to Table A.3 for sample data) (US Census Bureau, 2023). The data was used to identify per capita financial parameters and to determine the relationships with trails and active transportation investment.

We obtained the industry-wise county-level GDP data from Bureau of Economic Analysis (BEA, n.d.) for the years 2019 and 2020 (refer to Table A.2 for sample data) (U.S. Census Bureau, 2023d). The GDP data is the measure of economy and hence one of the important parameters for the analysis. The GDP data refers to current GDP and is in billion USD. The trail data was obtained from the Department of Natural Resources for the year 2019 (refer to Table A.4 for sample data) (Indiana Department of Natural Resources, n.d.a). This data contains county wise trail projects, type of trail, trail name, suitability, and their length. This is the primary data used for all the correlation analyses.

Active transportation investment data was obtained from INDOT (refer to Table A.6 for sample data).

3.1.1.2 Healthcare industry and transportation datasets. Data for the aforementioned factors in the general introduction for association of healthcare industry with transportation industry, were looked out for on public domains like Central Bureau of Statistics (CBS), CBP, US Bureau of Economic Analysis (BEA), INDOT, etc. The data collection activity involved exploring the relevant metrics associated with healthcare industry and overall transportation industry. Further, data review checks were in place to ensure the analysis conducted on the identified datasets address the objectives. Lastly, any outliers or data clean-up activity involved with these datasets were implemented prior to analyzing the datasets.

County healthcare budget data is collected for the year 2019 across 92 counties of Indiana state with emphasis on correlating the healthcare budget per capita against the transportation metrics (DLGF, 2023). In Appendix B, Table B.1 shows the sample data set for healthcare budget analyzed.

Another parameter explored for healthcare metric was the Medicare refunds. Multiple sources yielded data sets at different county levels and targeted the data set collection to be of 2019 year Dartmouth Atlas Project, 2022). Two data sources were identified as relevant data sources after data review checks and data clean up activity. Table B.2 and Table B.3 highlight a sample data set for the Medicare refunds data across different counties.

County specific healthcare spending involving different dollar amount data from cash and investment statements recorded by Indiana government was collected and analyzed to see the actual expenditure in healthcare sector (Indiana Gateway, n.d.). Table B.4 shows the sample data set for one such county—Adams County.

Another relevant metric whose data collection meant critical for the analysis was healthcare employee payroll and healthcare establishments county wise for the year 2019 (US Census Bureau, 2023e). These two data metrics were based on NAICS codes relevant to the healthcare industry. Healthcare payroll is regarded as the employee payroll data for populace working or contributing to the healthcare value chain. Healthcare establishments consist of data sets like number of healthcare firms, number of ambulatory services, etc. Table B.5 showcases a sample data set to give a brief overview of the data information for healthcare employee payroll and number of healthcare establishments.

Transportation metrics like miles data at roadways, county, local, state highway levels were explored and as a result, important categories of miles were analyzed further namely the state miles, roadway miles, county miles, local miles, and trail miles. The Indiana Department of Natural Resources have collated a database together to maintain the public trail information for planning active transportation development (Indiana Department of Natural Resources, n.d.a). Additionally, the Indiana department of Transportation, Roadway assets team is responsible for maintaining the INDOT roadway systems (INDOT, 2023). In Appendix B, Table B.6 displays the sample data set of roadway system assets for different counties.

Another critical metric named as transportation investments was considered as one of the essential metrics to base all the strategy planning to associate the impact of healthcare metrics on dollar value investments in the development of transportation infrastructure projects. Transportation investment data collection was again focused for the year 2019 and INDOT readily shared the data sets on Indiana state transportation projects investment for the year 2019.

Finally, since most of the metrics were analyzed on a per capita basis, we collected county wise population data set for the same timeline (STATS Indiana, n.d.). Also, there were few analyses conducted to consider the demographics influence on a particular correlation, hence age wise data sets were also collated for the purpose of regression analysis. Table B.8 shows sample county wise population data.

3.1.2 Micro-View (Data from Spatial Distribution)

For the micro-view assessment, the analytics is performed at the ZCTA level (Zip Code Tabulation Area) level. The data for spatial distribution of ZCTAs is obtained from the Census Bureau.

Cell phone location data: Cell phone data collects information about the precise location and timestamp of anonymous users. Figure 3.1(a) exhibits the sample data for users in the study. The data was acquired from a cell phone vendor. The cell phone data, if representative, can facilitate the identification of travel patterns between regions, reveal trip attraction and generation in various locations at different times of the day, and shed light on the utilization of different types of businesses by individuals. The data when plot spatially is shown in Figure 3.1(b). It covers all the areas in Indiana. In addition, it can be observed that the road segments also have pings located on them, i.e., the travel patterns of people are also accounted for by the data. The data for the March 2019, March 2020 and March 2021 was used to perform the analytics.

Point of Interest (POI) data: POI data refers to information about specific locations that may be of interest to people, businesses, researchers, and other organizations. The data includes detailed information about businesses and other locations, such as the name of the business, the type of business, the physical address of the location, the latitude and longitude coordinates of the location, and other attributes such as opening hours, phone number, and website. The data is collected from a variety of sources, including government records, online directories, and user-generated content. The data was used from SafeGraph (SafeGraph, 2023) which provides the POI data openly. The data for healthcare-based POIs is plot in Figure 3.2.

County Business Patterns (CBP) (US Census, 2023b): The CBP dataset includes information on the number of establishments, employment figures, and payroll statistics for various industries at the county, metropolitan, state and ZCTA levels. It also includes information on the industry classification of the establishments, which is based on the North American Industry Classification System (NAICS). It is often used to analyze trends in business formation and employment, as well as to understand the economic impact of various policies and investments in specific regions and industries. Although there exist other datasets about business formations (Mittal et al., 2022), the CBP data is released by the census and is openly available for analytics. The data gives information about the businesses in the 2nd week of March every year. Figure 3.3 shows the distribution of number of healthcare-based businesses in each ZIP Code Tabulation Area (ZCTA) in 2019, an insight obtained from this data.

Transportation investments data: The data was obtained by requesting INDOT. It contains the overall transportation investment projects in 2019. Overall, there is information of about 2,407 transportation projects in Indiana. It contains the following information.

- Location of the project: All counties have at least 1 or more projects. The maximum number of projects are present in the Marion County (9).
- Type of the project: Projects broadly include new road constructions, rehabilitations, additions of new lanes, maintenance, pavement improvements and interchange modifications.
- Dollar value of the investment: Ranges from $2,310 (patch and rehab pavement on I-65)—$728 million (I-69 segment Connecting SR 37 to I-465). The median cost of the projects was $462,808.

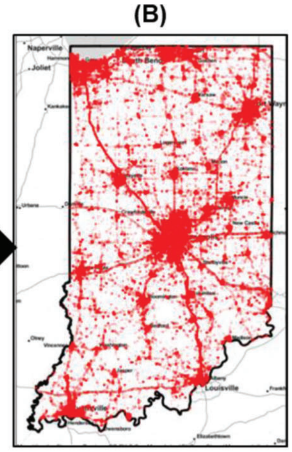
We focus on the new road construction projects for this project in terms of overall transportation.

Bikeways locations: The data was obtained from the webpage of IndyMPO (Indianapolis MPO, 2023) and contains the information about various proposed

(A)

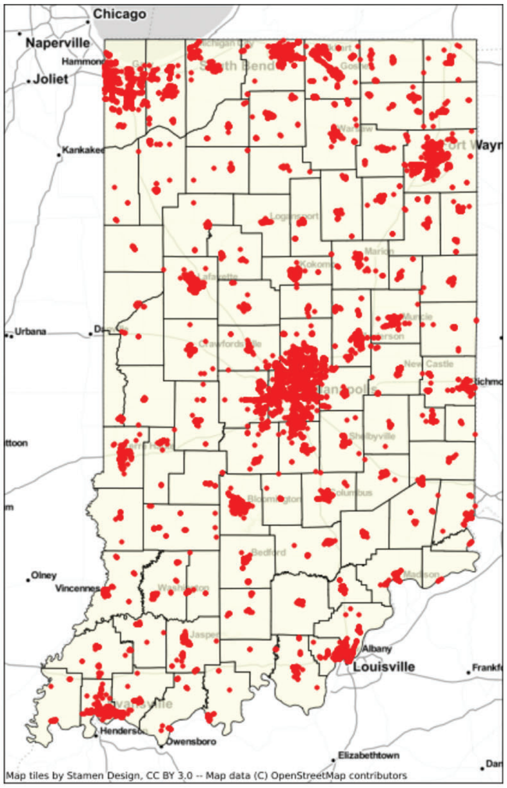
Device_ID	Latitude	Longitude	Timestamp
306ce6de-7b1d-40af-b96f-54b842d02ee1	xxxx	xxxx	1.573E+12
1721e7e5-bebc-43c9-b9dd-694961e6b2cd	xxxx	xxxx	1.573E+12
17409366-86d9-415b-9292-5631051626f4	xxxx	xxxx	1.573E+12
306ce6de-7b1d-40af-b96f-54b842d02ee1	xxxx	xxxx	1.573E+12
1721e7e5-bebc-43c9-b9dd-694961e6b2cd	xxxx	xxxx	1.573E+12

(B)



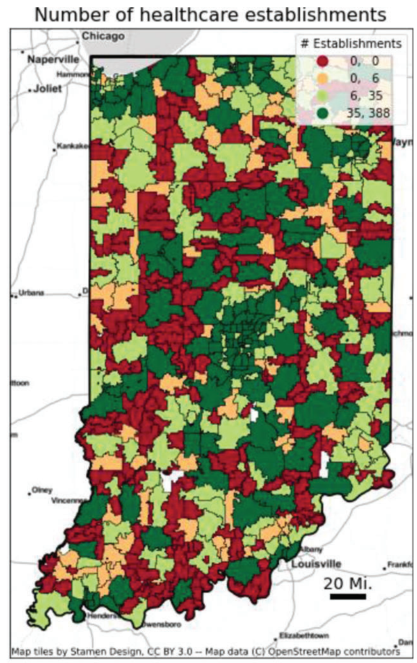
Note: Exact latitude, longitude and timestamp were obscured due to privacy issues. The spatial data has high density of pings in all the urban areas. Additionally, the road segments also have pings located on them.

Figure 3.1 (a) Sample cell phone data for Indiana, and (b) spatial plot of the data.



Note: These include all the businesses with the NAICS code starting with 62.

Figure 3.2 Locations of healthcare-based POIs from Safegraph data.



Note: The data is obtained from County Business Patterns (CBP) from Census. High number of healthcare establishments are observed in the Marion County region.

Figure 3.3 The number of healthcare-based businesses in each ZIP Code Tabulation Area (ZCTA) in 2019.

active transportation types of investment including trails, sidewalks, and bike lanes for 2020. As this data is from IndyMPO, the data is only available for areas within Indianapolis MPO (around Marion County). The data contains information about the location of the proposed investment and the length of the investment. Figure 3.4 shows the proposed active transportation investments in Indianapolis MPO for 2020.

American community survey data: The Census Bureau conducts a number of ongoing surveys throughout the decade to collect more detailed information on specific population groups (US Census Bureau, 2023a). This data is used for (1) accounting for demographics in the model and (2) evaluating trends of calculated indices with the demographics. The following variables are extracted and used in the study:

- population,
- population density,
- percent working age population,
- percent college completed,
- unemployment rate,
- median income,
- median house price,
- home occupancy percentage,
- car ownership rate, and
- number of POIs.

3.2 Datasets Highlighting the Connection Between Active Transportation and Business Growth

3.2.1 Macro-View (Background Information for Research)

- *Employment:* Employment data provides a measure of the presence of different industries in the region. We have used the data at a county level.
- *Industry GDP:* This data provides the contribution of all industries to the county GDP. The industry distribution is according to NAICS system. This allows us to understand the impact of active transportation on individual industries.
- *Trail miles:* This attribute provides the current status of trails in a county and the length in miles indicates the presence of active transportation infrastructure. This data is recorded based on information shared by trail providers and only includes the trails for which information was received. The trail length provides information about the total miles, irrespective of number of trails.
- *Number of trails:* This data provides an inventory of trails in the county which helps us understand the current infrastructure. This data provides information about the number of total trails, irrespective of miles.

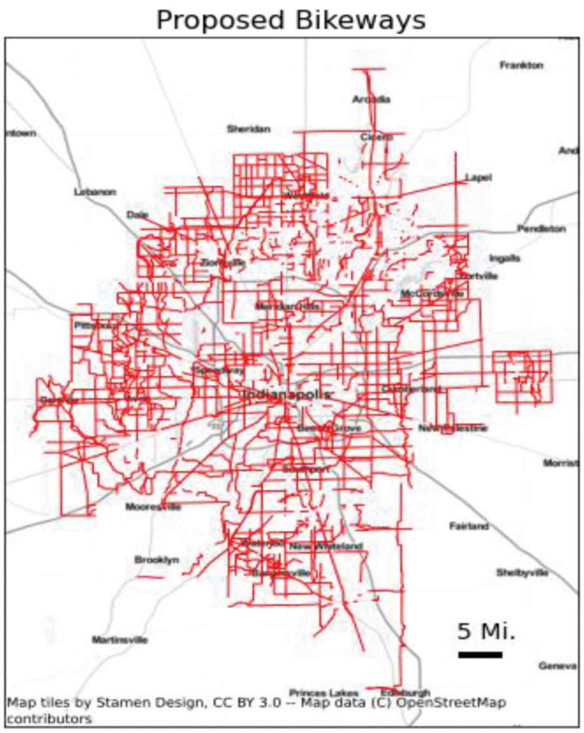


Figure 3.4 The proposed active transportation investments in Indianapolis MPO for new constructions in 2020. The density of these proposed active transportation investments is high for both urban core and suburbs of the MPO.

3.2.2 Micro-View (Data Assumptions and Restrictions)

- *Bikeways locations:* The data is used to understand where an investment in active transportation is in 2020. We have this data only for Indianapolis MPO region and therefore restrict our findings to this region.
- *County business patterns:* This data is used to understand how different industries grow in the regions where there has been an active transportation investment. It gives us the data on the number of establishments for different industries present in a ZCTA for different years.
- *Census demographics data:* The demographics data is used for the following: (1) to compare two regions and the changes in business growth between them; and (2) to assess the demographics of regions which observe high business growth and the regions which do not do so.

3.3 Datasets Highlighting the Connection Between Transportation and Healthcare Industry Success

3.3.1 Macro-View of Healthcare Industry

- *Healthcare budget, spending, Medicare refunds:* These data sets are critical in understanding the scale of expenditure and investments in the healthcare sector and how economic activity can be associated with the relevant transportation industry parameters.
- *Healthcare establishments:* This data set contains the number of employments in the healthcare sector across 92 different counties of Indiana, the healthcare employee payroll associated with the county wise healthcare professionals and other employment, number of healthcare firms present in each 92 counties in a year, and the number of emergency services like ambulatory services present in the different counties. These data sets are crucial in understanding and identifying certain counties which are in shortage of essential services, especially in the healthcare sector. Further based on how transportation features can aid in boosting the healthcare economic activity along with improvement in ease of accessibility in catering to these shortcomings for essential services like in a healthcare setting.
- *Transportation miles:* These data sets contain the information of number of roadway miles, state miles and county miles across different counties of Indiana state. This helps in understanding the transportation infrastructure of a particular county and how it can be linked to healthcare environment.
- *Transportation investment:* The data is utilized to understand and analyze the amount of investment necessary to improve the transportation infrastructure for identified counties in boosting the healthcare value chains. It contains data of different transportation infrastructure projects conducted in the years 2019, 2020, and 2021.

3.3.2 Micro-View of Healthcare Environment

- *Transportation investments data:* The data is used to understand where an investment in overall transportation is in 2020. We have this data only from the whole of Indiana and therefore, using this data we evaluate which regions observed high new transportation infrastructure construction.
- *Cell phone location data:* The data is used to evaluate the behavior of people and their usage of facilities and infrastructure. Two particular things where this data is employed at are (1) to assess the changes in trip patterns of the people when there is a transportation investment; and (2) to evaluate the changes in people's visits to healthcare related businesses when there is a transportation investment in the region.
- *Point of interest data:* This data is used to evaluate the locations of healthcare-based POIs. This is important when we are assessing people's visits to the healthcare-based facilities and how this change when there is a transportation investment.
- *County business patterns:* This data is used to understand how the healthcare industry grows in the regions where there has been a transportation investment. It gives us the data on number of establishments for healthcare related industries present in a ZCTA for different years.
- *Census demographics data:* The demographics data is used for the following: (1) to compare two regions and the changes in business growth between them; and (2) to assess the demographics of regions which observe high business growth and the regions which do not do so.

4. METHODS AND MODELING FRAMEWORK

4.1 Micro View

4.1.1 Data Analytics

4.1.1.1 Summary. Figure 4.1 shows the datasets and analytical tools used to investigate the relationship between active transportation investments and business growth. The ZIP Code Business Patterns (ZBP) dataset is used to measure the changes in business investments and growth, while the proposed bikeways dataset is used to identify the areas with active transportation investments. By analyzing the correlation between these two datasets, we can identify whether active transportation investments have a causal effect on business growth. These analytics can provide valuable insights into the potential economic benefits of active transportation investments and help decision-makers prioritize investments in areas that are likely to have the greatest impact on business growth. Further details on the methodology and results of this analysis will be presented in the following sections.

Figure 4.2 shows the datasets and analytical techniques to assess the relation between transportation investments and trip patterns and the healthcare industry. The changes in trip patterns are determined using cell phone location data, while the variations in visits to healthcare are analyzed by combining POI data and cell phone location data. Moreover, the changes in healthcare investments and growth are evaluated using the ZIP Code Business Patterns (ZBP). To evaluate the impact of transportation investments, the data from INDOT is used. These analytics help identify the causal effects of transportation investments on changes in trip patterns and healthcare. Further details regarding the results and implications are presented in subsequent sections of this paper.

4.1.1.2 Cell phone location data. In order to obtain reliable analytics and indices from cell phone data, it is important to perform certain necessary procedures. These include evaluating the representativeness and potential biases of the data, determining the users' residential locations based on their mobility patterns, and extracting trip information from the location ping data. The following is a detailed description of each component, including the methods and results of our analyses.

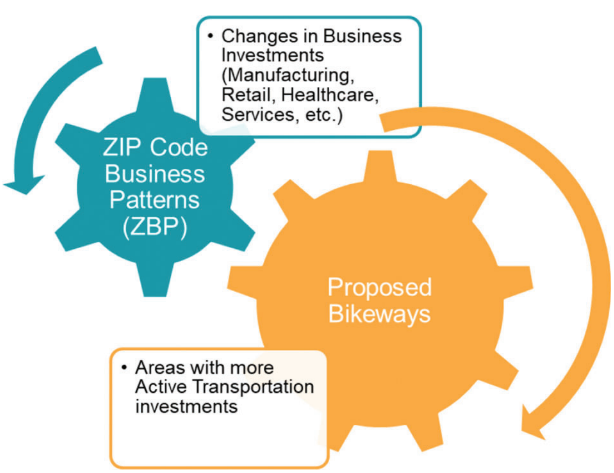


Figure 4.1 Datasets and analytics for assessing the relationship between active transportation investments and business growth.

1. *Data representativeness and biasness:* To ensure accurate transportation analysis using cell phone data, it is crucial to assess the representativeness and potential bias of the data. In this study, we evaluated the percentage of population represented by the cell phone data in each zone, finding that overall, the representativeness was 7.3% in March 2019, 19.8% in March 2020, and 16.5% in March 2021. Our results also revealed a significant positive correlation between the population inferred by cell phone data and the population from the census, with a magnitude greater than 0.99. Additionally, our findings indicate that there was no bias between rich and poor income quantiles in the data.
2. *Home inference:* Home locations of cell phone users play a critical role in evaluating characteristics of zones based on user characteristics. We estimate the home location of each user by extracting their location data during night hours 8 PM–6 AM) and performing a Meanfield clustering on those (Mittal et al., 2023). The resulting cluster head was considered the user's home location. To ensure accuracy, only data from users who had at least 7 distinct days of available data was used, a threshold selected to balance the number of filtered users with the noise in the home locations.
3. *Trip extraction:* The study extracted trips using GPS data from cell phones of users located in the state. Potent user days were filtered, stay regions were evaluated, and trips were extracted based on changes in stay regions. Trips outside the region and within the same zone were filtered out.

4.1.1.3 Trip patterns. The trips extracted provide detailed information on the origin and destination of each trip, allowing us to identify regions with high trip generation and attraction during different times of the day. This analysis can reveal changes in trip patterns resulting from transportation investments in a region. We evaluated the cumulative number of trips generated from each region throughout the day with particular focus on the morning peak hours. Our analysis accounts for the varied spatial representativeness and scales up the number of trips to the population level.

4.1.1.4 Visits to healthcare. This analysis is conducted to assess the behavior of users located in different zones in terms of access to healthcare POIs. If we detect the location of a cell phone user to be within the POI, the POI is visited by the user (Mittal et al., 2023). Therefore, we detect each POI a user visits and estimate the number of people visiting the POI every day or month. This is executed for each healthcare POI. Moreover, we evaluate the number of people visiting the healthcare POIs from outside the ZCTA of the POI. This assists in

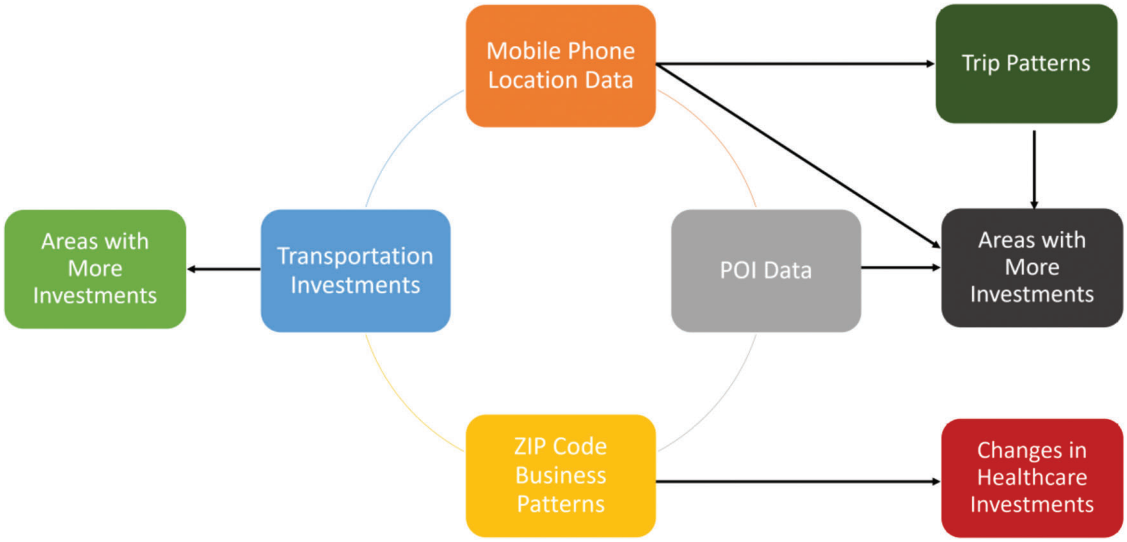


Figure 4.2 Datasets and analytics for assessing the relationship between overall transportation investments and trip patterns and the healthcare industry.

evaluating the zones and the changes in the visits to healthcare POIs in the zones. We account for the varied spatial representativeness and scale up the number of visits to the population level.

4.1.1.5 Business investments. We analyze business investments based on changes in the number of establishments in a particular industry. We use the County Business Patterns (CBP) data to obtain information about the number of businesses in an area over time. We examine changes in the number of businesses in other industries, including manufacturing, retail trade, professional, scientific, and technical services, educational services, healthcare and social assistance, arts, entertainment, and recreation, and accommodation and food services, in response to active transportation investments. Moreover, we examine the changes in the number of businesses for healthcare in response to the overall transportation investments. Furthermore, we consider the size of these businesses, with a focus on small businesses that have less than 50 employees (Berisha & Shiroka Pula, 2015), they are crucial for job creation, innovation, competition, and economic growth.

4.1.2 Evaluating Causal Effects

We are evaluating the causal effects between active transportation investments and business growth to understand the impact of these investments on the local economy. Active transportation investments, such as bike lanes, pedestrian walkways, and public transit systems, can potentially increase the accessibility of a particular area and stimulate economic growth by attracting new businesses and customers. By studying the changes in business growth following transportation investments, we can gain insights into the effectiveness of these investments and inform future planning decisions.

We use the model of Differences-in-Differences to estimate the causal effects of investments. DID is often preferred over simpler models like linear regression because it helps to control potential confounding factors and provides a more robust estimation of the causal effects. It may be preferred over linear regression in order to address selection bias, controlling for time-invariant unobserved factors, accounting for time-varying confounders, capturing dynamic changes and robustness to small sample sizes.

4.1.2.1 Problem framework. The causal relationship between active transportation investments and changes in business growth across various industries, such as manufacturing, retail trade, services, education, healthcare, and recreation and hospitality, is analyzed using a framework as shown in Figure 4.3. The study evaluates the change in the number of establishments for these industries as a result of active transportation investments using the proposed bikeway data from IndyMPO. The research employs the Difference in Differences model to assess the causal relationship and further analyze the causal effects. This analysis is only performed around the Indianapolis MPO area due to the availability of active transportation data at a ZCTA level.

The study examines the causal relationship between transportation investments and changes in trip patterns and healthcare growth across ZCTAs, as illustrated in Figure 4.4. The study employs transportation investments data from INDOT to evaluate the changes in trips generated from ZCTAs, morning rush hour trips, number of people visiting healthcare facilities in a ZCTA, number of healthcare establishments, and small healthcare establishments resulting from transportation investments. The analysis employs the Difference in

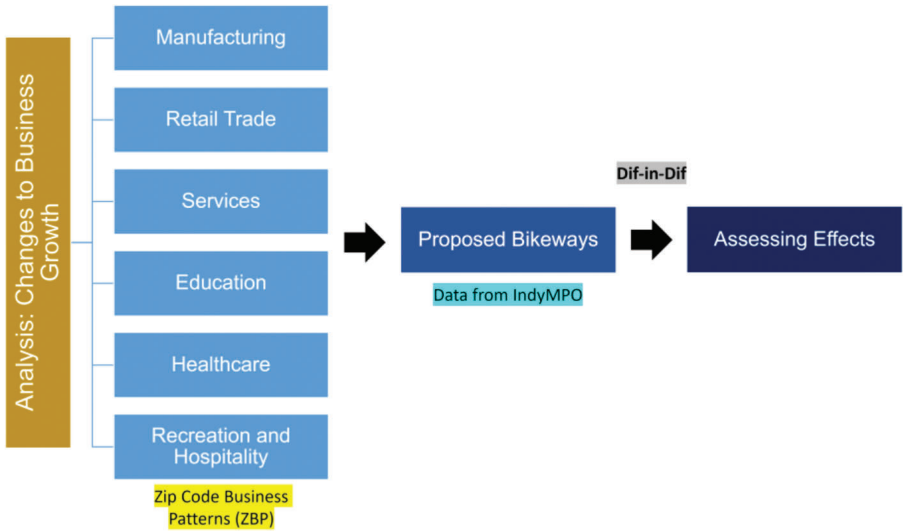


Figure 4.3 Framework for analyzing the causal relationship for change in business growth across different industries due to active transportation investments. It is performed using Difference in Differences model at a ZCTA level.

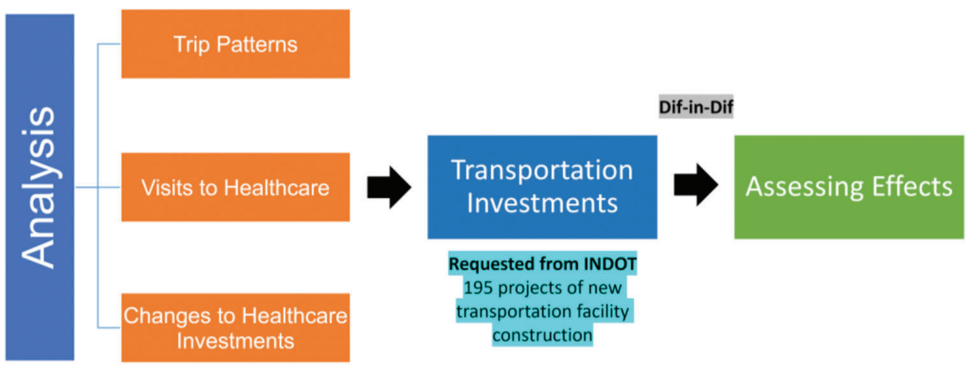


Figure 4.4 Framework for analyzing the causal relationship for change in trip patterns and healthcare growth due to transportation investments. It is performed using Difference in Differences model at a ZCTA level.

Differences model to assess the causal relationship and further investigate the causal effects. The analysis is performed for the entire state of Indiana due to the availability of active transportation data at a ZCTA level.

4.1.2.2 Differences-in-Differences (DID). The differences-in-differences (DID) model is a statistical method used to estimate the causal effect of a treatment or intervention on an outcome of interest. It is commonly used in economics and social sciences to evaluate the impact of policy changes or other interventions. A few examples include effects of minimum wage on employment rates (Card & Krueger, 1994), effects of police forces to reduce crime (DiTella & Schargrodsky, 2004), and assessment of health reforms (Harman et al., 2011).

The DID model works by comparing the changes in outcomes between two groups over time. One group is the treatment group, which receives the intervention or policy change, and the other is the control group, which does not receive the intervention. The basic idea behind the DID model is to compare the difference in the outcomes of the treatment and control groups before and after the intervention. The assumption is that, in the absence of the intervention, the difference in the outcomes of the two groups would remain constant over time. Therefore, any change in the difference in outcomes between the two groups after the intervention can be attributed to the intervention itself. The DID model can be expressed mathematically as:

$$Y_{it} = \beta_0 + \beta_1 \ Treatment_i + \beta_2 \ Post_t + \beta_3 \ (Treatment_i * Post_t) + A^* X_{it} + \in_{it}$$

Where,

- Y_{it} is the outcome of interest for individual i at time t,
- $Treatment_i$ is an indicator variable that equals 1 if individual i is in the treatment group and 0 otherwise,
- $Post_t$ is an indicator variable that equals 1 for time periods after the intervention and 0 otherwise,
- βs are the coefficients of each of the variables used.
- X are the covariates of individual i at time t. It is a matrix and can include multiple variables,

- A is the coefficients of the covariate variables of individual i.,
- $\in_{it}$ is the error term, and
- β_3 which measures the effect of the intervention on the outcome of interest. It is the coefficient of interest. β_3 being positive and statistically significant, suggests that the intervention had a positive effect on the outcome. Conversely, β_3 being negative and statistically significant, it suggests that the intervention had a negative effect on the outcome.

For significance of results, we perform linear regression on Y_{it}. However, a bigger data sample is required to do so. And therefore, multiple data samples for each treatment and control group by breaking it down into days or POIs or POI types as per the case and based data used.

With the DID model, however, the parallel trend assumption fails in cases where there are other confounding factors involved in receiving the treatments. There is a probability of receiving a treatment or intervention by an individual, given a set of observed covariates or characteristics. And DID does not account for this in its model resulting in inconsistent treatment effect estimate. This is dealt with conditioning the analysis with covariates (Xs) and matching the treatment and control groups better (Sant'Anna & Zhao, 2020).

4.1.2.3 Treatment groups. A treatment group, also known as an experimental group, is a group of individuals or units that receives a specific intervention or treatment being studied in an experiment or research study. The purpose of a treatment group is to evaluate the effect of the intervention or treatment on the outcome of interest, compared to a control group that does not receive the treatment.

For this study, the treatment groups are defined for both active transportation investment and overall transportation investment differently. For active transportation investments, the treatment groups include the ZCTAs where there is an investment in sidewalks, bike lanes, or trails using the data of proposed bikeways by IndyMPO. The treatment groups are therefore the ZCTAs around Indianapolis MPO. For the overall transportation investments, the treatment groups include the ZCTAs where there is a transportation investment on a new construction of greater than $75,000. These are assessed using the data requested from INDOT and are spread all over the state.

4.1.2.4 Control groups and matching. The control group is similar to the treatment group in every way except for the treatment that is being evaluated. The control group serves as a comparison group for the treatment group. By comparing the outcomes of the treatment group to the control group, we can estimate the causal effect of the treatment on the outcome of interest. The control group helps to isolate the effect of the treatment from other factors that may be affecting the outcome.

In general, there is a probability of receiving a treatment or intervention by a group, given a set of observed covariates or characteristics. DID does not account for this in its model resulting in inconsistent treatment effect estimate and failure to comply with the parallel trend assumption. To overcome this, proper matching between the control and treatment group is required which accounts for the observed covariates and the probability of receiving a treatment. Thus, we use propensity score matching (Rosenbaum & Rubin, 1983).

Propensity score is the probability of a treatment being assignment "conditional" on observed baseline covariates, $P(Z_i = 1|X_i)$. This is done to find a match of a treated group where the match or control is an individual who has same covariates but has not been treated. This is performed by fitting logistic regressions where predictors are covariates and predicate is existence of intervention. Using the probability calculated from the logistic regression, we find a closest match from the non-treated set of ZCTAs using K-Nearest Neighbor model. Figure 4.5 shows the control and treatment groups and corresponding matchings for both the active transportation investments and overall transportation investments.

4.1.2.5 Indices. The index of change in number of establishments is used for evaluating the relation of business growth due to active transportation construction. The businesses considered for this are the following.

1. Manufacturing (NAICS 31-33).
2. Retail trade (NAICS 44-45).
3. Professional, scientific, and technical services (NAICS 54).
4. Educational services (NAICS 61).
5. Healthcare and social assistance (NAICS 62).
6. Hospitality and recreation: arts, entertainment, and recreation and accommodation and food services (NAICS 71-72).

For evaluating the change in trip patterns and healthcare growth due to transportation construction, the following indices are considered.

1. Trip patterns.
    a. Trip generation of regions.
    b. Trip generation of regions during morning peak.
2. Visits to healthcare.
    a. Number of people visiting healthcare related POIs.
    b. Number of people from other regions visiting healthcare related POIs.
3. Changes to healthcare investments.
    a. Number of businesses located.
    b. Number of small businesses located.

Each index is normalized by the cost of investment in the ZCTA in order to control the differences in the

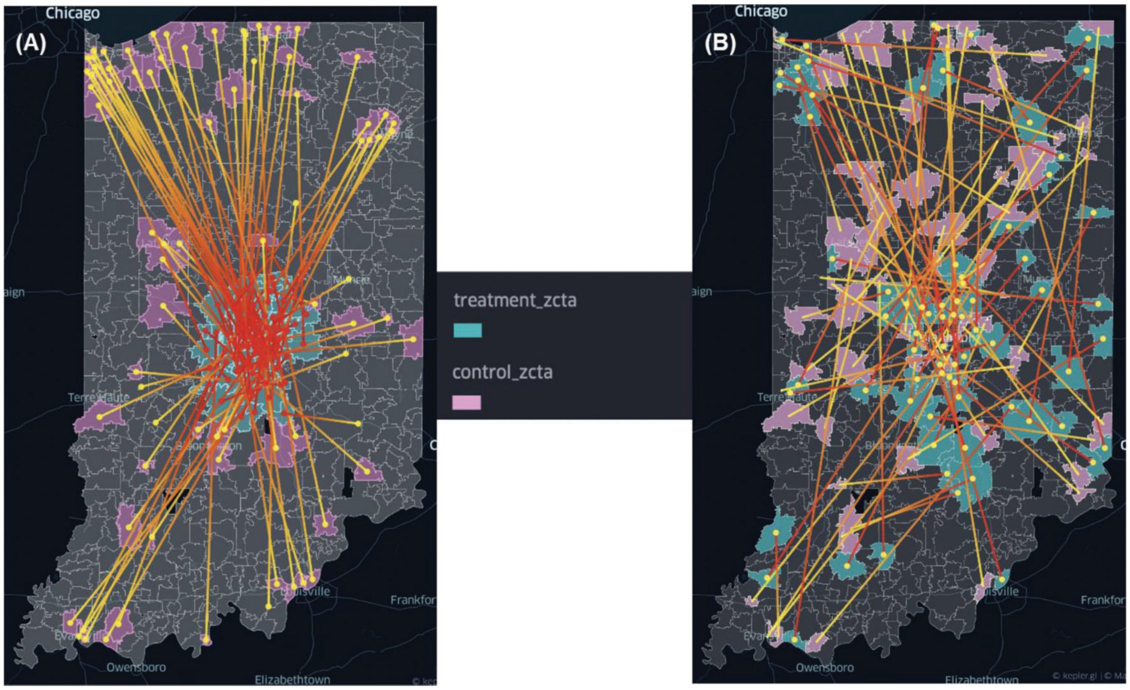


Figure 4.5 The control groups (blue), treatment groups (pink) and corresponding matching for (a) active transportation investments, and (b) overall transportation investments.

investment level itself. For each of the indices mentioned above, the causal effects can be observed for all the treatment ZCTAs, low-income group ZCTAs and the high-income group ZCTAs to compare the role of income in evaluating these changes. For active transportation, we also evaluate the differences in business growth for different types of infrastructure—sidewalks, bike lanes, and trails.

4.1.2.6 Low-income and high-income region definitions. Regions of low-income regions are defined as the regions or ZCTAs in which the median household income is less than 0.8 times the median household income of Indiana. This definition is adopted from the U.S. Department of Housing and Urban Development (HUD) (City of Madison Community Development Division, 2019). Similarly, regions of high income are defined as the regions or ZCTAs in which the median household income is greater than 1.75 times the median household income of Indiana.

4.1.2.7 Cost of active transportation investments. Active transportation investments consist of different types of investments (sidewalks, bike lanes, and trails) and the data provides the lengths of each investment. In order to evaluate the overall active transportation investments, we combine all three types of active transportation based on the cost of construction. We collect the data on the cost of construction of each type of active transportation per mile and multiply it by the cumulative length of construction of that particular type in the ZCTA. The following are the costs of construction per mile for each type of active transportation service.

1. *Bike lanes:* \$30 per feet = \$150,000 per mile (City of Kokomo Engineering Department, 2017).
2. *Sidewalks:* \$45 per feet = \$237,600 per mile (Purnell, 2023).
3. *Trails:* \$65 per feet = \$350,000 per mile (Indy Parks & Recreation, 2016).

4.2 Data Analytics and Insights: Macro View

4.2.1 Active Transportation

4.2.1.1 Initial analysis. The preliminary analysis started with a regression analysis of economic parameters with trail length. The purpose of performing regression analysis is to estimate the effect of some explanatory variables on the dependent variable. Through this analysis, we tried to see if there is any correlation between economic parameters and trail length. We have used Table C.1 through Table C.3 in this analysis. The R-squared values when trail miles regressed with population, GDP, and employment, range from 0.32 to 0.43. A correlation study is performed between independent variables in the multi-variable regression i.e., economic parameters. The correlation values are 0.92 to 0.98, from this it is inferred that GDP, population, and employment are closely related, and multi-variable is not required. Instead, it is required to choose one variable and proceed with further analysis.

While performing preliminary analysis to understand the relationship between trail miles and county GDP, the team identified three county data sets as outliers—Marion, Brown, and St. Joseph.

- *Marion:* Urban County in Indianapolis with a huge population.
- *Brown:* State park passing through this county has greater trail miles.
- *St. Joseph:* Buffalo run snowbell trail with higher trail miles.

4.2.1.2 Preliminary forecast using base regression. After performing the forecast of trail miles using GDP based on the regression equation: *Trail miles = 0.000005*GDP (in millions),* we found that there were variances with respect to trends of GDP vs. trends of trail miles. The following are possible reasons for variances.

1. The regression fit: The adjusted R-squared value for the regression is just 41% for the regression. This indicates poor prediction accuracy of the regression model.
2. Presence of outliers: Additional outliers might have a skew impact on the results.

We have used Appendix A: Table A.2 for this analysis.

4.2.1.3 Exploratory analysis on data. To assess reasons for variance in forecast, we investigated the data some more. The following analyses were performed.

1. Trend analysis for change in GDP vs. change in trail miles.
2. Analysis of counties grouped at a threshold of 20 miles of trails.
3. Time series data analysis for population, GDP, active transportation investment, trail counters.
4. Geographical trends in GDP, trail miles.

4.2.1.4 Trend analysis for change in GDP vs. change in trail miles. Under this analysis, we tried to plot all the counties and identify trends in change in GDP vs. change in trail miles as shown in Figure 4.6. We observed that there was a high variance in change in miles vs. change in GDP plot for counties less than 20 miles. We have used Table A.1 and Table A.2 from Appendix A for this analysis.

Based on the result, we explored the possibility of grouping the counties into two separate groups on the basis of number of miles.

- Counties with more than 20 miles.
- Counties with less than 20 miles.

4.2.1.5 Analysis of counties grouped at a threshold of 20 miles of trails. We have tried to explore the counties based on grouping at 20-mile threshold. We performed regression analysis on both the groups and tried to establish correlation for these counties. Although the regression showed positive results, upon detailed inspection, the threshold of 20 miles did not have any physical significance.

The following results were obtained after performing the regression.

1st iteration: For this analysis, data from Table A.4 was divided into two groups. We have also used Table A.2 for this analysis. There are 39 counties with less than 20 trail miles.

Regression analysis was performed, with intercept set to zero and with intercept, which yielded the results as shown in Table C.4 through Table C.11.

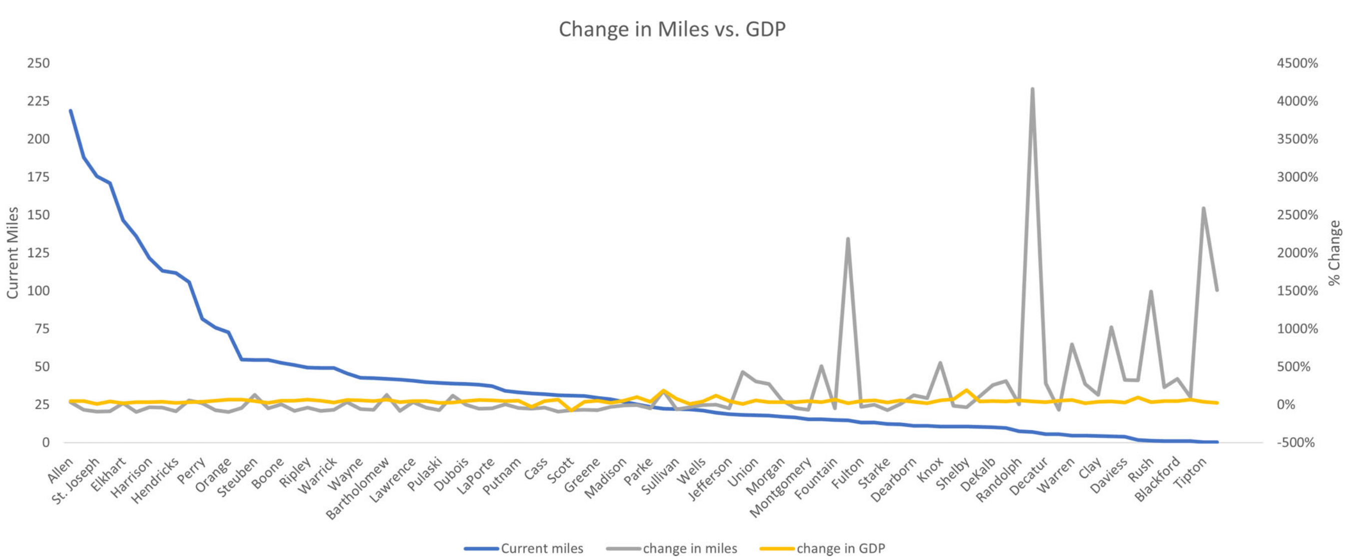


Figure 4.6 Plot for change in miles vs. change in GDP county wise sorted for 2019 trail miles.

Reducing the constant terms to zero had a drastic effect on the regression output.

We see that for counties with less than 20 miles of trails, the relationship turns from highly correlated to uncorrelated when intercept is not forced to zero. For counties with more than 20 miles, we see a similar trend. For the initial regression of counties with more than 20 miles of trails, only Marion and Brown counties were considered as outliers. After outlier analysis, we removed the following outliers from the dataset.

- *Spencer:* Utility sector is dominant; utility contributes to only 2% of Indiana GDP, Lincoln State Park.
- *Hamilton:* High income population, high presence of finance, real estate, business services, high trail miles.
- *St. Joseph:* 5th most populous county, urban county, high contribution in finance, real estate, education, healthcare, and manufacturing.
- *Vanderburgh:* 7th most populous county, 8th smallest by area, urban county, high contribution in finance, real estate, education, healthcare, and manufacturing.

After removal of outliers, it is observed that the removal of outliers is improving the correlation between GDP and trail miles. However, counties with less than 20 miles of trails do not show any significant correlation between trails and GDP. Counties with higher number of trails show a positive correlation between trails and GDP. We further dove into more data and found out the following.

When looking at the industry contribution for the <20 miles and >20 miles groups, as shown in Table 4.1 and Table 4.2, we found that that the former had more agro-forestry, manufacturing, and utility sector contribution whereas the later had more contribution in education, healthcare, finance, real estate, and business services. The results are as shown in Table C.12 and Table C.15 in Appendix C. The data used was from Table A.2 and A.4.

Analyzing the urbanization data, from food access research Atlas data from the USDA (USDA ERS, 2021), suggests that counties with more than 20 miles of trails are more urbanized than those with less than 20 miles of trails, as shown in Table 4.3.

4.2.1.6 Time series data analysis for population, GDP, active transportation investment and trail miles. Analyzing the time series data would provide insights into whether a certain predictor was leading and causing changes in other variables. Unfortunately, due to lack of sufficient time-series data for trail miles and active transportation investment, we were not able to achieve any insights from this analysis. We have used 2019 to 2021 data for this analysis.

4.2.1.7 Geographical trends in GDP, trail miles. While looking at the geographical perspective of trail miles (Figure 4.9), GDP (Figure 4.7 and Figure 4.10), population (Figure 4.8), etc. we observe that there is a higher concentration of GDP, population, and trail miles in the central and northern region of the state, particularly around the Marion/Hamilton counties.

4.2.1.8 Regression analyses. To further explore relationships, we identified additional variables and performed regression analyses on the following.

4.2.1.8.1 Number of firms vs. trail miles. The purpose of this regression is to find out whether the presence of industries in terms of absolute number of working establishments suggests a presence of active transportation infrastructure.

For this particular analysis, Brown and Hamilton counties have been removed as outliers after performing the outlier analysis on initial regression.

As the result shows in Figure 4.11, the number of firms shows a healthy correlation with the trail miles. We also see the same in the geographical representation where a higher concentration of number of firms is accompanied by a higher tally of trail miles. The results can be accessed in Table C.16 and Table C.17 in Appendix C.

TABLE 4.1
Industry wise GDP for counties with <20 miles and >20 miles of trails ($ billion)

Industry GDP 2020 Grouped by Number of Miles (billion $)	Less Than 20	More Than 20
Agriculture, forestry, fishing, and hunting	1.70	1.90
Arts, entertainment, recreation, accommodation, and food services	1.17	10.53
Construction	2.26	14.94
Educational services, healthcare, and social assistance	2.70	32.35
Finance, insurance, real estate, rental, and leasing	5.30	57.75
Information	0.46	5.55
Manufacturing	16.34	78.25
Mining, quarrying, and oil and gas extraction	0.46	0.69
Other services (except government and government enterprises)	1.03	6.95
Professional and business services	1.78	30.44
Retail trade	2.75	18.43
Transportation and warehousing	1.42	10.64
Utilities	2.91	3.31
Wholesale trade	1.38	16.68

TABLE 4.2
Industry wise GDP % for counties with <20 miles and >20 miles of trails (%)

Industry GDP 2020 Grouped by Number of Miles (%)	Less Than 20 Miles (%)	More Than 20 Miles (%)
Agriculture, forestry, fishing, and hunting	4%	1%
Arts, entertainment, recreation, accommodation, and food services	3%	4%
Construction	5%	5%
Educational services, healthcare, and social assistance	6%	11%
Finance, insurance, real estate, rental, and leasing	13%	20%
Information	1%	2%
Manufacturing	39%	27%
Mining, quarrying, and oil and gas extraction	1%	0%
Other services (except government and government enterprises)	2%	2%
Professional and business services	4%	11%
Retail trade	7%	6%
Transportation and warehousing	3%	4%
Utilities	7%	1%
Wholesale trade	3%	6%

Note:
Green numbers indicate higher industry GDP while red numbers indicate lower industry GDP. This categorization is done for industries where there is a significant difference between industry GDP for less than and more than 20 miles of trail.

TABLE 4.3
Urban tracts in counties with <20 miles and >20 miles of trails

Category	Urban Tracts	Total Tracts	Percent
Less than 20	105	271	39
More than 20	936	1,230	76

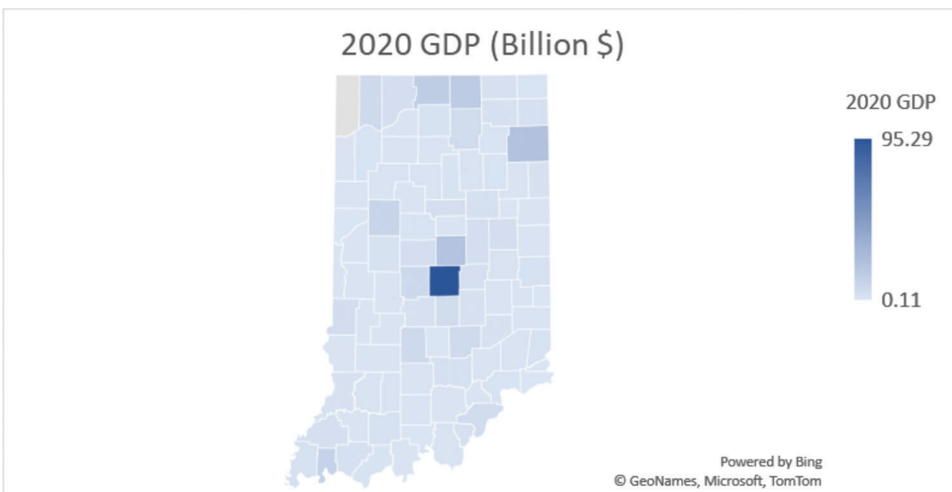


Figure 4.7 Geographical distribution of 2020 GDP ($ billion).

4.2.1.8.2 Specific-industry GDP, firms vs. trail miles.

1. *MFRE GDP vs. trail miles*

The following regression considers GDP for specific industries and their correlation with trail miles, as shown in Figure 4.12. The industries considered include manufacturing, finance, insurance, real estate, rental, and leasing (MFRE). The purpose of this regression is to find out whether the economic activity of specific industries in terms of GDP suggests a presence of active transportation infrastructure in the region.

For this analysis, Marion, Brown, and Hamilton counties have been removed as outliers after performing the outlier analysis on initial regression. The results can be accessed in Table C.18 and Table C.19.

As the result suggests, the t-stat values are sufficiently high to support the hypothesis. Also, the p-values for the regression seem to be very low which signifies a good correlation. However, adjusted

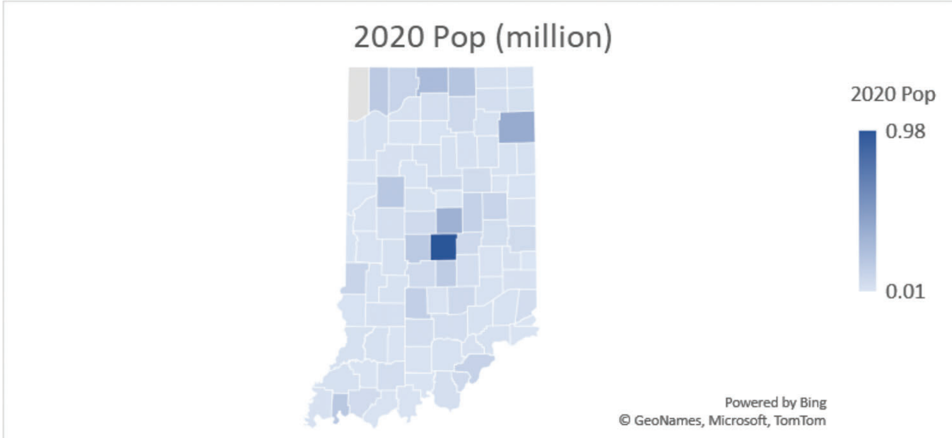


Figure 4.8 Geographical distribution of 2020 population (million).

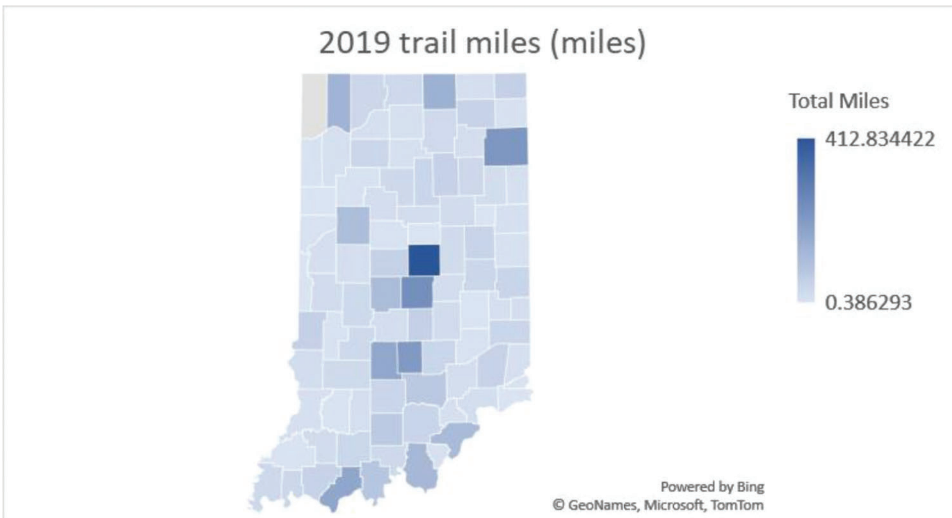


Figure 4.9 Geographical distribution of 2019 trail miles.

R-squared is not lower which might cause lower prediction accuracy when using the equation for forecasts.

2. MFRE number of firms vs. trail miles

The following regression considers the number of establishments for specific industries and their correlation with trail miles, as shown in Figure 4.13. The industries considered include manufacturing, finance, insurance, real estate, rental, and leasing. The purpose of this regression is to find out whether the presence of specific industries in terms of number of establishments suggests a presence of active transportation infrastructure in the region. For this particular analysis, Brown and Hamilton counties have been removed as outliers after performing the outlier analysis on initial regression. The results can be accessed in Tables C.20 and C.21.

Similar to the GDP correlation, the number of firms correlation also supports high association. The adjusted R-squared value is higher than that for GDP correlation which suggests better prediction accuracy.

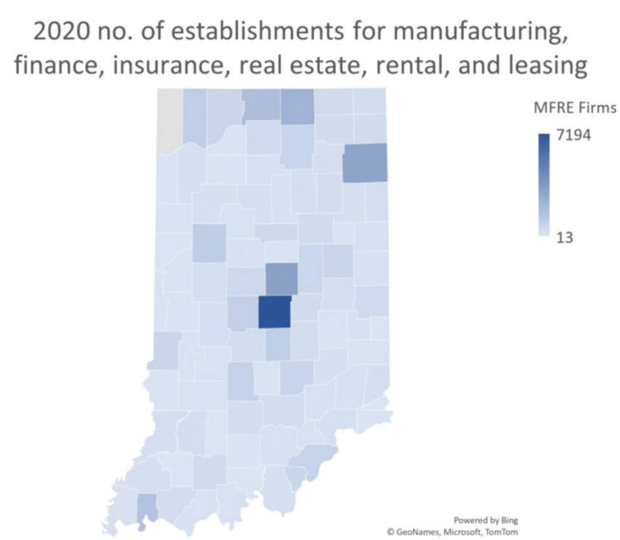


Figure 4.10 Geographical distribution of the number of establishments for manufacturing, finance, insurance, real-estate, and leasing (MFRE) in 2020.

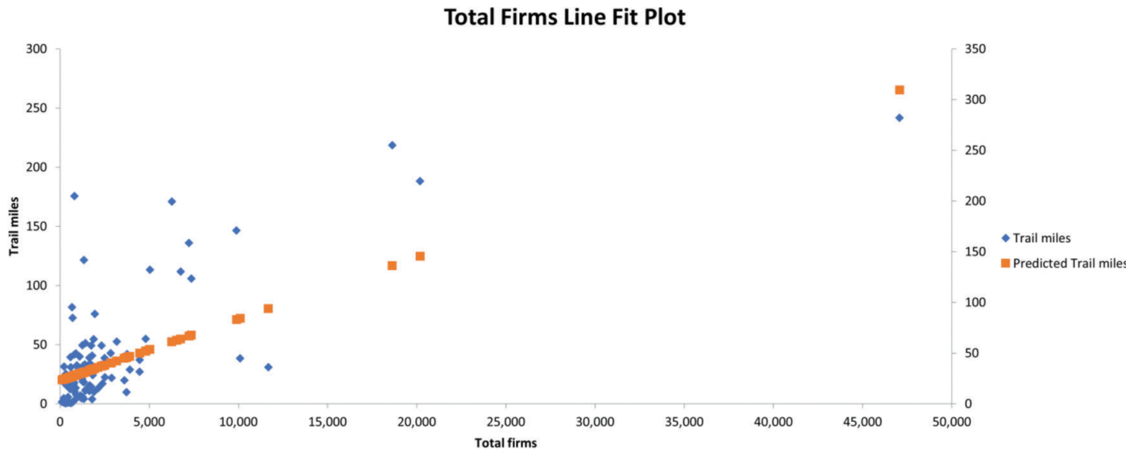


Figure 4.11 Total firms vs. trail miles line fit plot.

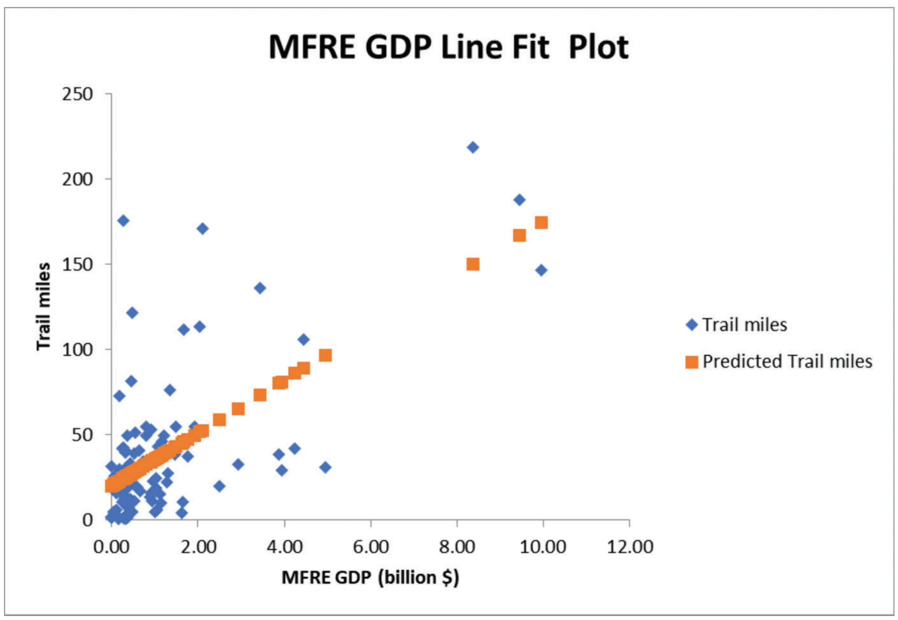


Figure 4.12 MFRE GDP vs. trail miles line fit plot.

4.2.1.8.3 GDP/capita, population vs. active transportation investment. Another way to look at active transportation infrastructure is the active transportation investment data. We ran the regressions for GDP/capita and population against the active transportation investment to see if economic activity, population support the active transportation investment decisions. We obtained poor results for both the correlations. Possible reasons for this might be because of lack of sufficient data for active transportation investment. The results can be accessed in Tables C.22 through Table C.25.

4.2.1.8.4 GDP/capita vs. trail miles. We additionally tried to look at correlation between GDP/capita and trail miles to understand the same relation with a different parameter. Again, the correlation was poor. It possibly suggests that the average earnings and population density in a region might not have a significant effect on the active transportation infrastructure. The results can be accessed in Tables C.26 and C.27.

4.2.1.9 Comparison with other states

4.2.1.9.1 Illinois trail study. To understand the significance of the relation between population and trail miles, and to compare the results obtained above, a similar study was performed for Illinois state. The county-wise population and trail information (number of trails, length of trails) data were collected from the Illinois Department of Transportation (IDOT, n.d.).

4.2.1.9.2 Outliers. After analyzing the data, it is identified that since Chicago is part of Cook County, it has an indefinite proportion of the population compared to all the other counties. So, further in the

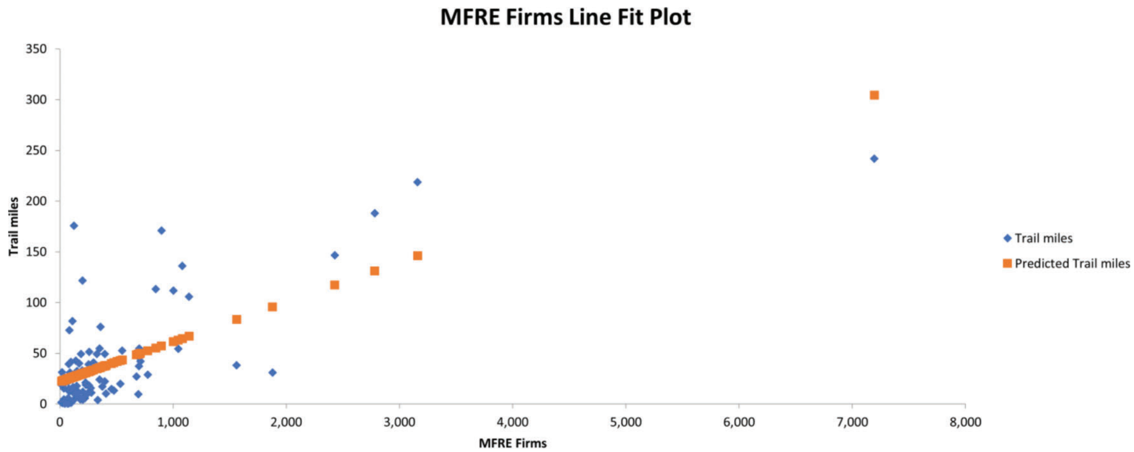


Figure 4.13 MFRE number of firms vs. trail miles line fit plot.

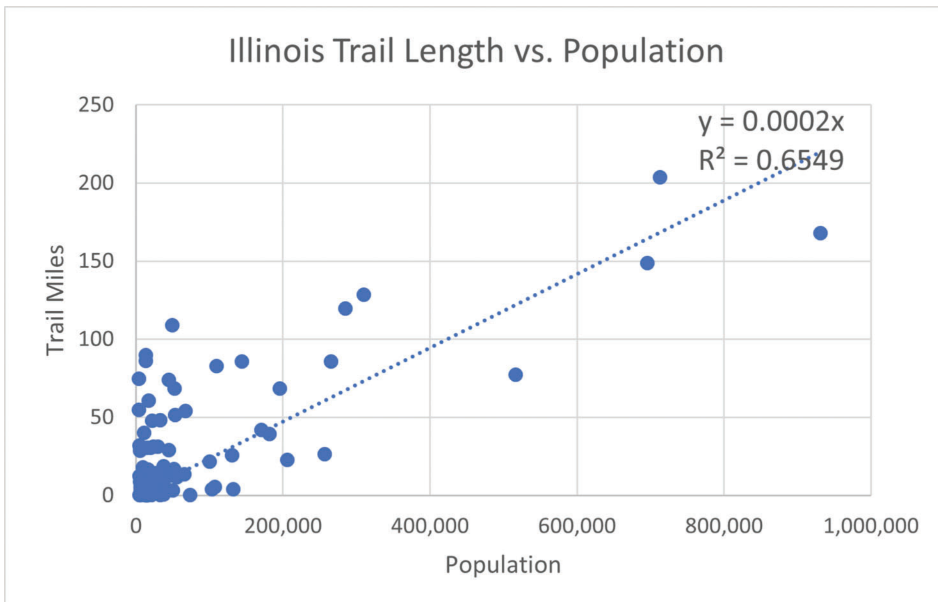


Figure 4.14 Illinois trail mile length vs. population.

analysis Cook County is not considered. Regression analysis is performed for population and trail miles after removing the outlier and the below equation and graph, in Figure 4.14, are obtained.

$$Population = 0.0002 * Trail\ Miles$$

It is evident that Indiana has three times trail miles/population compared to Illinois State.

4.2.1.10 Pareto analysis. The purpose of this analysis is to find out major contributing counties with respect to trail miles, GDP and population and find counties where there is an opportunity to make improvements. The following three pareto plots (Figure 4.15, Figure 4.16, and Figure 4.17) and map plots (Figure 4.18, Figure 4.19, and Figure 4.20) depict the distribution of trails, GDP, and population in Indiana counties. From the analysis, we see that 70% of trails are accounted for by 30% of the counties. Also, 60% of GDP and population are accounted for by 30% of Indiana counties. We see commonalities between high GDP, population counties and high trail counties. Possible reasons are high urbanization of the counties as depicted in Table C.24. It also supports the earlier regression analysis of active transportation vs. population and GDP. The analysis tables can be found in Table C.28 through Table C.30.

4.2.2 Takeaway

This section focuses on analysis of the data of the variables and allows to identify which variables allow to establish any relationship between active transportation and economic growth. Through regression analysis, this section helps identify and establish a relationship

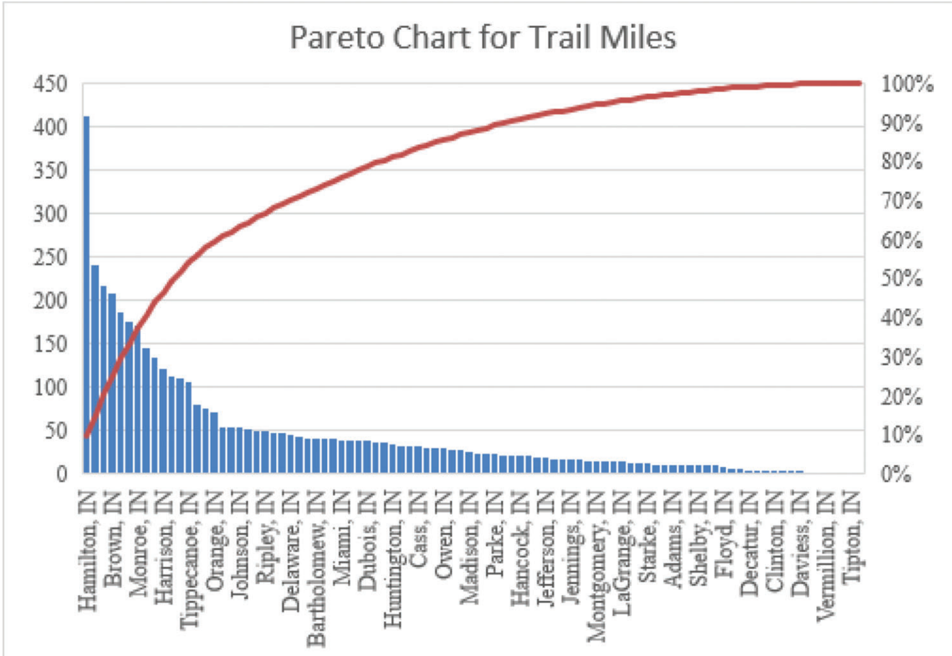


Figure 4.15 Pareto chart for trail miles.

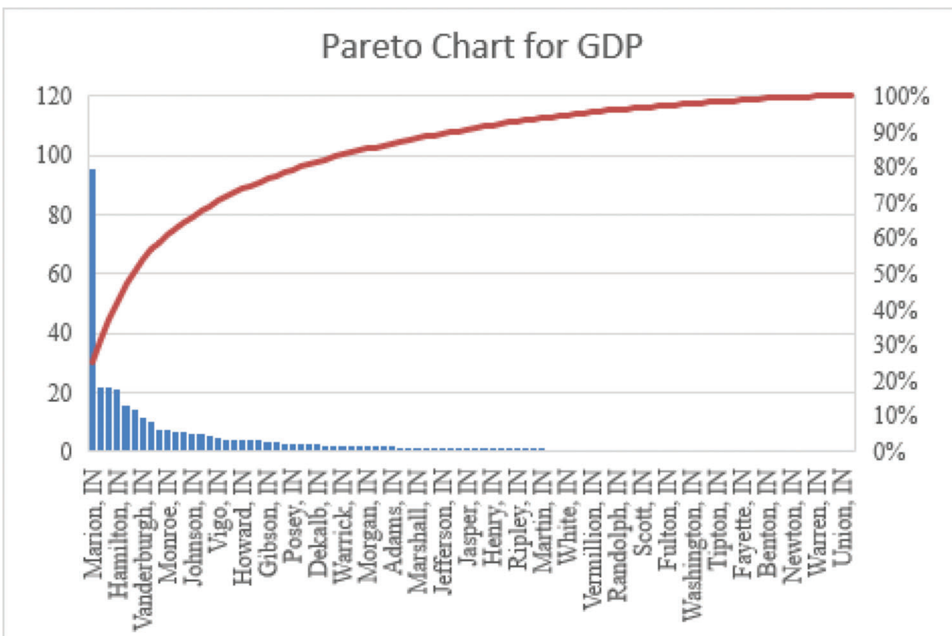


Figure 4.16 Pareto chart for GDP.

between active transportation parameters (trail miles) and the economic parameters (industry GDP, number of firms) which varies for counties with greater than or less than 20 miles of trails. It is also concluded that the manufacturing, finance, insurance, retail estate, rental and leasing industries are the highly impacted industries by active transportation, thus showing how which industries would be growing with active transportation development.

4.2.3 Healthcare Industry

We collected data for several healthcare metrics and transportation metrics as shown in the Table 4.4. We performed regression analysis to identify any potential relationship among these metrices and thereby determine the relationship between healthcare industry and transportation.

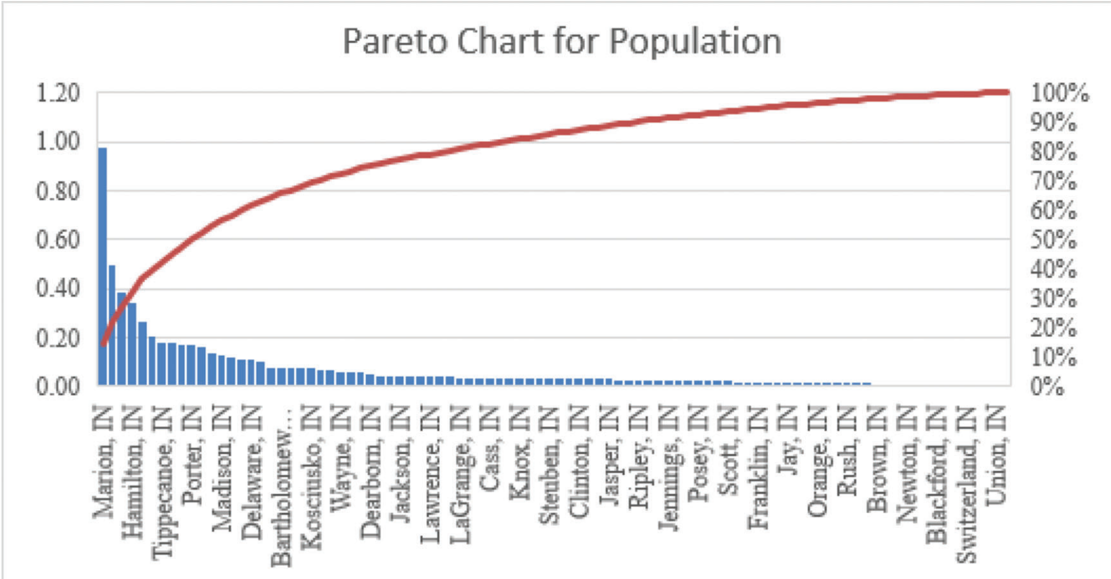


Figure 4.17 Pareto chart for population.

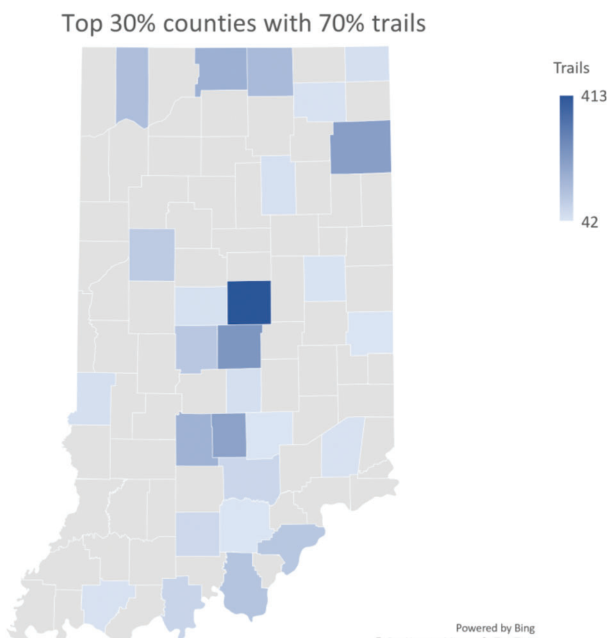


Figure 4.18 Top 30% of counties with 70% of trails.

Using the data for these metrices, we performed some exploratory data analysis. While performing correlation analysis to identify the relationship between these metrices, we determined that not all the metrices yielded definitive results. This was due to several reasons like insufficient data and absence of any relationship, among others. Thus, certain metrices were eliminated from further consideration and analysis.

County-level healthcare budget failed to identify the actual amount that the county spent on healthcare industry and only provided the budget prepared by the county. Since there was a huge disparity between the two, we could not use healthcare budget to gauge the presence of healthcare industry in a county. The data also failed sanity checks for dollar amounts involved.

The healthcare spending data obtained at the county level failed to represent the true data set comprising of all the participants involved in the healthcare value chain, the pharmaceutical producers, hospitals, pharmacies, healthcare professionals, healthcare firms, insurers, and patients. The healthcare spending data seems promising to reach estimated national average per-capita healthcare spending, but not close enough to use for analysis.

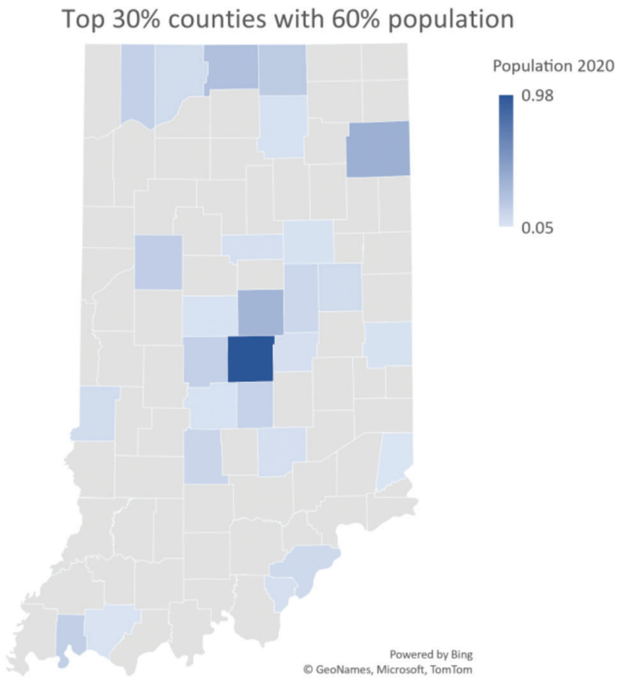


Figure 4.19 Top 30% of counties with 60% of the GDP.

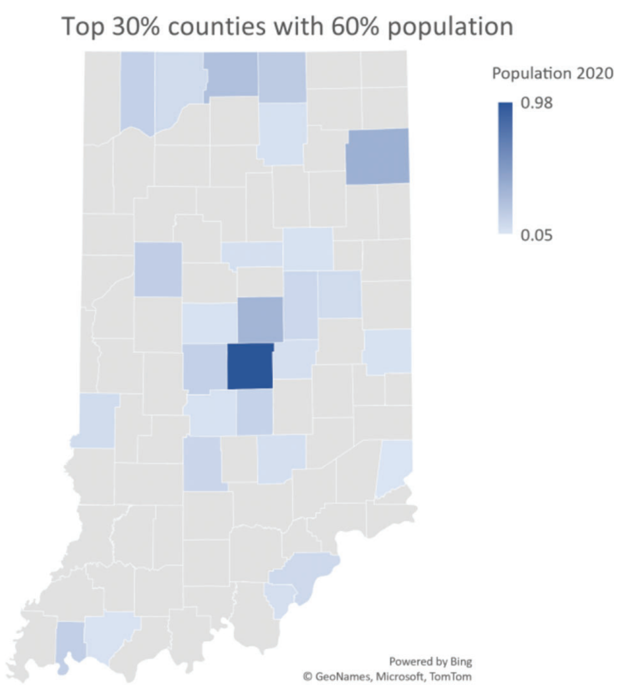


Figure 4.20 Top 30% of counties with 60% of the population.

The Medicare reimbursement data was obtained first from one of the two data banks listed in Table B.2. The data set obtained was analyzed at a per-capita level against county trail miles. The per-capita value of Medicare refunds over a year tends to be constant in value with changing miles per capita, which makes it unfit for study. We explored other data sets as mentioned in Table B.3 to check whether the Medicare refunds

TABLE 4.4
Determinants of healthcare and the transportation industry

Healthcare Metric	Transportation Metric
County-level healthcare payroll	Trail miles
Number of healthcare firms	County-level roadway miles
County-level healthcare budget	Population density
Medicare refunds	Investment in transportation
County-level healthcare spending	–
Number of ambulatory services	–

renders to be an unfit healthcare metric for association with transportation industry. The preliminary analysis of another Medicare refunds data set and regression analysis fails to deduce any correlation between Medicare refunds against the trail miles per capita at the macro level. Hence, Medicare refunds metric is disregarded as the healthcare metric showing least potential in associating with the transportation industry parameters directly.

4.2.4 Healthcare Payroll Analysis

County healthcare payrolls refers to the sum-total of payrolls for all employees involved in the healthcare industry as is classified by a series of NAICS codes (446, 524, 621, 622, 623). The industries that are categorized under these NAICS codes have been considered as components of the healthcare industry.

4.2.4.1 Healthcare payrolls (Health_pyrl) vs. trail miles. County trail miles refers to the sum of the trail miles present in a specific county. Regression was used as a means of analysis for these factors. A line was fit for county data points labelled for healthcare payrolls and trail miles, after outliers were removed. The outliers for these factors were: Marion County (excluded from both analyses ARE disproportionately high *Payroll: Trail miles* as well as *Payroll: Road miles* value) and Brown County (excluded from county trail miles analysis, disproportionately low *Payroll: Trail miles*).

Using the trail miles data from Table B.6, regression analysis was performed to understand the relationship between the healthcare metric—payroll and transportation metric—trail miles. A scatter plot was developed, as shown in Figure 4.21, where healthcare payroll is the independent variable, and the trail miles is the dependent variable.

We can observe here that there are two outlier data points—representing Marion and Brown counties, which deviate from expected trends. Marion County has a higher than usual healthcare payroll due to the presence of Indianapolis while Brown County has higher than usual trail miles due to the presence of state parks.

As shown in Figure 4.22, a line was fit for data points labelled for healthcare payrolls and trail miles with the trend line highlighted and outliers removed. The fitted line parameters are noted in Table D.1 that yields the equation below.

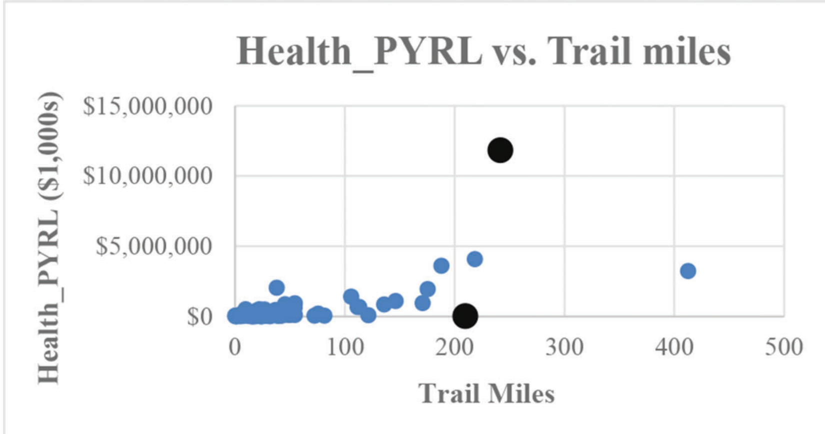


Figure 4.21 Scatter plot of healthcare payroll vs. trail miles.

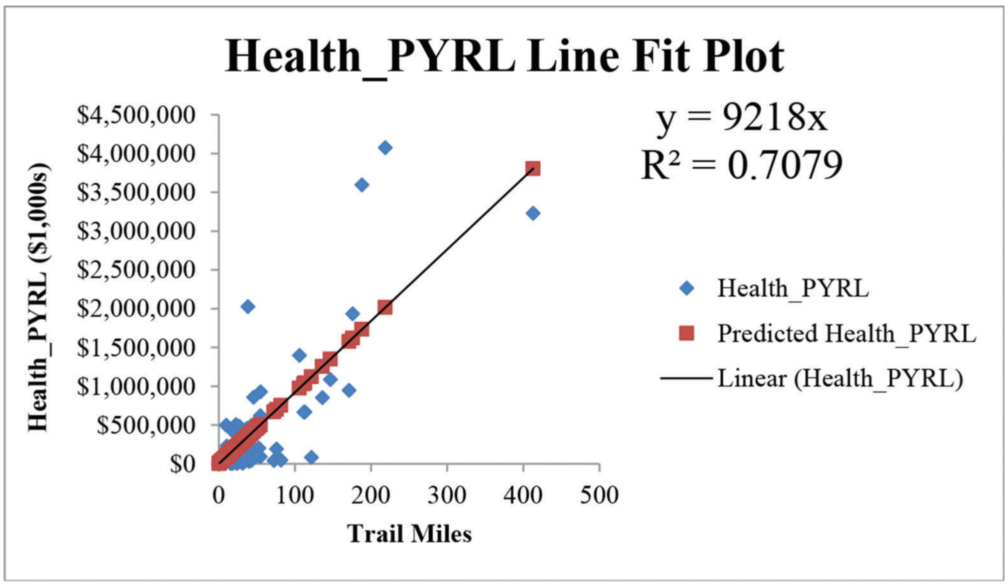


Figure 4.22 Healthcare payroll vs. trail miles.

*Healthcare Payrolls (in $1,000s) = 9,218 * Trail Miles*

It is of essential importance to note that based on the regression analysis and feedback received from healthcare and transportation industry participants, trail miles may not be an appropriate metric to analyze due to them not representing ease of accessibility to healthcare establishments. A more appropriate general transportation metric suggested was roadway miles.

4.2.4.2 Healthcare payrolls vs. roadway miles. Next, the relation between healthcare payroll and roadway miles was explored. A scatter plot was generated where the independent variable was healthcare payroll while the dependent variable was roadway miles, as shown in Figure 4.23. The cluster marked in blue represents amounts >$200,000 and the cluster marked in red represents amounts <$200,000.

Refer to Table 5.3 which provides the statistical results for the regression analysis, and it shows that the relationship for the entire dataset is poor.

It is evident from the graph that there appear to be two smaller trends that would explain the relationship better than one overall trend. This behavior was sufficiently captured by splitting the dataset at the healthcare payroll value of $200,000 (in $1,000s). The resulting two clusters were the following.

- *County Healthcare Payroll (in $1,000s) < $200,000*
- *County Healthcare Payroll (in $1,000s) > $200,000*

Figure 5.24 shows the regression analysis performed on Cluster 1 data with fitted line trend equation. While Figure 5.25 shows the regression analysis performed on Cluster 2 data with fitted line trend equation. Again, Marion County data point was an outlier due to the higher-than-normal healthcare payroll compared to the

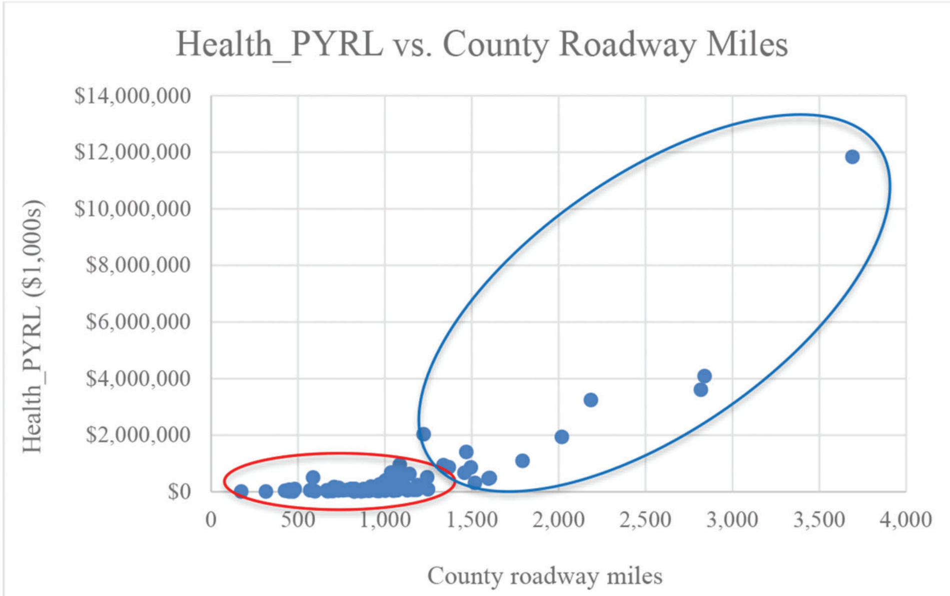


Figure 4.23 Clustered view of healthcare payroll vs. roadway miles.

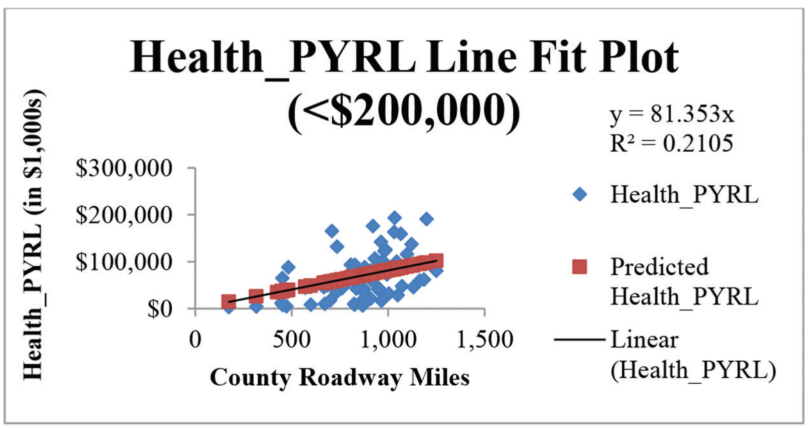


Figure 4.24 Healthcare payroll vs. road miles for Cluster 1.

low roadway miles due to smaller geographical area and dense population.

The resulting relationship equations for both the clusters are as follows.

*Cluster 1: Healthcare Payrolls (in $1,000s) = 81.353 * County Roadway Miles*
*Cluster 2: Healthcare Payrolls (in $1,000s) = 840.47 * County Roadway Miles*

The segregation provides a better relationship which is evident when comparing the statistical results refer to Table D.3 with that in the Table D.4. As is evident, there is an improved R-squared value for each individual cluster compared to the combined data value.

Results and discussion: Cluster 1 signifies a low payroll employee group (<$200,000) residing in counties where the roadway miles infrastructure is not developed to its full potential. Hence it identifies these counties where there is huge scope for transportation infrastructure development which will boost the economic payroll activity of healthcare employees. The identified counties in Cluster 1 can drive targeted strategies for transportation investment in building road infrastructure which uplifts the healthcare industry and eventually improves the healthcare employee payroll by 10 times as they move from Cluster 1 to Cluster 2. It is essential to treat low payroll employees of the healthcare sector separately with high payroll employees when projecting strategies for the future economic development of healthcare industry payroll based on the targeted investments in the development of transportation infrastructure.

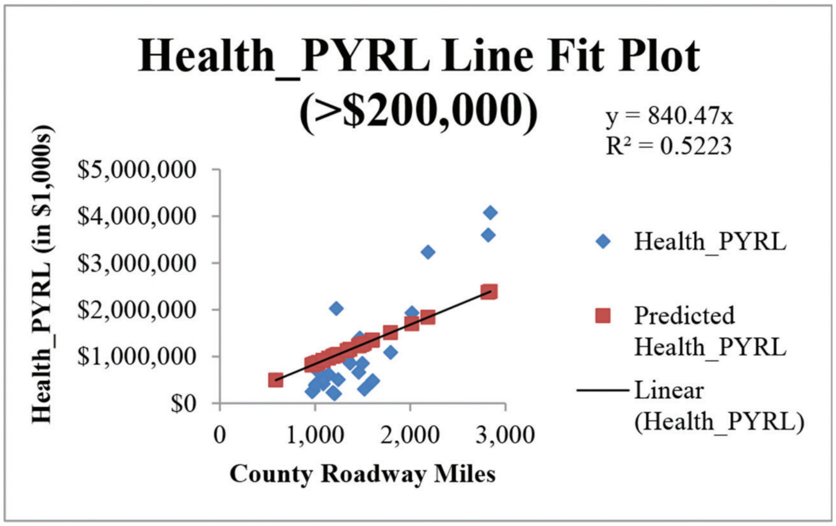


Figure 4.25 Healthcare payroll vs. road miles for Cluster 2.

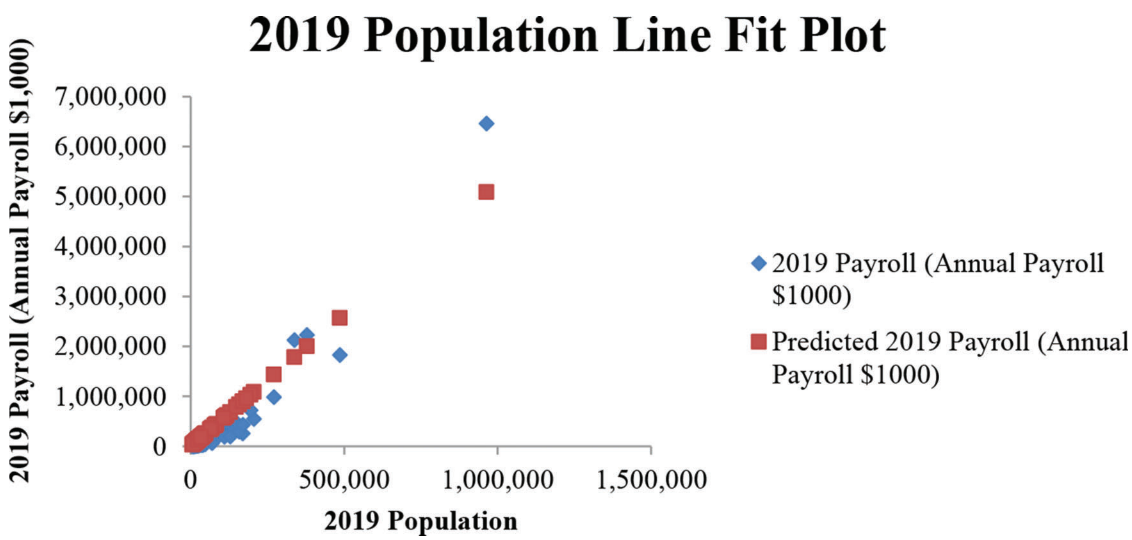


Figure 4.26 Healthcare payroll vs. population

4.2.4.3 Healthcare payroll correlation with population.

Hypothesis: If population trends across Indiana counties are changing then there is a significant impact on healthcare payroll across the counties and thereby the healthcare industries across the counties.

Regression analysis: Figure 4.26 shows the line fit plot with healthcare payroll as the independent variable and population as the dependent variable with trend line fitted for the data.

*Correlation Equation: Healthcare Payrolls (in $1,000s) = 5.276 * Population*

From the regression analysis summary, as it is highlighted in Table D.4, it can be clearly seen that there is a direct influence of population on the economic parameters like payroll for healthcare industry. Thus, it can be said that growth in population drives the growth in healthcare industry. It leads to a hypothesis of analyzing the demographic standpoint of population at macro level across different counties as a way to understand how the healthcare industry is shaped by population.

Results and discussion: It is established that there is significant correlation between population of a county versus the healthcare payroll of that county and population plays an important role in governing the strategies for healthcare economic developments.

4.2.4.4 Demographic analysis of healthcare employee payroll.

Hypothesis: Since population plays an important role in healthcare payroll, the age demographic of population influences the healthcare payroll and thereby healthcare industry. Based on the data collected, it is convenient to group population in two major categories namely age 44 to 64 and age 65+ to assess their impact on the healthcare payroll.

4.2.4.4.1 Regression analysis for age group 1 (44 to 64). A scatter plot was developed, as shown in Figure 4.27, where the healthcare payroll is the independent variable and the population in the age group cluster (44 to 64) is the dependent variable. A line is fitted for the data to determine the trend in the relationship that is defined by the following equation.

*Healthcare Payrolls (in $1,000s) = 21.458 * (Population of age group 44 to 64)*

As observed from Table D.5, the p-value, and t-stat values of the regression analysis for age group 44 to 64 signify a strong correlation of this particular age group on healthcare economic data point—employee payroll. It may play a critical role in identifying an approach towards formulation and development of plans and strategies for association of healthcare industry with transportation since transportation is correlated with population.

4.2.4.4.2 Regression analysis for age group 2 (65+). A scatter plot was developed, as shown in Figure 5.28, where the healthcare payroll is the independent variable and the population in the age group cluster (65+) is the dependent variable. A line is fitted for the data to determine the trend in the relationship that is defined by the following equation.

*Healthcare Payrolls (in $1,000s) = 34.838 * (Population of age group 65+)*

Based on the Table D.6, the p-value and t-stat value of the regression of the age group 65+, it is also recommended that this particular age group also influences the employee payroll data but there can be different approach in building action plan and strategies for results based on this age group.

Results and discussion: From the analysis, it is clear that different age groups have different needs with respect to healthcare and transportation parameters, as depicted through the correlation equations obtained from the regression analysis. It should be noted from this analysis that age groups 44 to 64 and 65+ must be treated separately when considering the demographics in identifying strategies and action plans for healthcare economic development. Hence, demographic scenario plays a critical role in formulation and implementation of different strategies to link economic developments of transportation industry with healthcare industry.

4.2.4.5 Healthcare payroll correlation with population, road miles, trail miles with and without demographics.

Hypothesis: If population demographics along with identified transportation metrics change, then it collectively impacts healthcare payroll and thereby healthcare industry.

To explore this hypothesis, a multi-regression analysis was performed where the healthcare payroll is the independent variable and population and the transportation attributes—road miles and trail miles, are the dependent variables. The regression was performed with and without considering the age demographics. This analysis will yield results that lead to effective ways of formulating strategies for transportation to boost the healthcare industrial value chain.

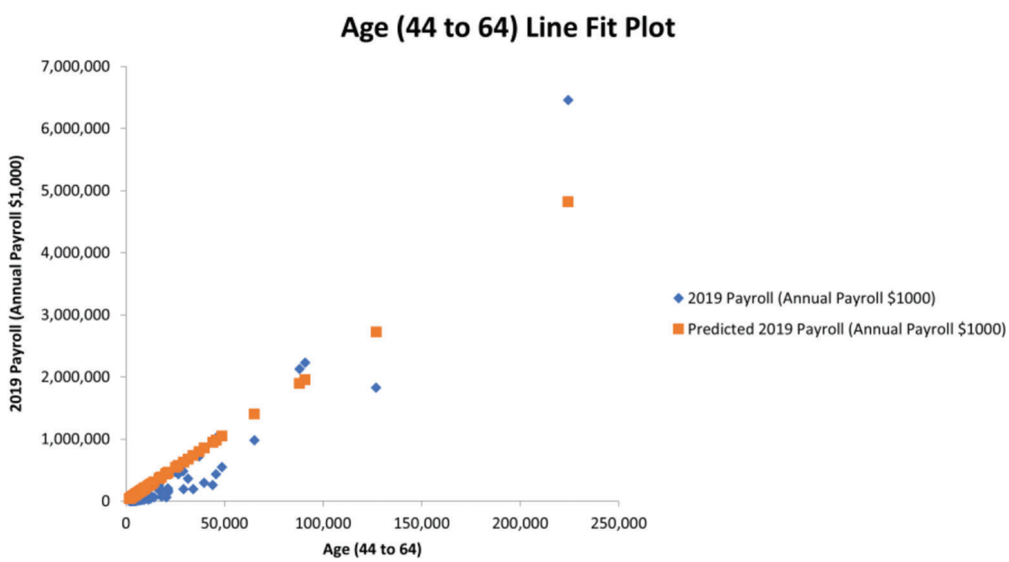


Figure 4.27 Healthcare payroll vs. age group (44 to 64).

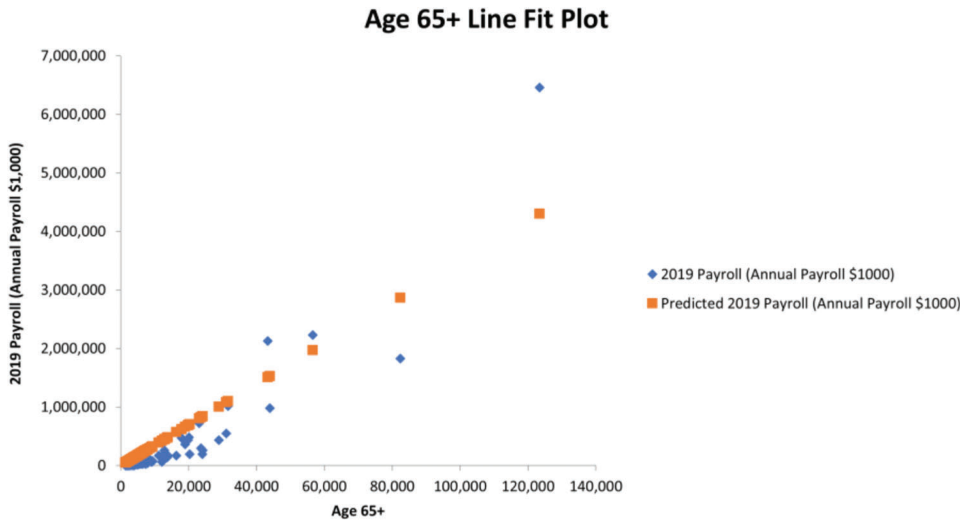


Figure 4.28 Healthcare payroll vs. age group (65+).

Regression analysis without age group demographics:

*Healthcare Payrolls (in $1,000s) = 6.893 * Population – 250.8 * Road Miles +4.27 * Trail Miles*

Regression analysis with age group (44 to 64) and age group 65+ demographics:

*Healthcare Payrolls (in $1,000s) = 86.8 * (Age group 44 to 64) – 71.16 * (Age group 65+) – 135.9 * Road Miles – 851.2 * Trail Miles*

Clearly, both the regression analysis led to significant correlation of population, with (refer to Table D.7) and without age group demographics (refer to Table D.8) in influencing the impact of transportation parameters like road miles and trail miles towards the healthcare payroll.

Result and discussion: In order to project the impact of a certain strategy and action plan on healthcare economic parameter (employee payroll), we do see significant involvement of road miles, trail miles and population progression across different counties.

4.2.5 Healthcare Firms Analysis

These analyses have been conducted based on a hypothesis that hospitals/healthcare industry follow population movement trends and eventually transportation needs to invest in counties following the population trends so as to better the accessibility for healthcare establishments and population density.

4.2.5.1 Number of healthcare firms vs. county healthcare payrolls/county roadway miles. The number of healthcare firms in a county was obtained from the NAICS datasheet. The firms representing the NAICS codes mentioned above were considered again.

As expected, the number of healthcare firms shows a very high correlation with county healthcare payrolls (0.94). The metric also shows correlation with county roadway miles at a similar scale to county healthcare payrolls (0.89). Table D.9 shows the sample data of county-wise number of healthcare firms as classified by NAICS codes. Table D.10 highlights data showing correlation between previously analyzed factors (healthcare payroll, county roadway miles) and the new identified factor (number of healthcare firms).

4.2.5.2 Healthcare firms correlation with population. In order to reiterate the statement that healthcare industry follows population, please see the Figure 4.29 which shows the population densities scattered over Indiana map county wise and how the healthcare firms/ number of ambulatory services are established. Pictorially it explains that healthcare industry is following the population over the time.

But it is also essential to check the correlation and/or regression equations to prove the hypothesis statement. Regression analysis:

*No. of Healthcare Firms = 0.02 * Population*

Figure 4.30 displays the number of healthcare firms line fit plot versus population across different counties.

Based on the regression parameters shown in Table D.11, it clearly indicates that there exists a strong linear one-to-one relation between population and number of healthcare firms.

4.2.5.3 Healthcare firms per capita correlation with transportation investment. In this analysis, we want to target the correlation between the number of healthcare firms per capita and transportation investments. We discuss how we can strategize based on the number of healthcare firms per capita being developed in a county and build an action plan for transportation industry to act on some transportation development projects in counties where we see lot of residuals. Figure 4.31 depicts a strong visualization of the density

Figure 4.29 County wise geographic visualization of population, healthcare firms, and ambulatory services.

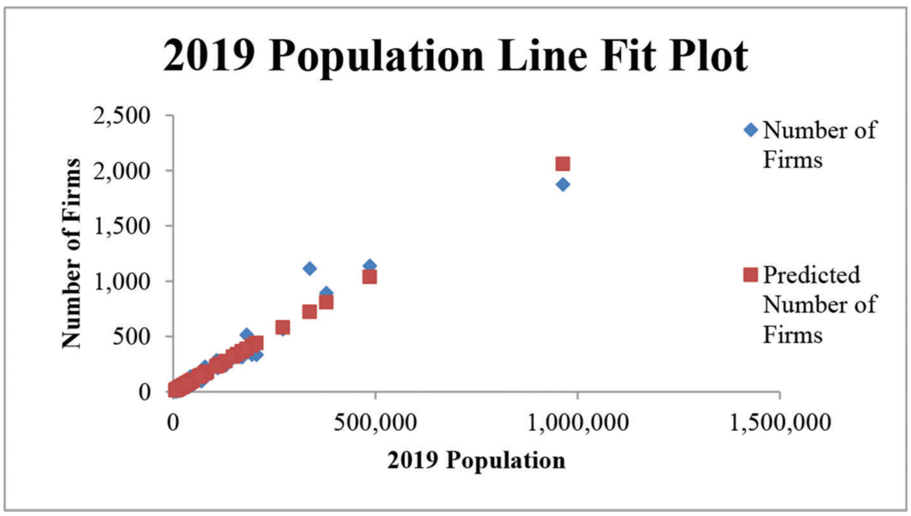


Figure 4.30 Healthcare firms vs. population.

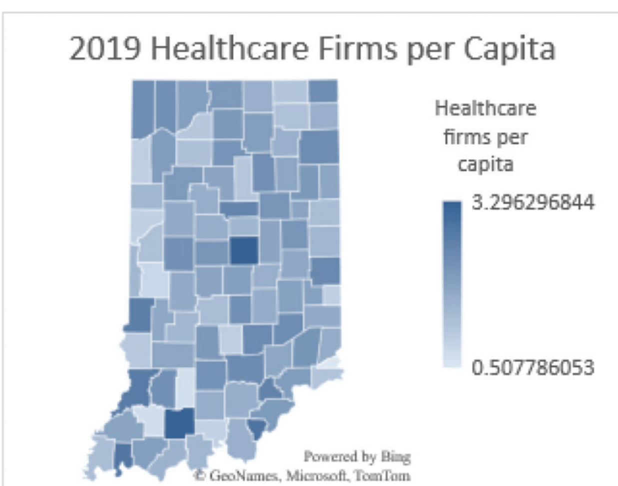


Figure 4.31 County wise geographic visualization of healthcare firms per capita.

of healthcare firms spread across different counties of Indiana when gauged against the population parameter.

Hypothesis: If number of healthcare firms per capita changes then the transportation investment also changes.

Regression analysis:

Transportation Investment (in \$) = 6,444,354 * *No. of Healthcare Firms per Capita*

After analyzing the line fit plots as shown in Figure 4.32 and regression output tabulated in Table D.12, we do identify outliers which may affect the correlation coefficients. By removing the high disproportionate values of investment and healthcare firms per capita. So, it's essential to check the correlation after removing the outliers identified having extremely disproportionate values.

After removing outliers, the outliers identified are Allen, Daviess, Floyd, Hamilton, Lawrence, Morgan, Marion, Wabash counties.

Transportation Investment (in \$) = 4,719,484 * *No. of Healthcare Firms per Capita*

As we keep identifying the outliers and eliminate the spread these outliers create on number of healthcare firms, it is clear that major set of counties follow the population driven trend as visible in the Figure 4.33 with guided influence of transportation metrics on

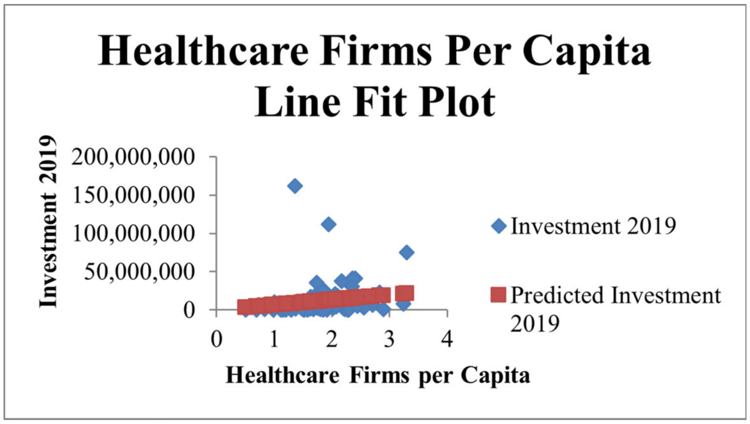


Figure 4.32 Transportation investment vs. healthcare firms per capita.

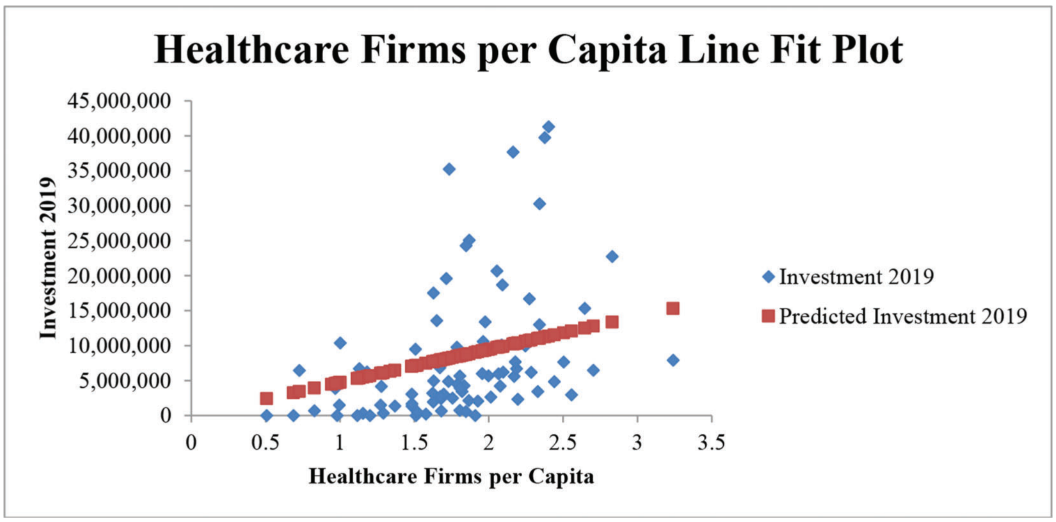


Figure 4.33 Transportation investment vs. healthcare firms per capita excluding outliers.

selection of counties which require the development of healthcare establishments. Additionally, the investments in the transportation infrastructure in these identified counties may lead to better planning of development of healthcare establishments when the regression equation parameters shown in the Table D.13 are considered.

4.2.5.4 Healthcare firms correlation with transportation investment. Upon analyzing the number of healthcare firms per capita trends scattered across different counties and its correlation with transportation investment, it is now essential to look at absolute number of healthcare firms' relation with investment parameter and seek for outliers which can become the basis for building focused strategies for these outliers or rather identified counties.

Hypothesis: If total healthcare firms change and then the transportation investment also changes. Regression analysis without removing outliers:

*Transportation Investment (in $) = 48,655 * No. of Healthcare Firms + 4,058,964*

Upon analyzing the line fit plots as shown in the Figure 4.34, it is clearly evident that there are outliers which skew the correlation equation concluded from the regression parameters shown in Table D.14 available in Appendix D. Upon conducting the outlier analysis by finding maximum and minimum residual values, Lake County and Morgan County identified as outliers. Further these identified counties were excluded from the regression analysis. Figure 4.35 shows the transportation investment line fit plot versus the number of healthcare firms after removing the outliers from the data set. Further the correlation equation can be concluded from the regression summary output displayed in Table D.15 available in Appendix D. After removing outliers:

*Transportation Investment (in $) = 54,945.6 * No. of Healthcare Firms + 1,780,518*

Results and discussion: Upon establishing the correlation equation, one can utilize these relations in making a data driven decision in choosing the right amount of investment to the set of identified counties

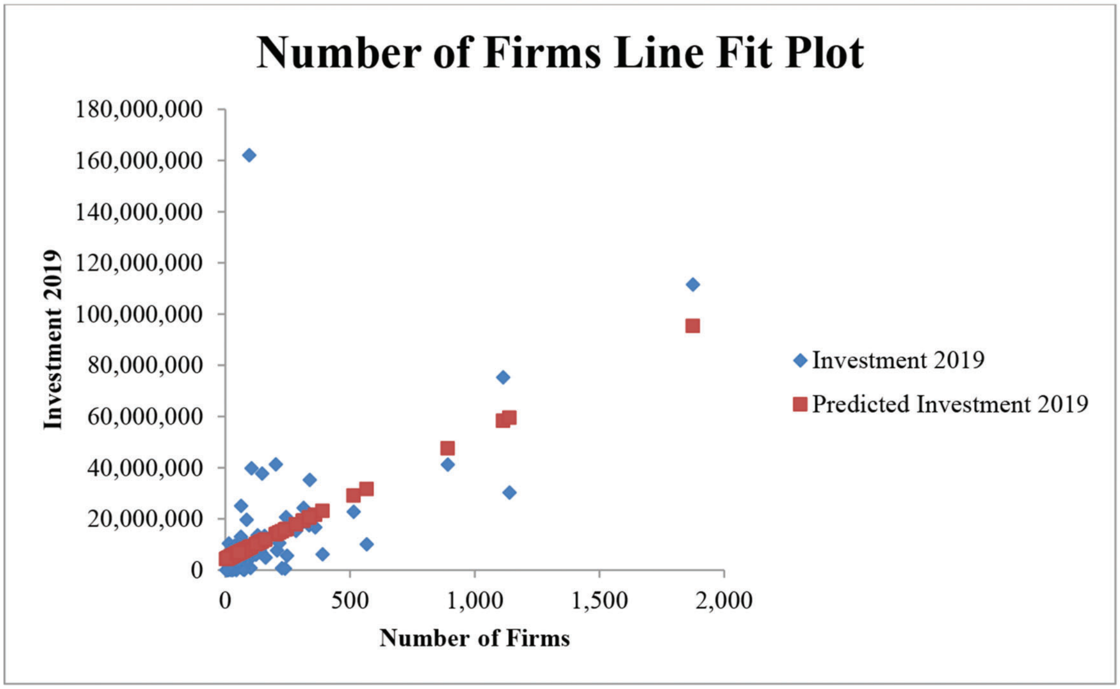


Figure 4.34 Transportation investment vs. number of healthcare firms.

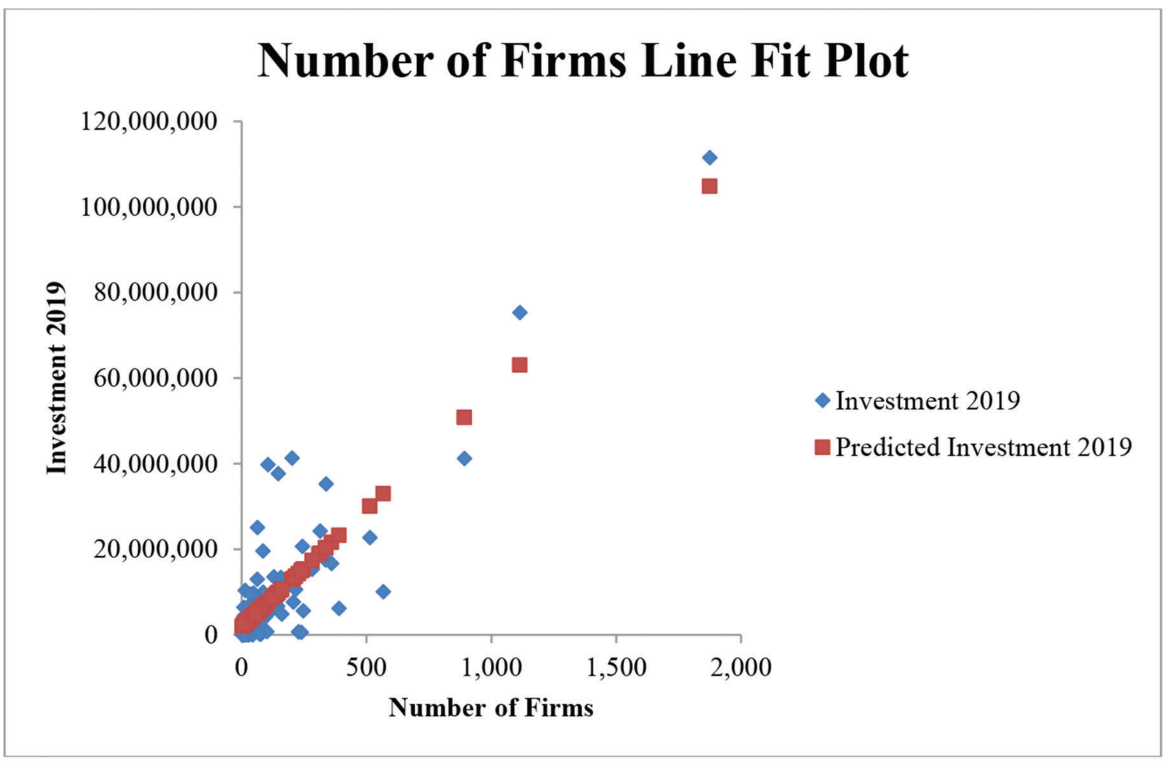


Figure 4.35 Transportation investment vs. healthcare firms (excluding outliers).

which require the improvement in the healthcare sector based on population trends. Furthermore, it can clearly improve the ease of accessibility to these healthcare firms with correct investment in the identified counties.

4.2.6 Ambulatory Service Firm Analysis

4.2.6.1 Number of ambulatory firms versus transportation investment. As we establish the correlation of number of healthcare firms versus transportation metrics, we also aim to explore other relevant healthcare industry metrics—number of ambulatory firms at a macro level for different counties. Figure 4.36 provides the geographic scatter visualization of the number of emergency ambulatory service locations across different counties in Indiana for the year 2019.

Hypothesis: To aid the increase in number of ambulatory service locations, there should be an increase in the transportation investment for development of transportation infrastructure that aims at better ease of accessibility.

To investigate this hypothesis, a scatter plot was developed where the transportation investment is the independent variable and ambulatory service locations is the dependent variable. A line was fit to explore the trend between the two attributes that yielded the following equation. Regression analysis without outliers removed:

*Transportation Investment (in $) = 75,468.6 * No. of Ambulatory Services + 4,513,554.5*

It is evident from Figure 4.37, that that Lake and Morgan counties have extreme residual values which swindle the correlation equation tabulated in from the regression statistics shown in Table D.16. To obtain better and reliable results, these outliers were removed, and the regression analysis was repeated. A line was fit for the new regression that yielded the following equation.

*Transportation Investment (in $) = 87,977.2 * No. of Ambulatory Services + 2,117,272.3*

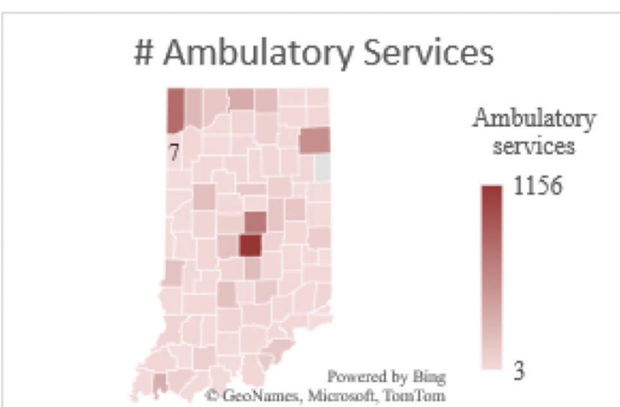


Figure 4.36 County wise geographic visualization of number of ambulatory services (2019).

Figure 4.38 shows the number of transportation investment line fit plot versus the number of ambulatory services after removing the identified outliers from the original regression analysis. The summary of the regression resulting in a correlation equation can be obtained in Table D.17. It is evident that the regression results and thereby the correlation significantly increased after removing the outliers. Thus, a trend can be observed between the transportation investment and the number ambulatory service locations.

This correlation is essential in guiding the investment of transportation industry to boost the appropriate growth of healthcare emergency services to counties, which are below the correlation trend line.

4.2.6.2 Number of ambulatory services versus state miles and road miles, respectively. The relationship between the number of ambulatory services and the road miles across different counties was explored to thereby determine any potential relationship between healthcare industry and transportation.

Scatter plots were created with state miles and road miles as the dependent variable and the ambulatory services as the independent variable to perform a regression analysis. A line was fit to study the trend for the data, and it yielded the following equations for both the plots:

*State Miles (# of miles) = 0.0833 * No. of Ambulatory Services + 112.3*

*Road Miles (# of miles) = 2.617 * No. of Ambulatory Services + 807.2*

It is clear that the number of ambulatory services have a direct relationship with road miles, according to Figure 4.40, and not with the state miles alone shown in Figure 4.39, across the counties at a macro level. Refer to Table D.18 that provides the summary of the regression analysis to explore the indirect impact of transportation development on the ease of accessibility to the elements of healthcare establishments.

4.2.7 Takeaway

This section helps determine the relationship between transportation and healthcare metrics. Using the data, we are able to identify which healthcare metrics are impacted by which transportation metrics. It also helps identify the counties that do not follow the trend or are outliers and therefore need to be removed from consideration. The healthcare payroll is associated with the number of road miles, although payroll needs to be divided into two categories due to a huge spread. Population age groups also have an impact on the healthcare payroll and thus transportation development can be targeted accordingly. Healthcare firms and ambulatory services are impacted by population driven transportation and well-connected interstate highway network.

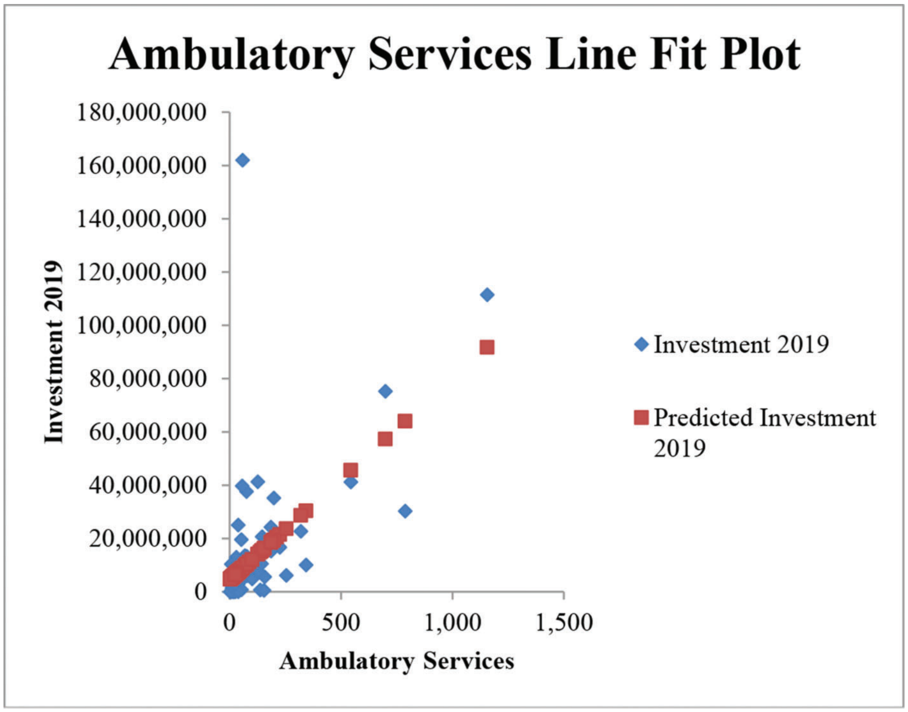


Figure 4.37 Transportation investment vs. number of ambulatory services.

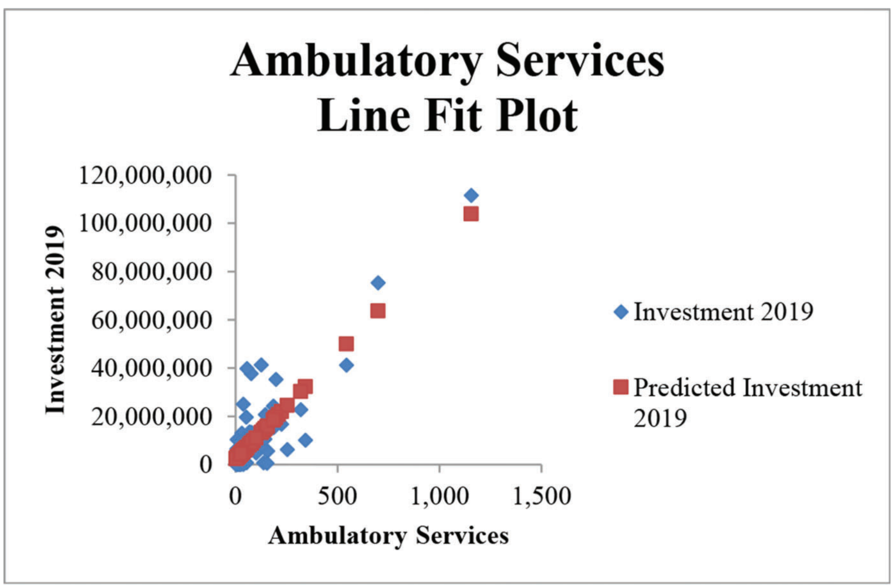


Figure 4.38 Transportation investment vs. number of ambulatory services (excluding outliers).

4.3 Data Analytics and Insights: Micro View

4.3.1 Trip Patterns

To gain further understanding of the trip attraction and generation patterns of various regions by analyzing the yearly trip patterns we evaluated the number of trips per user for both trip attraction and generation, as a means of standardizing the overall trips in relation to the population of each respective area. Standardizing trip data by population is important for a more accurate comparison between regions of varying population sizes. Without normalizing the data, regions with larger populations would naturally have more trips, making it difficult to compare trip attraction and generation patterns between regions.

As expected, in terms of inter-zip code trips, the major urban centers such as Indianapolis, Fort Wayne, Bloomington, Evansville, South Bend, and Lafayette are identified as the highest trip generators and

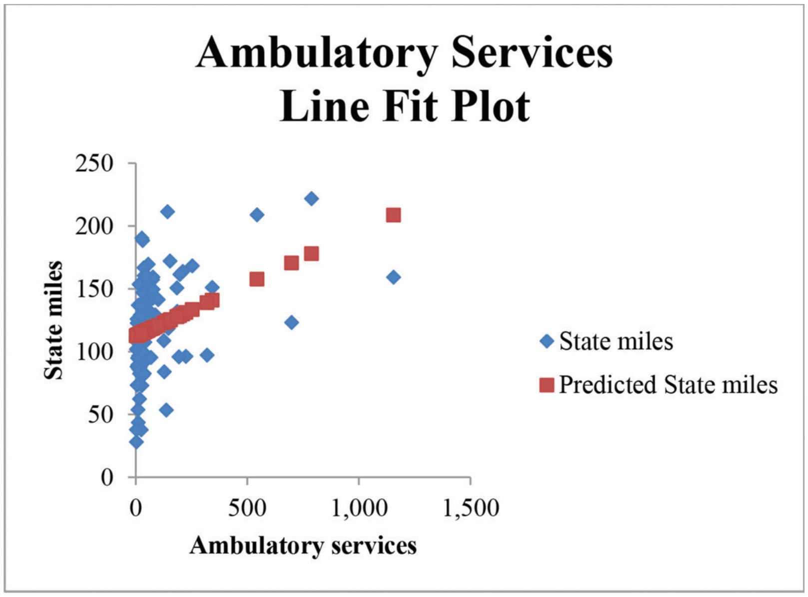


Figure 4.39 State miles vs. number of ambulatory services.

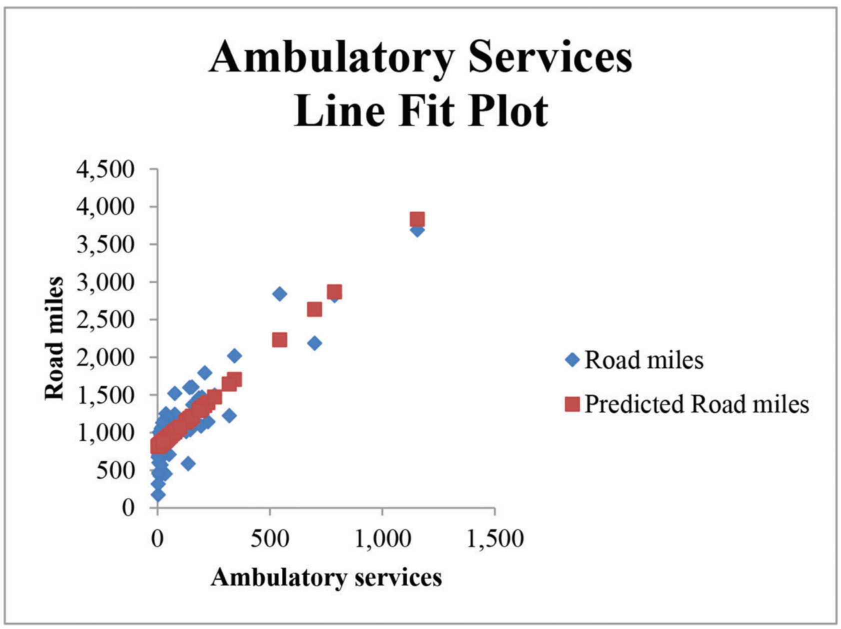
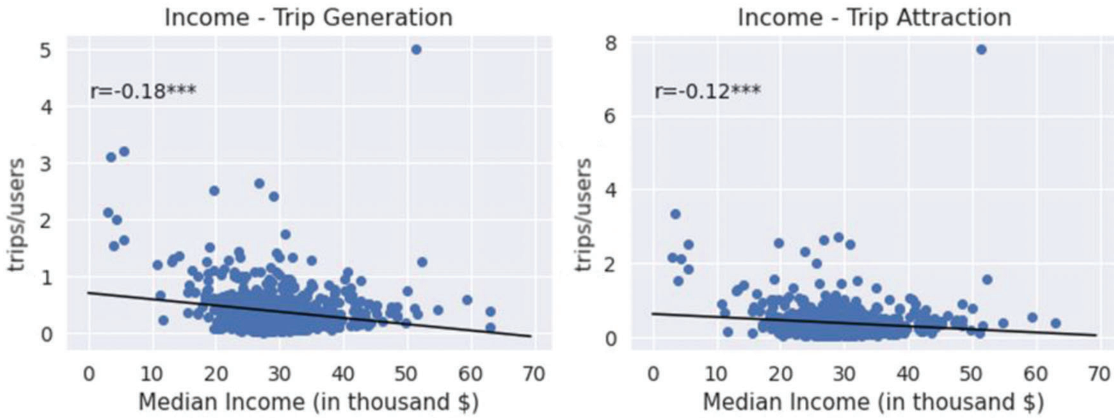


Figure 4.40 Road miles vs. number of ambulatory services.

attractors. Figure 4.41 explores the relationship between trip generation and attraction patterns with median income across ZCTAs. We found that areas with lower median income tend to exhibit higher trip generation and attraction patterns compared to areas with higher median income. Areas with high trip generation and attraction rates tend to experience greater traffic congestion and higher demand for transportation infrastructure. As such, it is critical to consider the socio-economic characteristics of the area when designing transportation systems and infrastructure. Our results suggest that a more targeted approach to transportation planning may be necessary to effectively manage transportation demand and alleviate congestion in lower-income areas. This could include investment in public transportation systems, improving access to non-motorized modes of transportation, and promoting alternative work arrangements that reduce the need for daily commuting.

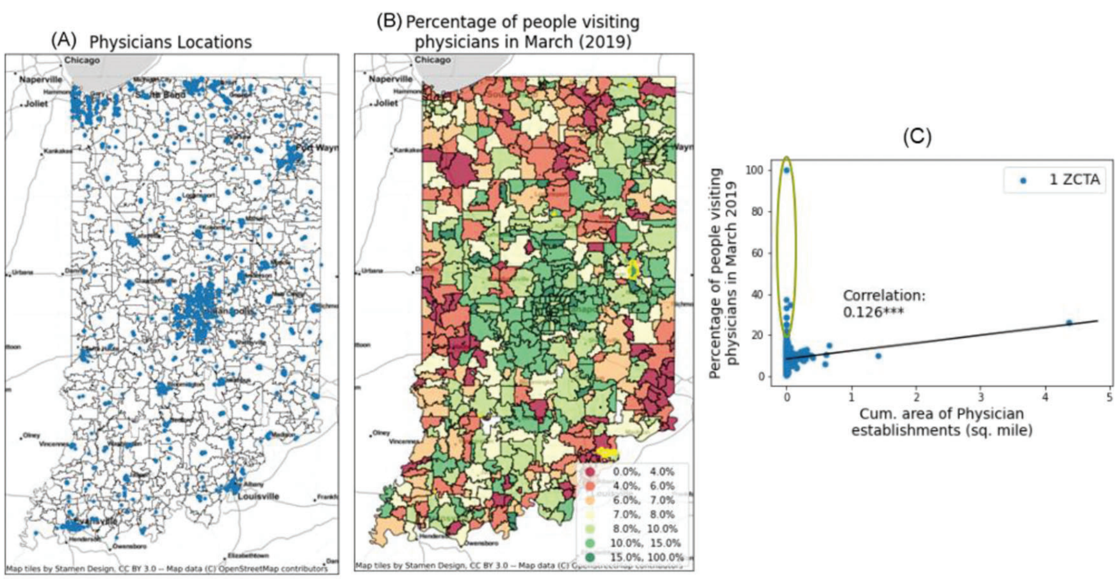
4.3.2 Visits to Healthcare

Visits to health are analyzed using the cell phone location data and the POI data. Analyzing visits to healthcare is an important tool for improving healthcare services and outcomes for a population. Figure 4.42



Note: Statistically significant negative correlation between trip generation and attraction with median income across ZCTAs. Areas with lower median income show higher trip generation and attraction patterns.

Figure 4.41 Correlation of trip generation and attraction with median income across the ZCTAs.



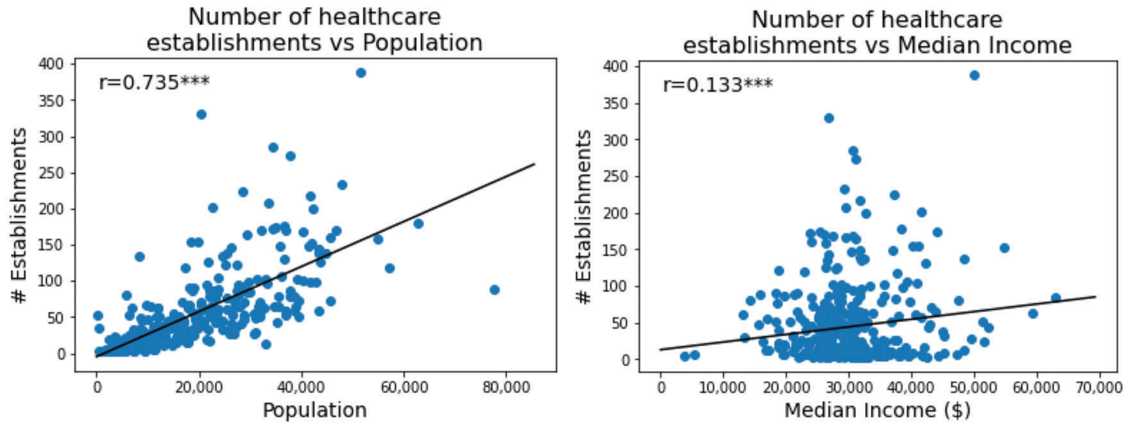
Note: Physician location and percentage of people visiting physicians are higher in urban areas (esp. Indianapolis). There are many zones with no physician clinics but that have a high percentage of visits to physicians (yellow boundary ZCTAs in B and points encircled with yellow in C.)

Figure 4.42 (a) Location of physicians' POIs, (b) percentage of people visiting physicians for each ZCTA in March 2019, and (c) relation of percentage people visiting physicians and cumulative area of physicians establishment in the ZCTA.

examines the location of physicians' point of interest (POIs), the percentage of people visiting physicians in each ZCTA in March 2019 and the relationship between the percentage of people visiting physicians and the cumulative area of physicians' establishments in each ZCTA. The analysis reveals that the locations of physicians and the percentage of people visiting physicians are higher in urban areas, particularly in Indianapolis. However, we also observe many zones with no physician clinics but high percentages of visits to physicians. This suggests that access to healthcare facilities may be limited in certain areas, even though the demand for healthcare services is high. This information can be used to identify areas where additional healthcare facilities are needed to meet the healthcare needs of the population. Furthermore, understanding the relationship between the location of healthcare providers and healthcare utilization can help policymakers and healthcare professionals make informed decisions about resource allocation and healthcare planning.

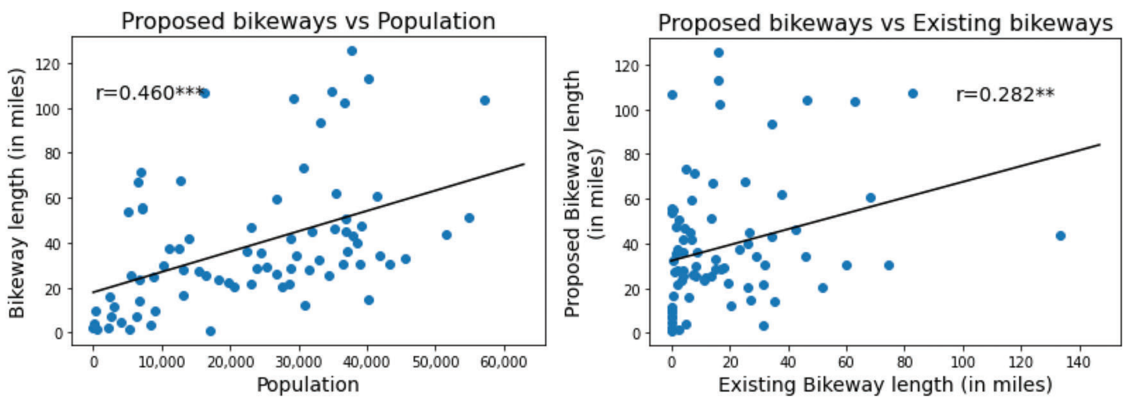
4.3.3 Healthcare Establishments

We analyze the number of healthcare establishments in each ZCTA using the data of county (or zip code)



Note: There is a significant positive correlation between the number of healthcare establishments in a ZCTA and its population and median income, which implies that more healthcare establishments are in wealthier, more highly populated areas.

Figure 4.43 Correlation between the number of healthcare establishments and demographics of population and median income for ZCTAs.



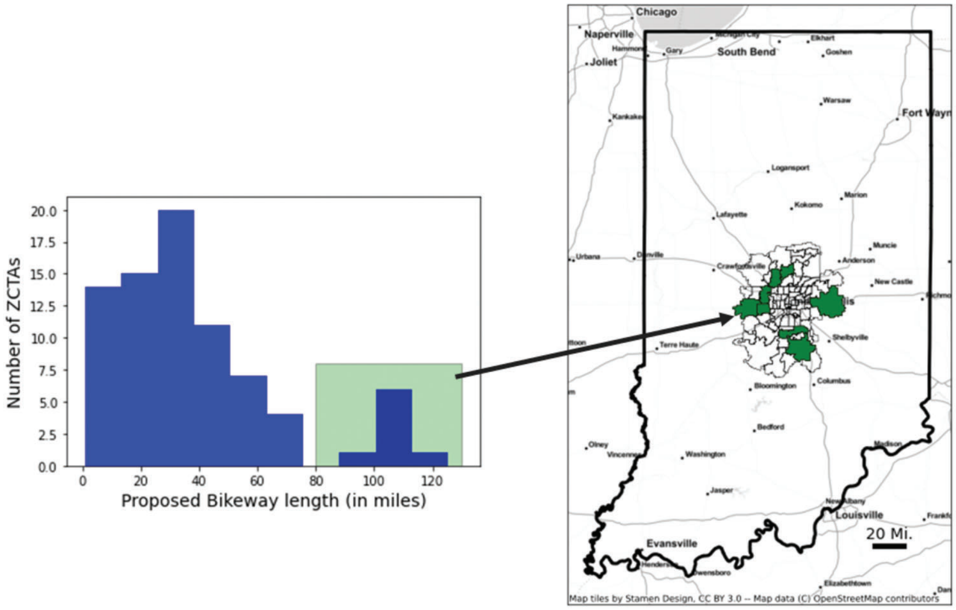
Note: There exists a statistically significant positive correlation between the proposed bikeway lengths and the population and existing bikeway lengths.

Figure 4.44 The correlation between the lengths of proposed bikeways for each ZCTA and the corresponding population and length of the proposed bikeways.

business patterns (CBP/ZBP) from the Census Bureau. The relationship between the number of healthcare establishments and the demographics of population and median income for ZCTAs was examined in 5.43. The findings reveal a significant positive correlation between the number of healthcare establishments in a ZCTA and its population and median income. This implies that areas with a larger population and higher median income tend to have more healthcare establishments. The implications of this finding are noteworthy, as it suggests that healthcare businesses are more likely to thrive in areas where there is a higher demand for healthcare services, which may include wealthier communities with greater access to healthcare resources. This also highlights the importance of considering demographic factors when making decisions regarding the placement of healthcare establishments. This could inform healthcare policy and planning initiatives, as this information may be used to identify areas that are underserved and in need of additional healthcare resources. The results could also be used to inform investment strategies in the healthcare sector, helping to ensure that resources are allocated efficiently and effectively.

4.3.4 Proposed Bikeways

The data on proposed bikeways was collected from the website of IndyMPO and is used as a proxy for active transportation investments. There is a proposed bikeway in about 76 ZCTAs in and around Marion County and these are considered when the relationship between active transportation and the industry growth is explored. Figure 4.44 examines the correlation between the proposed bikeway lengths and the population and existing bikeway lengths of each ZCTA in our study area. The results indicate a statistically significant positive correlation between the proposed bikeway lengths and both the population and existing bikeway lengths. This implies that areas with higher population and existing bikeway infrastructure tend to have longer and more proposed bikeways and active transportation investments.



Note: The x-axis shows the range of proposed bikeway lengths, which vary from 5 miles to 120 miles. The proposed bikeways with highest lengths (>90 miles) are all located in the suburbs of Marion County.

Figure 4.45 The histogram displays the distribution of proposed bikeway lengths across ZCTAs.

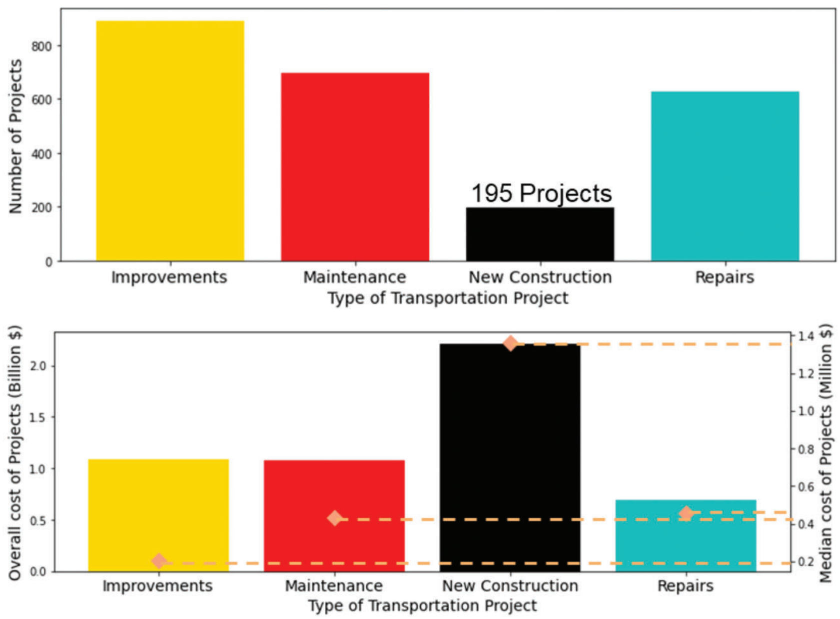
This underscores the importance of considering the existing infrastructure and population when planning and prioritizing bikeway development projects. Areas with a higher population and longer existing bikeway networks may require more extensive and interconnected bikeway networks to meet the demand for active transportation options. This also suggests that bikeway planning should account for the needs and preferences of the local population, particularly in areas with a higher population. This could include conducting community engagement efforts to gather input from residents, considering their travel patterns, and identifying key destinations to ensure that bikeways are planned and designed to effectively serve the needs of the community.

The proposed bikeways' distribution across ZCTAs can be observed through the histogram displayed in Figure 4.45. The x-axis of the histogram shows the range of proposed bikeway lengths, which vary from 5 miles to 120 miles. It is interesting to note that the highest proposed bikeway lengths (>90 miles) are all located in the suburbs of the Marion County. This highlights the potential for increased biking infrastructure in suburban areas, which could provide greater connectivity and accessibility for residents to various destinations. This can have numerous implications, including promoting active transportation, reducing traffic congestion, and improving public health outcomes. By understanding the distribution of proposed bikeway lengths, policymakers and city planners can prioritize and allocate resources towards developing and expanding bikeway infrastructure in areas with greater potential for impact.

4.3.5 Transportation Investments

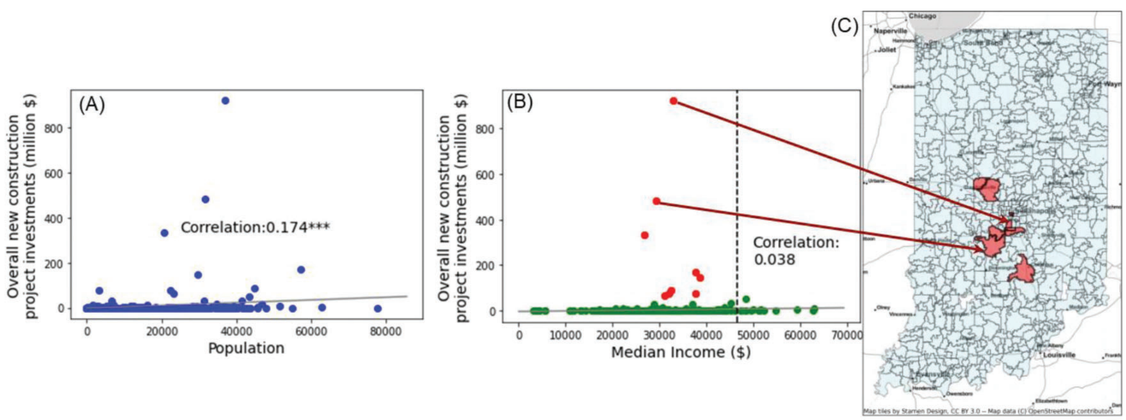
The transportation data is obtained from INDOT which contains the information about the transportation projects performed by INDOT in 2019. Figure 4.46 illustrates the number of projects and cumulative costs of different types of transportation projects. It can be observed that new constructions have the least number of projects, with approximately 195 projects, while all other types of improvements, maintenance and repairs have a significantly higher number of projects. However, the highest cumulative investment is made for new transportation construction projects. These projects also have the highest median project cost among all types of transportation projects. In contrast, the least amount of money is spent on repairs by INDOT. High projects and investments are observed in the suburbs of Marion County and the area around Bloomington. These investments are majorly related to sections of I-65 and SR 37 in the suburbs of Marion County and construction of sections of I-69 in the Bloomington area. Furthermore, the least median project cost is observed for improvement-based projects.

These findings indicate that the state of Indiana has invested heavily in new transportation construction projects, which could result in significant improvements in transportation infrastructure. Additionally, it underscores the emphasis on expanding and building new transportation infrastructure. The relatively lower investment in repairs and improvements shows the decreased life cycle costs. These findings shed light on the prioritization of resources and funding allocation for different types of transportation projects.



The fewest number of projects are for new constructions (about 195 projects), while all other types of improvements, maintenance, and repairs have a significantly higher number of projects. Overall, the highest cumulative money is invested for the new transportation construction related projects. These projects also have the highest median project cost observed. The least money is spent on repairs by INDOT, and the least median project cost is observed for improvement-based projects.

Figure 4.46 The number of projects and the cumulative costs of the projects for each type of transportation projects.



Note: The transportation investments in ZCTAS are positively correlated with population while there is an insignificant correlation with median income. Therefore, both richer and poorer regions have an investment of new transportation construction by INDOT. The areas of highest investments (marked in red in B and C) are around the suburbs of Indianapolis and Bloomington.

Figure 4.47 The correlation between the transportation investments in ZCTAs and corresponding population and median income.

Understanding the distribution of projects and costs across different types of transportation projects can inform policymakers and transportation agencies in making strategic decisions about resource allocation, project prioritization, and investment strategies. This information can contribute to more efficient and effective transportation planning, ensuring that limited resources are allocated in a manner that maximizes the benefits and impacts of transportation investments.

Figure 4.47 reveals a positive correlation of transportation investments in different ZCTAs with the population. However, the correlation with median income is found to be insignificant, implying that both richer and poorer regions have investments in new transportation construction by INDOT. This suggests that transportation investment is not solely based on the wealth of an area, but rather, on the need for infrastructure development to accommodate the population. Interestingly, the areas with the highest investments in new transportation construction are around the suburbs of Indianapolis and Bloomington, indicating that these regions have been identified as high priority for transportation development. This finding highlights the importance of strategic planning and targeted investment in infrastructure development to meet the needs of growing populations and address transportation challenges in urban areas. Overall, the results suggest that transportation investments are driven by both population and infrastructure needs, and not solely by income levels of an area.

5. RESULTS

5.1 How Active Transportation Investments Attract Businesses

5.1.1 Macro-View Results of Business Attractiveness

Drawing conclusions from all the regression analyses, active transportation showed correlation with total GDP, specific industry GDP, no of firms. The same parameters did not show much relation with active transportation investment, possibly due to lack of sufficient data in active transportation investments. We observe that regression can be further improved by identifying additional macro-economic, demographic, geographic variables uncorrelated to each other as much as possible.

After performing the regression analysis on various industry GDP against trail miles, we identified the correlation between industry GDP and trail miles, where higher the correlation coefficient, greater is the correlation between the variables, here industry GDP and trail miles. Based on the correlation coefficient, we found that active transportation is closely related to finance, insurance, real estate, rental, and leasing, professional and business services, and construction industries, as shown in Table 5.1. This supports our earlier findings through literature review that active transportation infrastructure promotes the economy through construction related jobs, businesses, supporting bicycle and pedestrian-oriented businesses and tourism and that it improves property values near the infrastructure. For this analysis, we have excluded Marion, Brown, and St. Joseph counties as they are already established outliers.

5.1.2 Micro-View Results of Business Growth on Investment

5.1.2.1 Summary. For micro-view, we examine the impact of active transportation investments on business growth by analyzing the changes in the number of establishments. Our analysis is conducted at the ZCTA level and includes results for individual ZCTAs as well as aggregated data for the entire state and specific demographic groups such as low and high-income areas. To facilitate regional differentiation, we present investment cost normalized results. Specifically, we report the average net change in the number of establishments per $10 million investments. We also assess the impact of each active transportation type, such as sidewalks, bike lanes, and trails, on business growth by presenting a normalized index for each type. Furthermore, we explore the correlation between the normalized index and various demographic factors to identify trends and insights for each industry type.

Table 5.2 presents net change in establishment counts and normalized change per $10 million AT investment. Education and hospitality/recreation industries experienced the highest growth. Manufacturing was the only industry to decrease. Normalized results showed a decrease in manufacturing and retail trade establishments, and an increase in healthcare, particularly in low-income areas. Low-income areas saw higher growth across all industries compared to

TABLE 5.1
Industry GDP and trail miles correlation

Industry	Correlation
Agriculture, forestry, fishing, and hunting	0.33
Arts, entertainment, recreation, accommodation, and food services	0.73
Construction	0.80
Educational services, healthcare, and social assistance	0.67
Finance, insurance, real estate, rental, and leasing	0.85
Information	0.79
Manufacturing	0.43
Mining, quarrying, and oil and gas extraction	0.00
Other services (except government and government enterprises)	0.73
Professional and business services	0.83
Retail trade	0.77
Transportation and warehousing	0.46
Utilities	0.13
Wholesale trade	0.74

Notes:
The green numbers indicate a correlation coefficient greater than 0.8.
The orange numbers indicate a correlation between 0.5 and 0.8.
The red numbers indicate a correlation of less than 0.5.

TABLE 5.2
The net change in the number of establishments and the average net change in the number of establishments per $10 million of investments due to AT investments for 2020

	Index: Net Change in Number Estimation			Index: Average Net Change in Number Estimation per 10 Million AT Investment		
Industry	**Overall**	**Low-Income Areas**	**High-Income Areas**	**Overall**	**Low-Income Areas**	**High-Income Areas**
Manufacturing	-27	-9	3	-3	-8	0
Retail trade	7	17	0	-5	2	0
Professional, scientific, and technical services	46	23	7	2	3	0
Educational services	391	8	-3	10	4	-1
Healthcare	40	44	14	6	11	2
Hospitality and recreation	149	33	25	9	3	1

TABLE 5.3
Differences in industry growth based on AT type: change in the number of establishments due to a 10 million investment in a different active transportation type

	Side Walks			Bike Lanes			Trails		
	Index: Average Net Change in Number Estimation per 10 Million								
Industry	**Overall**	**Low-Income Areas**	**High-Income Areas**	**Overall**	**Low-Income Areas**	**High-Income Areas**	**Overall**	**Low-Income Areas**	**High-Income Areas**
Manufacturing	-2	-4	0	-11	-24	-1	-16	-8	0
Retail trade	-1	1	0	2	4	0	10	-5	0
Professional, scientific, and technical services	1	2	1	-3	5	0	70	5	0
Educational services	8	2	-1	35	9	-2	17	2	0
Healthcare	1	6	1	4	27	1	-5	7	0
Hospitality and recreation	2	2	3	-4	0	12	-74	13	0

high-income areas. Thus, showing higher returns in these low-income regions.

We also assess the differences in industry growth based on AT types in Table 5.3. We can see that different industries and income levels are affected differently by different types of active transportation investments, including sidewalks, bike lanes, and trails. it appears that for low-income areas, the healthcare industry has seen the most positive change in the number of establishments per 10 million for side walks and bike lanes. For high-income areas, the hospitality and recreation industry has seen the most positive change in the number of establishments per 10 million for bike lanes. For trails, the professional, scientific, and technical services industry has seen the most positive change in the number of establishments per 10 million overall and in low-income areas. For side walks, the educational services industry has seen the most positive change in the number of establishments per 10 million overall. While for bike lanes, the educational services industry has seen the most positive change in the number of establishments per 10 million overall. It's also worth noting that for low-income areas, the manufacturing industry has seen a negative change in the number of establishments per 10 million for all three types of active transportation. Overall, the effectiveness of different types of active transportation investments varies by industry and income level and this information can be used for policy design.

We also assess the correlation between the normalized index and various demographic factors to identify trends and insights for each industry type. This is summarized in Table 5.4. Regions with lower unemployment rates and population densities had a positive association with the net change in manufacturing establishments, while higher median income and AT investment costs were positively associated with the net change. This shows that manufacturing industry will grow more in the suburban/rural areas (areas with low population density). However, for service-based establishments the opposite is observed which grow more in high population density areas. There is a significant negative correlation between the net change in service establishments per $10 million AT investment and the AT investment costs in the region. This suggests that areas with higher AT investment costs may not necessarily see the same positive impacts on service-based establishments as areas with lower AT investment costs. Similarly, this is observed for healthcare industry,

TABLE 5.4
The correlation of change in the number of establishments per industry due to AT investments (normalized by the investment cost) and demographics of the region

Index	Population	Population Density	Median Income	Unemployment Rate	# POIs	Investment Cost
Manufacturing	0.025	-0.35**	0.17	-0.3*	0.046	0.18
Retail trade	0.28**	0.19	-0.044	0.096	0.19	0.25**
Professional, scientific, and technical services	-0.083	0.38***	-0.15	0.12	0.092	-0.2
Educational services	0.057	0.024	-0.059	0.065	-0.11	-0.022
Healthcare	-0.16	-0.029	-0.04	0.095	-0.17	-0.19
Hospitality and recreation	-0.16	-0.024	0.037	-0.069	-0.075	-0.26**

Notes:
Orange numbers have a p-value<0.3.
Blue numbers have a p-value<0.1.
Green numbers have a p-value<0.1.
*implies p-value<0.1.
**implies p-values<0.05.
***implies p-value<0.01).

showing that active transportation investments lead to a healthier overall lifestyle reducing the demand for new establishments. Policymakers should consider the industry type and demographic factors when making decisions on active transportation investments.

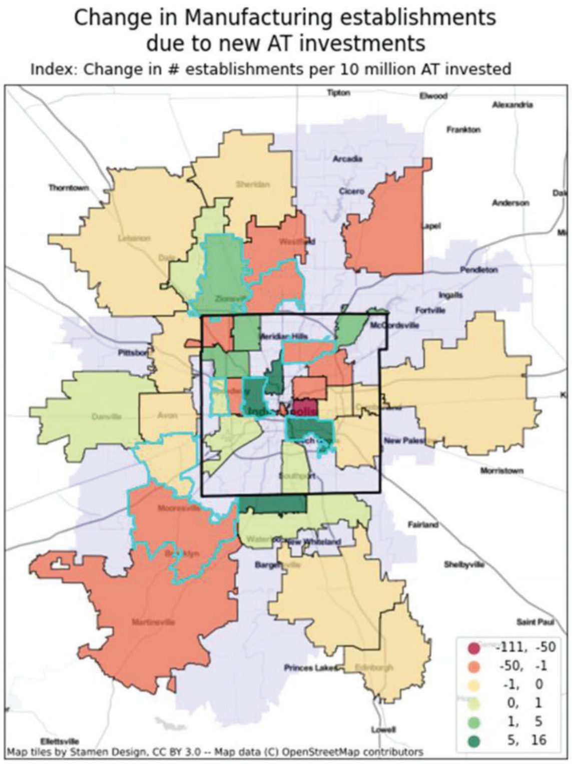
5.1.2.2 How active transportation investments in Indianapolis MPO region attract businesses. This section presents the index of net change in the number of establishments resulting from investments in active transportation infrastructure for the year 2020 (pre-COVID). To measure this net change, we utilize two key metrics: N_c which represents the number of establishments that would hypothetically exist if no investment was made in active transportation infrastructure (i.e., the counterfactual scenario), and N_a, which represents the actual number of establishments observed when such investment is made (i.e., the observed scenario). The difference between these two values is used to calculate the net change in the number of establishments resulting from active transportation investment.

To ensure fair and accurate comparisons, all of our results are normalized by the cost of the active transportation investment. This normalization enables us to evaluate the net change more precisely in the number of establishments that can be attributed to the investment in active transportation infrastructure, while controlling for the associated costs.

Overall, our analysis provides valuable insights into the potential economic impacts of investments in active transportation infrastructure. By quantifying the net change in the number of establishments resulting from such investments, we can better understand the benefits of active transportation infrastructure beyond just its impact on individual mobility.

5.1.2.2.1 Manufacturing (NAICS 31-33). The manufacturing sector is comprised of various industries that produce goods using mechanical, physical, or chemical transformation. Major industries within this include food manufacturing, beverage and tobacco product manufacturing, textile mills, textile product mills, apparel manufacturing, leather and allied product manufacturing, wood product manufacturing, paper manufacturing, plastics and related support activities, petroleum and coal products manufacturing, chemical manufacturing, plastics and rubber products manufacturing, nonmetallic mineral product manufacturing, primary metal manufacturing, fabricated metal product manufacturing, machinery manufacturing, computer and electronic product manufacturing, electrical equipment, appliance, and component manufacturing, transportation equipment manufacturing and furniture and related product manufacturing.

In this study, we analyze the impact of active transportation investments on the number of manufacturing establishments in the year 2020. Specifically, we evaluate the net change in the number of manufacturing establishments for each $10 million of AT invested. Our findings, as presented in Figure 5.1, reveal a decrease in the number of manufacturing establishments in the region. Overall, we observed a net decrease of 27 manufacturing establishments due to AT investments in 2020. Investing $10 million in AT results in a decrease in the number of manufacturing establishments of three per ZCTA on an average. However, this effect was not uniform across the region. In particular, the city core of Indianapolis experienced a larger decrease in the number of manufacturing establishments, while the decrease in suburbs and rural parts of the region was relatively lower. It's also important to note that our analysis revealed some regions in the city core that actually observed an increase in the number of manufacturing establishments as a result of AT investments. This finding suggests that the impact of AT investments on manufacturing establishments is



Note: There are many ZCTAs in the city core and suburbs that observed a decrease. However, there was a significant increase in some parts of the Indianapolis city core. The ZCTAs with cyan colored boundaries have statistically significant changes in the number of manufacturing establishments. The Marion County is also highlighted with a black boundary.

Figure 5.1 The change in number of manufacturing establishments due to active transportation investments for the year 2020 (per $10 million of AT invested).

not homogeneous across different regions and can be influenced by local factors.

Figure 5.2 displays scatter plots that examine the relationship between the net change in manufacturing establishments per $10 million of active transportation investment in each Zip Code Tabulation Area (ZCTA) and the demographic characteristics of the respective ZCTAs. The plot illustrates that regions with lower unemployment rates and population densities have a positive association with the net change in manufacturing establishments. This finding suggests that active transportation investments may have a positive effect on manufacturing establishments in less densely populated areas. Such regions offer a less congested environment and possess greater availability of land and resources to support the establishment and growth of new manufacturing businesses. Moreover, in areas of lower unemployment rates, there may be a higher demand for goods and services, attracting more manufacturing establishments.

Additionally, the scatter plots show that higher median income and AT investment costs are also positively associated with the net change in manufacturing establishments per $10 million of AT investment (sidewalk: -2, bike lanes: -11, and trail: -16). This implies that active transportation investments may be particularly beneficial in regions with higher economic prosperity as the regions have a more diversified and advanced economic base and offer greater demand for goods and services in the region. The returns in terms of manufacturing establishments per dollar investment are higher when the investments in AT are more as AT investments contribute to a more efficient and sustainable transportation system. There is reduced congestion and improved mobility creating a conducive environment for manufacturing businesses, allowing them to transport goods and services more efficiently and cost-effectively.

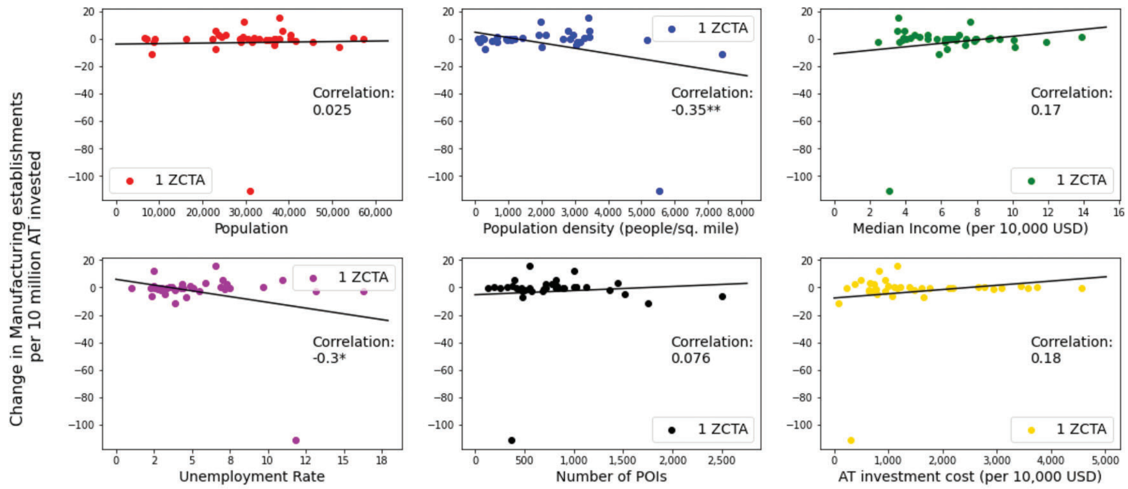
The findings from this figure support our overall hypothesis that active transportation investments can have positive economic impacts by creating new manufacturing jobs and promoting economic growth in certain regions. However, we also acknowledge that the relationship between active transportation investments and manufacturing job creation may be more complex and influenced by other factors not captured in this analysis, such as the type of manufacturing industry or existing transportation infrastructure in the region. Further research is needed to fully understand the relationship between active transportation investments and economic development.

Considering low-income regions, an AT investment in 11 low-income ZCTAs resulted in a net decrease of 9 manufacturing establishments. On average, an investment of $10 million in active transportation yielded a net decrease of 8 establishments per ZCTA for low-income regions. Conversely, an AT investment in 2 high-income ZCTAs resulted in a net decrease of 3 manufacturing establishments. On average, an investment of $10 million in AT yielded a net change of 0 establishments per zip code for high-income regions.

The data indicates that the impact of active transportation investments, such as sidewalks, bike lanes, and trails, on the net change in manufacturing establishments per zip code varies by investment type. Investing $10 million in sidewalks resulted in an average net decrease of 2 manufacturing establishments per zip code, while the same investment in bike lanes and trails had greater negative impacts, with an average net decrease of 11 and 16 establishments per zip code, respectively.

In low-income regions, the negative impact of investing $10 million in AT on the net change in manufacturing establishments per zip code was greater than in high-income regions. For instance, investing $10 million in bike lanes led to an average net decrease of 24 establishments per zip code for low-income regions, compared to 1 establishment per zip code for high-income regions.

These findings suggest that careful consideration of both the type of AT investment and the income level of the region is crucial when assessing the potential impact on the net change in manufacturing establishments per zip code.



Note: The scatter plot displays individual data points representing the ZCTAs. The net change in manufacturing establishments exhibit a positive association with lower unemployment rates and population densities. Furthermore, higher median income and investment costs are also positively associated with the net change in manufacturing establishments per 10 million investments.

Figure 5.2 Scatter plots illustrating the correlation between the net change in manufacturing establishments per $10 million of active transportation investment in each ZCTA and the demographic characteristics of the respective ZCTAs.

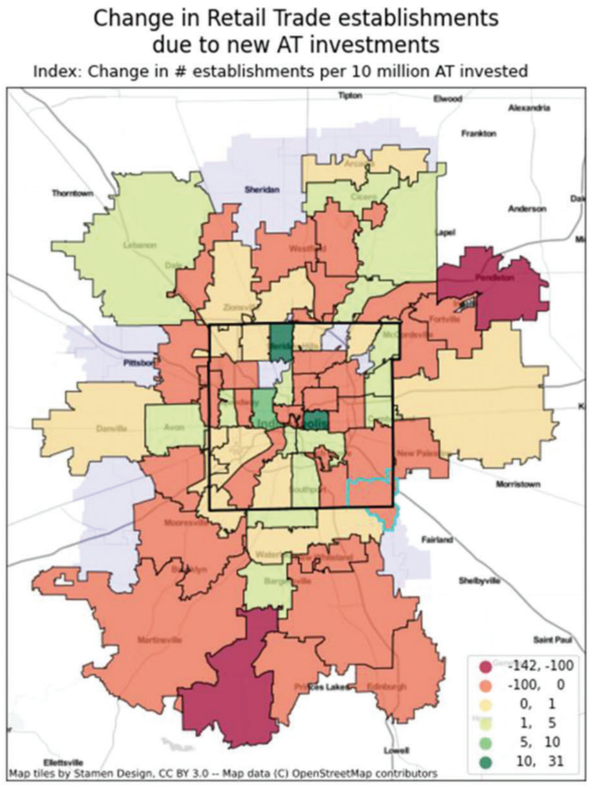
5.1.2.2.2 Retail trade (NAICS 44-45). Retail trade is a sector of the economy that includes businesses involved in the sale of finished goods to the general public for personal or household consumption. This sector is classified by the North American Industry Classification System (NAICS) under code 44-45. It encompasses a wide range of businesses, including department stores, specialty stores, grocery stores, and online retailers. Retail trade businesses may sell a variety of goods, such as clothing, electronics, food and beverages, furniture, and appliances.

The retail trade sector is a significant contributor to the economy, accounting for a substantial portion of consumer spending and supporting millions of jobs across the country. As a result, changes in the number of retail trade establishments can have important implications for local and regional economies. Figure 5.3 presents the change in the number of retail trade establishments due to AT investments in the year 2020, per $10 million of AT invested across different ZCTAs. The majority of ZCTAs observed a decrease in the number of retail trade establishments in response to AT investments. Investing in 66 ZCTAs resulted in a net increase of 7 retail trade establishments. On average, investing $10 million in active transportation led to a net decrease of five retail trade establishments per ZCTA. However, some parts of the Indianapolis city core saw a significant increase in the number of retail establishments. These results suggest that the impact of AT investments on the number of retail trade establishments varies depending on the specific location and context of the investment.

Additionally, our analysis revealed that there is a positive association between the net change in retail trade establishments per dollar investment and the number of points of interest (POIs). ZCTAs with higher POIs tend to have more commercial activity and foot traffic, creating favorable conditions for new retail trade establishments to thrive. ZCTAs with higher active transportation investment costs may indicate greater commitment and prioritization of AT infrastructure, which can result in improved connectivity, accessibility, and attractiveness for retail trade establishments.

No significant correlation was found between the net change in retail trade establishments per $10 million of active transportation investment and the median income of ZCTAs. The analysis revealed an overall net change of 17 retail trade establishments due to investing in 14 low income ZCTAs, resulting in an average net change of two retail trade establishments per $10 million AT investments per zip code. In contrast, investing in 6 high income ZCTAs resulted in no significant net change in the number of retail trade establishments, with an average net change of 0 retail trade establishments per zip code.

The net change in retail trade establishments varies based on the type of active transportation investment. Specifically, investing $10 million in sidewalk infrastructure results in a decrease in the number of establishments per zip code on an average, while investing the same amount in bike lanes results in an increase in the number of establishments. Trails show the largest positive impact, with an average increase of 10 establishments per zip code for $10 million of investment. Additionally, there is variation based on the income level of the ZCTAs, with low-income regions experiencing greater positive effects from bike lanes and negative effects from trails compared to the overall averages. No change was observed in high-income regions for any type of AT investment. These results suggest that the type of AT investment should be considered when planning for economic development in different income level regions.



Note: While the majority of ZCTAs in both the city core and suburbs experienced a decrease in the number of retail trade establishments, there was an increase observed in some parts of the Indianapolis city core. The ZCTAs with cyan-colored boundaries indicate statistically significant changes in the number of retail trade establishments. Additionally, Marion County is highlighted with a black boundary to indicate the geographic extent of the analysis.

Figure 5.3 The change in the number of retail trade establishments in response to active transportation investments in the year 2020, measured per $10 million of AT invested.

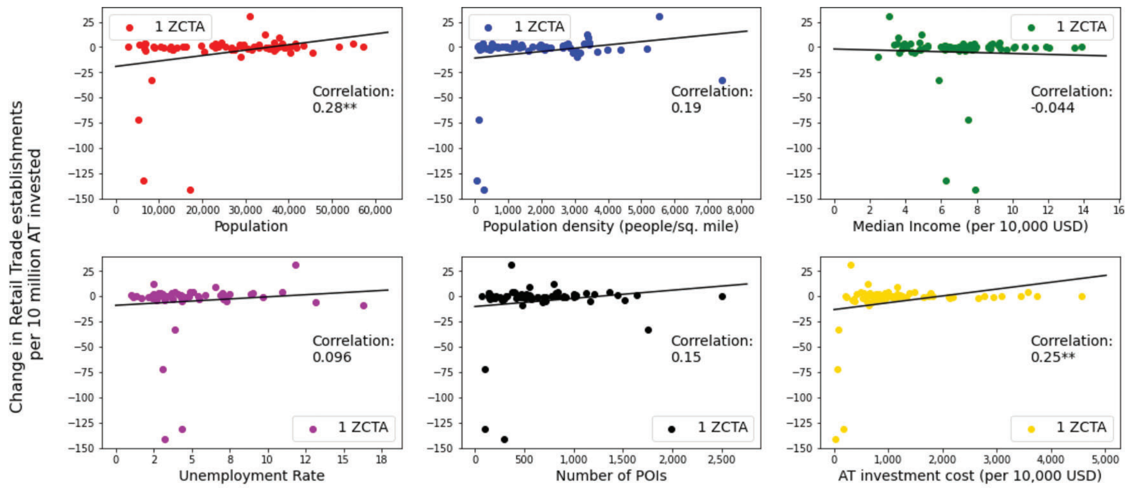
5.1.2.2.3 Professional, scientific, and technical services (NAICS 54). Professional, scientific, and technical services are a group of industries that include businesses that provide specialized services requiring a high degree of expertise. This sector includes a wide range of businesses, such as legal services, accounting and bookkeeping, architectural and engineering services, research and development, advertising, and consulting services.

Studying changes in establishments of professional, scientific, and technical services can help policymakers and researchers make informed decisions about economic development, workforce planning, and innovation. Figure 5.5 illustrates the relationship between the change in the number of service-based establishments in response to active transportation investments and the corresponding amount invested in the year 2020, measured per $10 million of AT invested. The figure shows that the majority of ZCTAs in the city core experienced a net increase in the number of service-based establishments, while suburbs and rural parts of the city witnessed a decrease. Overall, the results show that the investment in AT had a positive impact on the service-based establishments in the Marion County area, with a net change of 46 establishments resulting from an investment in 60 ZCTAs. On average, investing $10 million in AT resulted in a change of 2 service-based establishments per zip code. These findings suggest that AT investments can have a significant impact on the number of service-based establishments, particularly in urban areas.

The results of our analysis, as shown in Figure 5.4, indicate that there are several factors that influence the net change in services-based establishments per $10 million of active transportation investment. One of the key findings is that population density has a positive correlation with the net change in retail trade establishments. This suggests that areas with higher population densities may be more attractive for services-based businesses and that active transportation investments could potentially enhance the accessibility and vibrancy of such areas.

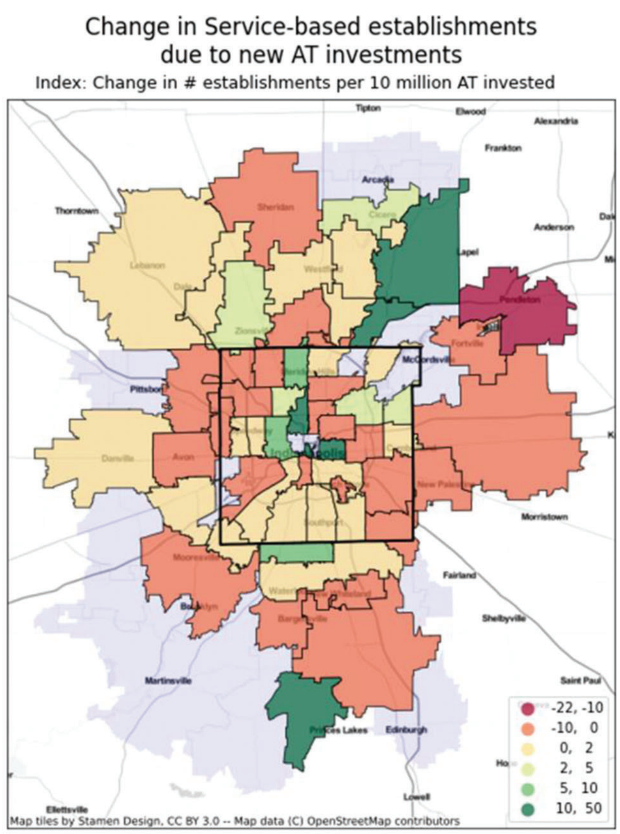
The median income of regions is negatively correlated with the net change in services-based establishments. This implies that regions with lower median income tend to experience a greater increase in professional, scientific, and technical services establishments compared to regions with higher median income. We found that investing $10 million in active transportation results in a significant increase in the number of service-based establishments in low-income ZCTAs, with an average of 3 establishments per zip code. Specifically, investing in 13 low-income ZCTAs resulted in a net increase of 23 service-based establishments. Conversely, for high-income ZCTAs, investing $10 million in AT resulted in no net change in the number of service-based establishments, with an average of 0 establishments per zip code. Investing in 4 high-income ZCTAs resulted in a net change of 7 service-based establishments. This could be due to various factors, such as the lower cost of doing business in terms of rents, salaries, and other operating costs, availability of workforce, less competition, and higher demands in these lower income regions, which may attract establishments of this industry to the lower income areas. This finding highlights the potential for AT investments to support economic development in low-income areas by promoting the growth of businesses in the professional, scientific, and technical services sector. Additionally, this information can be useful for policymakers and urban planners when making decisions about allocating resources for AT infrastructure improvements.

Furthermore, analyzing the impact of active transportation investments on the number of professional, scientific, and technical services establishments in a given region, we found a significant negative correlation between the net change in such establishments per $10 million of AT investment and the AT investment costs



Note: Each data point on the scatter plot represents an individual ZCTA. The net change in retail trade establishments per $10 million of AT investment is positively correlated with the population, population densities, number of POIs, and AT investment costs of the respective ZCTAs.

Figure 5.4 Correlation between net change in retail trade establishments per $10 million of active transportation investment and demographic characteristics in ZCTAs.



Note: The majority of ZCTAs in the city core experienced an increase in the number of service-based establishments, while suburbs and rural parts of the city witnessed a decrease. Marion County is highlighted with a black boundary to indicate the geographic extent of the analysis.

Figure 5.5 The change in the number of service-based establishments in response to active transportation investments in the year 2020, measured per $10 million of AT invested.

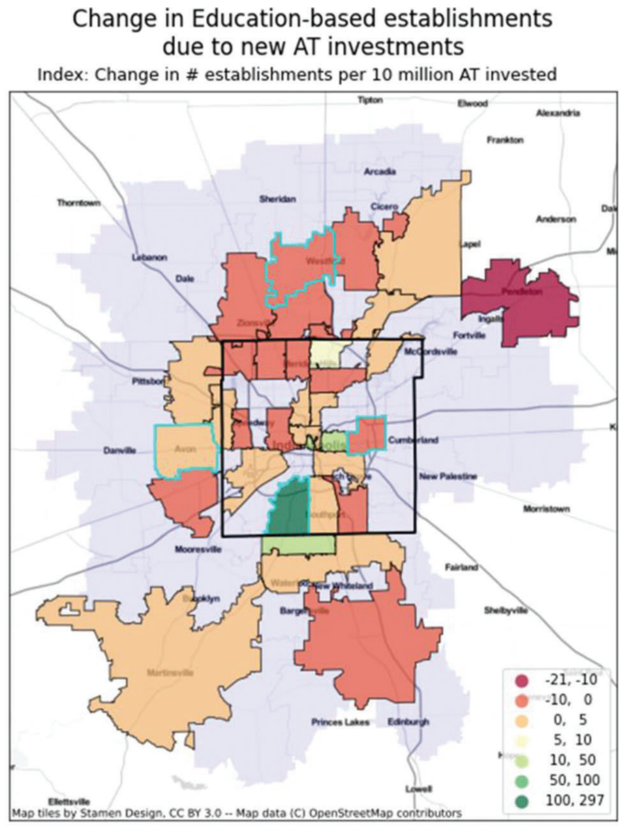
in the region. This suggests that areas with higher AT investment costs may not necessarily see the same positive impacts on services-based establishments as areas with lower AT investment costs. It is therefore important to carefully consider the costs and benefits of AT investments in different regions, and to prioritize investments in areas where they are likely to have the greatest impact on economic growth and development.

The net change in professional, scientific, and technical services establishments varies significantly based on the type of AT investment. When considering the effect of sidewalk investments, there is an increase in establishments in response to investments in this type of infrastructure. On investing in $10 million of sidewalks, the average change in establishments per zip code is one for all regions, two for low-income regions, and one for high-income regions. On the other hand, $10 million of bike lane investments result in a negative net change in service-based establishments, with an average decrease of 3 establishments per zip code across all regions. However, there is a positive increase of 5 establishments per zip code on an average in low-income regions on investing $10 million in bike lanes. In high-income regions, the average change in establishments is 0, suggesting no significant effect of bike lane investments. Finally, trail investments have the most significant effect on service-based establishments, with an average change of 70 establishments per zip code per $10 million of trails, which is substantially higher than the other types of AT investments. In low-income regions, the average change in service-based establishments is five per zip code, which is relatively lower than the overall average. As with the other types of AT investments, there is no significant change in establishments in response to trail investments in high-income regions. These results suggest that the impact of AT investments on establishments varies considerably based on the type of AT infrastructure and the income level of the region.

5.1.2.2.4 Educational services (NAICS 61). Education services include establishments primarily engaged in providing instruction and training in a wide variety of subjects. This category includes schools, colleges, universities, and other institutions that offer academic, vocational, and technical courses. It also includes establishments that provide specialized training, such as business schools, language schools, and driving schools.

Education-based establishments are critical to the growth and development of any community, as they are responsible for providing educational services and training to the workforce and can have a significant impact on the community's human capital development. By analyzing changes in education-based establishments, the government can gain insights into the areas where their AT investments are having the most significant impact. Figure 5.6 indicates that there was a significant variation in the changes in education-based establishments in response to AT investments across different regions of the city. The majority of ZCTAs in the city core experienced an increase in the number of education-based establishments in response to AT investments. However, in contrast, the suburbs and rural parts of the city witnessed mixed changes in the number of education-based establishments. Overall, the net increase in the number of education-based establishments resulting from AT investments was 391, as a result of investing in 35 ZCTAs. It was found that investing $10 million in AT results in a net increase of 10 education-based establishments per zip code on average.

There is no significant correlation between the changes in the number of education-based establishments in response to AT investments and the demographics of each ZCTA. This indicates that the impact of AT investments on the education sector is not influenced by the demographic factors such as population density, income, or urbanization level of a particular area. However, there were a few differences in comparing the lowest income groups and highest income groups of ZCTAs. There was an overall increase of eight establishments in low income ZCTAs after investing in 8 ZCTAs. On average, investing $10 million in AT results in a change of four establishments per zip code in low-income regions. On the other hand, there is a decrease of three education-based establishments in high income ZCTAs after investing in two ZCTAs. On average, investing $10 million in AT results in a decrease of one establishment per zip code in high income regions. This suggests that the impact of AT investments on the number of establishments is not the same across the topmost and bottommost income groups of ZCTAs. Therefore, the policymakers need to carefully consider the income level of the target area and tailor their investments accordingly



Note: The majority of ZCTAs in the city core experienced an increase in the number of education-based establishments. In contrast, the suburbs and rural parts of the city witnessed mixed changes in the number of education-based establishments. The cyan-colored boundaries indicate the ZCTAs with statistically significant changes in the number of establishments. The analysis was conducted within the geographic extent of Marion County, which is highlighted with a black boundary.

Figure 5.6 The impact of active transportation investments on the number of education-based establishments in 2020, measured per $10 million of AT invested.

to ensure that they have a positive impact on the local economy.

The impact of AT investments on education-based establishments varies depending on the type of AT investment. Investing $10 million in sidewalk infrastructure, for example, resulted in an average net increase of 8 education-based establishments per zip code. On the other hand, investing in $10 million of bike lanes resulted in an average net increase of 35 education-based establishments per zip code, while investing in $10 million of trails resulted in an average net increase of 17 education-based establishments per zip code. Furthermore, there impacts differ based on the income level of the area. For low-income regions, investing $10 million in sidewalk infrastructure resulted in an average net increase of 2 education-based establishments per zip code, while investing in $10 million of bike lanes resulted in an average net increase of 9 education-based establishments per zip code.

For high-income regions, however, investing in sidewalk infrastructure resulted in an average net decrease of 1 education-based establishment per zip code, while investing in bike lanes resulted in an average net decrease of 2 education-based establishments per zip code.

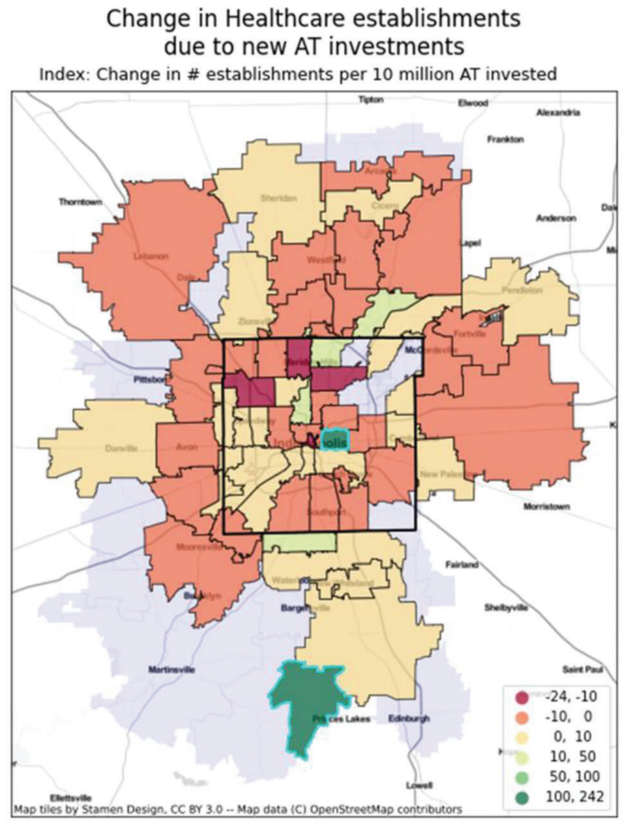
These findings suggest that the type of AT investment made can have a significant impact on the number of education-based establishments in a given area. By carefully considering the potential impacts of different types of AT investments on education-based establishments, policymakers and planners can make more informed decisions about how to allocate resources to support the development of education-based establishments and enhance the overall livability of communities.

5.1.2.2.5 Healthcare and social assistance (NAICS 62). Healthcare and social assistance industries include establishments primarily engaged in providing healthcare and social assistance to individuals. These establishments include hospitals, clinics, nursing and residential care facilities, home healthcare services, social assistance services, and more.

It is important to assess the changes in the healthcare and social assistance industries as they are essential for providing healthcare services to individuals and communities and represent a significant portion of the overall economy. Additionally, changes in their performance can have ripple effects on other sectors of the economy. Figure 5.7 shows that the majority of ZCTAs in the city core experienced a decrease in the number of healthcare establishments, while the suburbs and rural areas witnessed varied changes. Overall, there was a net increase of 40 healthcare establishments resulting from investing in AT in 61 ZCTAs, equivalent to an average increase of 6 healthcare establishments per zip code for every $10 million invested in AT. Therefore, the effects of AT investments on healthcare establishments vary significantly depending on the location and type of investment. The majority of the observed increase is in establishments related to residential facilities for individuals with intellectual and developmental disabilities, mental health facilities, substance abuse facilities, and independent health practitioners.

We observe a significant negative correlation between the net change in healthcare establishments per $10 million of active transportation investment and the population and number of points of interest (POIs) in a ZCTA. In other words, as the population and number of POIs in a ZCTA increases, we observe a decrease in the net change of healthcare establishments resulting from active transportation investments. This may be due to various factors, such as limited available space for healthcare facilities, higher costs of establishing and maintaining healthcare establishments in densely populated areas, and higher demand for non-healthcare-related services and amenities in commercial areas.

Further, we observe a significant negative correlation between the net change in healthcare establishments per $10 million of active transportation investment and the cost of such investments. In other words, as the cost of active transportation investments increases, the net increase in healthcare establishments reduces. It is important to note that this negative correlation does not necessarily mean that AT investments have a detrimental effect on healthcare establishments. Rather, it suggests that there may be a trade-off between investing in AT infrastructure and healthcare services. This may be due to the fact that active transportation investments lead to a healthier overall lifestyle (increased physical activity, improved mental health, and reduced stress levels) and reduction in the prevalence of chronic diseases, reducing the demand for healthcare services in the long run. Moreover, active transportation investments improve the accessibility of current healthcare service, thus reducing the demand for new establishments. These findings highlight the importance of carefully considering the cost-effectiveness of active transportation investments, particularly in relation to their potential impact on healthcare establishments. It also shows the success of active



Note: The majority of ZCTAs in the City Core experienced a decrease in the number of healthcare establishments, while the suburbs and rural areas witnessed varied changes. Cyan-colored boundaries indicate ZCTAs with statistically significant changes in establishments. Analysis conducted around Marion County, highlighted by a black boundary.

Figure 5.7 The effects of active transportation investments on healthcare establishments in 2020, measured per $10 million of AT invested.

transportation investments in terms of reduced demand for healthcare facilities.

Despite the insignificant correlation observed between net change in healthcare establishments per $10 million of active transportation investment and median income, there is still a discernible difference between the poorest and richest income groups. The analysis revealed that investing in AT resulted in a higher net increase in the number of healthcare establishments for low-income regions compared to high-income regions. Specifically, the overall increase in the number of establishments in low-income ZCTAs was 44, as a result of investing in 13 ZCTAs. Investing $10 million in AT resulted in a change of 11 establishments per zip code on average for low-income regions. On the other hand, the overall increase in the number of establishments in high-income ZCTAs was 14, as a result of investing in 5 ZCTAs. Investing $10 million in AT resulted in a change of only 2 establishments per zip code on average for high-income regions. The results indicate that AT investments are more impactful in increasing the number of healthcare establishments in low-income areas compared to high-income areas. This information is essential for policymakers to identify and prioritize areas where AT investments can have the most significant impact on increasing access to healthcare services, especially for underserved communities.

The impact of active transportation investments on healthcare services establishments varies significantly based on the type of AT investment. We examined the changes in healthcare services establishments in different ZCTAs based on the type of AT investment—sidewalks, bike lanes, and trails. Our analysis revealed that the net change in healthcare services establishments per $10 million of AT investment varied significantly based on the type of AT investment.

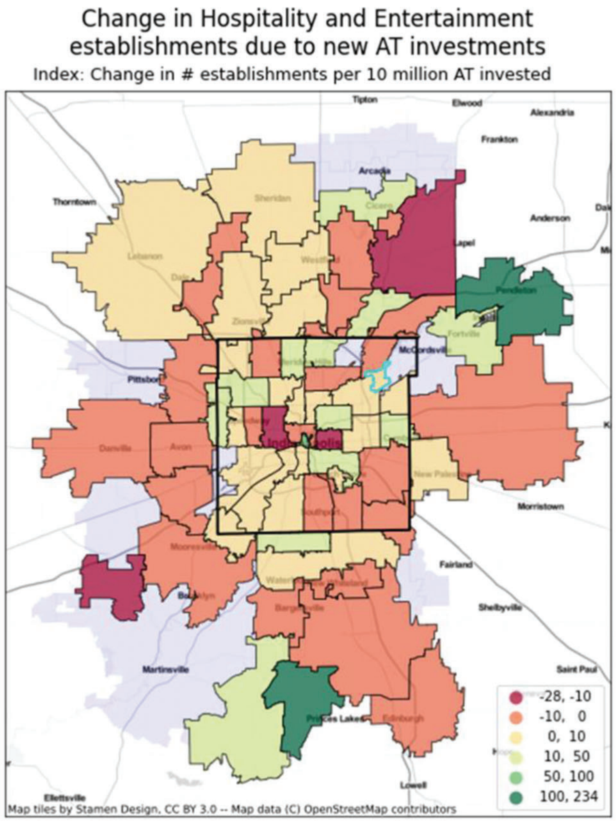
The results showed that investing $10 million in sidewalks led to an average increase of 1 healthcare service establishment per ZCTA. In low-income regions, this change was higher at 6 establishments per ZCTA, while in high-income regions, it was lower at 1 establishment per ZCTA. Investing $10 million in bike lanes had a more significant impact, resulting in an average change of 4 healthcare services establishments per ZCTA. In low-income regions, this change was substantially higher at 27 establishments per ZCTA, while in high-income regions, it was lower at 1 establishment per ZCTA. In contrast, investing $10 million in trails led to a negative average change of 5 healthcare services establishments per ZCTA, indicating a decrease in healthcare services establishments. However, in low-income regions, this change was positive, with an average increase of 7 healthcare services establishments per ZCTA. In high-income regions, there was no significant change, with an average increase of 0 healthcare services establishments per ZCTA.

These findings suggest that the type of AT investment plays a critical role in determining the impact on healthcare services establishments. Bike lanes appear to have the most significant positive impact, while trails have a negative impact on healthcare services establishments in general but a positive impact in low-income regions. Sidewalks have a relatively small positive impact. The impact of all types of AT investments is generally lower in high-income regions compared to low-income regions. Overall, our study highlights the need for policymakers to consider the type of AT investment when planning infrastructure improvements, as well as the socioeconomic context of the areas in which the investments are made, to maximize the benefits to healthcare services establishments.

5.1.2.2.6 Hospitality and recreation (NAICS 71-72). Hospitality and recreation industry include both arts, entertainment, and recreation and accommodation and food services, the two sectors defined by the North American Industry Classification System (NAICS). Arts, entertainment, and recreation (NAICS code 71) includes establishments primarily engaged in providing leisure, amusement, and entertainment services. This can include businesses such as performing arts companies, sports teams, museums, and amusement parks. Accommodation and food services (NAICS code 72) includes establishments primarily engaged in providing lodging and/or preparing meals, snacks, and beverages for immediate consumption. This includes businesses such as hotels, restaurants, and food trucks.

Figure 5.8 examines the effect of active transportation investments on the hospitality and recreation-based establishments in 2020, as measured per $10 million of AT invested. While the city core and suburban ZCTAs experienced a decrease in the number of hospitality and recreation-based establishments, we found that in the rural areas and some suburban parts of the county, many regions experience an increase in establishments due to AT investments. These increases were observed in the amusement and recreation industries, performing arts companies, and spectator sports. Overall, we observed that investing $10 million in AT resulted in an increase in the number of establishments of 9 per zip code on an average. This resulted in a net change of 149 establishments due to the investment in 66 ZCTAs. Our analysis suggests that AT investments have the potential to support the development of these establishments in certain regions, particularly in rural and suburban areas. This provide evidence for the potential economic benefits of investing in AT infrastructure, particularly in areas where these types of establishments are scarce or underdeveloped.

Our analysis indicates that there exists a significant negative correlation between the net change in hospitality and recreation-based establishments per $10 million of active transportation investment and the population of the ZCTA. Specifically, we found that as the population of a ZCTA increases, there is a decrease in these types of establishments, despite the same amount of AT investment. Areas with larger populations may have already established a sufficient number of such establishments to meet the demand of the local



Note: Both the city core and suburban ZCTAs experienced a decrease in the number of hospitality and recreation-based establishments. However, in the rural areas and some suburban parts of the county, many regions experience an increase in establishments due to AT investments. Cyan-colored boundaries indicate ZCTAs with statistically significant changes in establishments. Analysis conducted around the Marion County, highlighted by a black boundary.

Figure 5.8 The impact of active transportation investments on hospitality and recreation-based establishments in 2020, measured per $10 million of AT invested.

population, and therefore may not require additional ones while for areas with smaller populations, there may be a greater demand for these establishments, and hence an increase in their number with AT investments. Additionally, the availability of land and other resources may differ between high-population and low-population areas, which could impact the development of these establishments.

We also observe a significant negative correlation between the net change in hospitality and recreation-based establishments per $10 million of active transportation investment and the amount of investment made in active transportation. This finding suggests that there may be a trade-off between investing in active transportation infrastructure and supporting the development of hospitality and recreation-based establishments in a given region. One potential explanation for this is that active transportation infrastructure may be taking up space or resources that could otherwise be used for the development of these establishments. For example, constructing bike lanes or sidewalks may require the removal of on-street parking, which could be detrimental to local businesses that rely on nearby parking spaces for customers. This highlights the need for local governments to carefully consider the potential trade-offs of investing in active transportation infrastructure and to explore ways to support the development of these establishments in conjunction with such investments.

We observe no significant correlation between the net change in hospitality and recreation-based establishments per $10 million of AT investment and the median income of the ZCTA. However, we observed variations in the change in hospitality and recreation investments between the poorest and richest areas, as a result of active transportation investments. In low-income regions, we found a net change of 33 establishments due to investing in 14 ZCTAs. This resulted in an average change of 3 establishments per zip code for every $10 million of AT investment. On the other hand, in high-income regions, we found a net change of 25 establishments due to investing in 5 ZCTAs, resulting in an average change of 1 establishment per zip code for every $10 million of AT investment. These findings suggest that active transportation investments may have a greater impact on the development of hospitality and recreation-based establishments in low-income regions compared to high-income regions. Policymakers can, therefore, prioritize AT infrastructure investments in areas where these types of establishments are lacking, with the potential to generate economic growth and job opportunities.

Our analysis reveals that the net change in hospitality and recreation-based establishments varies significantly based on the type of AT investment. Specifically, we observe that the establishment changes resulting from sidewalk, bike lane, and trail investments are quite different from each other. For sidewalk investments, we observe that investing $10 million in AT results in a change of 2 establishments per zip code on an average. Interestingly, the change is consistent across low and high-income regions. In contrast, our analysis reveals that bike lane investments have a negative impact on the number of establishments. Specifically, investing $10 million of AT in bike lanes results in a decrease of 4 establishments per zip code on an average. However, we also observe that the impact of bike lane investments varies significantly across different income levels. While the net change is negligible for low-income regions, high-income regions experience a significant increase of 12 establishments per zip code on an average. This finding suggests that while bike lane investments may not be effective in promoting the development of establishments in low-income regions, they may have a positive impact on high-income areas.

Finally, our analysis reveals that trail investments have a highly negative impact on the number of establishments. Specifically, investing $10 million of AT in trails results in a decrease of 74 establishments per zip code on an average. However, we observe that the impact of trail investments varies significantly across different income levels. While low-income regions experience a modest increase of 13 establishments per zip code on an average, high-income regions experience no net change in the number of establishments. This suggests that trail investments may be an effective way to promote the development of hospitality and recreation-based establishments in low-income areas but not in high-income regions.

In conclusion, our findings demonstrate that the type of active transportation investment has a significant impact on the net change in hospitality and recreation-based establishments. These findings should be considered when making decisions about investing in AT infrastructure, particularly when trying to promote the development of hospitality and recreation-based establishments.

5.1.2.3 Takeaways. We analyze the impact of active transportation investments on various economic sectors in the Marion County region. Notably, investments in active transportation were found to have varying effects on different industries. Manufacturing establishments experienced a net decrease in response to active transportation investments, with greater reductions in the city core. The net change in service-based establishments, particularly education-based and healthcare establishments, showed positive associations with lower population density, higher median income, and active transportation investment costs, suggesting that active transportation investments can enhance economic development in less densely populated and higher-income areas. Additionally, the type of active transportation investment significantly influenced the changes; bike lanes were associated with increased service-based establishments, while trails had a negative impact overall but were beneficial in low-income regions. Understanding these nuances is crucial for informed policy decisions regarding active transportation investments and their potential economic benefits in various sectors.

5.2 How General Transportation Investments Attract Healthcare Businesses

5.2.1 Macro-View of Healthcare Industry

Budgets for healthcare at the county level were unable to account for the county's healthcare industry. The information on healthcare spending is encouraging, but there aren't any reliable data sources that include all of the players in the healthcare value chain and their contributions to the overall county-level healthcare budget. The Medicare refunds statistic is disregarded because it has the least capacity to directly relate to the characteristics of the transportation business. The number of road miles added to the healthcare staff payroll across counties is recognized as the healthcare statistic with the most potential for evaluating the economic impact of transportation advancements. Additionally, it's crucial to divide the payroll of healthcare workers into two significant groups so that counties can be targeted using the clusters as a guide.

It has been demonstrated that there is a strong relationship between a county's population and its healthcare payroll, and that this relationship influences the techniques used to guide the county's economic development in the healthcare sector. Regarding transportation and healthcare requirements, different age groups have distinct needs. The creation and execution of various strategies to link the economic growth of the transportation industry with that of the healthcare industry are greatly influenced by the demographic scenario. When formulating strategies and action plans for the economic development of the healthcare sector, the population must be segmented into the appropriate age groups while taking demographics into account. We do find a major participation of transportation infrastructure along with the population expansion trend when attempting to forecast the impact of a certain strategy and action plan on the healthcare economic parameter viz-a-viz healthcare employee payroll.

To improve accessibility for healthcare facilities and population density, transportation investments must be made in counties that follow population trends. Hospitals and the healthcare sector follow population mobility trends. Most counties follow a population-driven pattern, with the influence of transportation metrics helping to steer the selection of counties where the growth of healthcare facilities is necessary. Additionally, improvements to the transportation infrastructure in the identified counties may result in improved planning for the development of healthcare facilities.

One can use the correlation equations governing the amount of transportation investment based on the number of healthcare firms in a county to make a data-driven decision about how much money to invest in the set of identified counties that need to improve their healthcare sector based on population trends. Furthermore, with the right investment in the designated counties, it can unmistakably increase the ease of access to these healthcare organizations.

Last but not least, creating a well-connected road network will help with the expansion of emergency services like ambulatory services. An increase in transportation spending for the construction of transportation infrastructure aimed at enhanced accessibility is necessary to achieve such important advancements.

5.2.2 Micro-View of Healthcare Industry

5.2.2.1 Summary. We conducted a micro-level analysis to investigate the impact of transportation investments on trip patterns, healthcare facility visits, and the growth of the healthcare industry. We analyzed changes in these factors at the ZCTA level and aggregated data for the entire state and specific demographic groups, including low and high-income areas.

TABLE 5.5
The net change in trip patterns and the usage and growth of healthcare and the average net change per $10 million of investments due to transportation investments

Index		Net Change			Average Net Change per $10 Million Investment		
		Overall	Low-Income Areas	High-Income Areas	Overall	Low-Income Areas	High-Income Areas
Trip patterns	Trips generated	22,435,000	2,450,000	-696,000	1,435,500	1,247,300	-439,000
	Trips generated during morning rush hours	1,257,000	145,000	-101,000	133,350	95,500	-21,100
Visits to healthcare	Number of people visiting healthcare	36,800	66,250	-18,200	-11,110	40,400	-8,630
	Number of people visiting healthcare from outside ZCTAs	36,800	66,150	-18,150	-10,950	40,350	-8,600
Healthcare investment	Number of healthcare establishments	-5	-3	9	-2	1	5
	Number of small healthcare establishments	5	-8	30	-13	1	14

To differentiate regional impacts, we normalized investment costs and reported the average net change per $10 million of investment. Additionally, we examined the correlation between the normalized index and various demographic factors to identify trends and insights for each analysis. Our findings provide insights into the impact of transportation investments on the healthcare industry and can inform policymakers in making decisions regarding transportation investments.

Table 5.5 reveals important insights regarding the impact of transportation investments on trip patterns, healthcare usage, and healthcare growth. Overall, transportation investments have led to a net increase in the number of trips generated, particularly during morning rush hours. However, this positive trend is not consistent across all income areas, as high-income areas have experienced a net decrease in the number of trips generated. In low-income areas, transportation investments have resulted in a net increase in the number of people visiting healthcare facilities, including those coming from outside ZCTAs. However, in high-income areas, there has been a net decrease in these numbers, indicating a potential disparity in healthcare access between income groups due to transportation investments. Furthermore, transportation investments have had a positive impact on the growth of healthcare establishments and small healthcare establishments in low-income areas, as evidenced by a net increase in their numbers. However, overall, there has been a net decrease in the number of healthcare establishments, including small healthcare establishments, indicating potential challenges in healthcare growth in other areas.

These findings highlight that the effects of transportation investments on trip patterns, healthcare usage, and healthcare growth are contingent on demographic and regional characteristics. Policymakers should carefully consider these impacts and their distribution across income areas when developing policies related to transportation investments and healthcare access. Targeted policies may be needed to ensure equitable healthcare access, particularly in low-income areas. Additionally, promoting the growth of small healthcare establishments in low-income areas may require additional attention and support, as transportation investments may not always lead to positive outcomes for these areas.

We also assess the correlation between the normalized index and various demographic factors to identify trends and insights for each index. This is summarized in Table 5.6. There is a weak negative correlation between the change in the number of people visiting healthcare and people visiting healthcare from outside ZCTAs due to AT investments (normalized by investment cost) and median income. This suggests that, in low-income regions, transportation investments can attract populations to visit healthcare-related POIs, which can lead to an increase in economic activity and better healthcare outcomes for the local population. This suggests that targeted policies should be developed to promote the growth of healthcare facilities and improve healthcare access in low-income areas. None of the metrics is correlated with the cost of investment, showing that higher investment does not necessarily lead to more changes in trip patterns or higher growth/usage of healthcare facilities.

5.2.2.2 Trip patterns

5.2.2.2.1 Trip generation. Trip generation refers to the number of trips that will be generated by a particular region to all destinations such as a residential neighborhood, office building, or shopping center. It is an essential input for transportation planning, as it helps to estimate the demand for transportation infrastructure and services and determine the appropriate level of investment needed to meet that demand.

Assessing the impact of transportation investments on the change in trips generated from a region is significant as this is crucial to evaluate the effectiveness

TABLE 5.6
The correlation of change in the number of establishments per industry due to transportation investments (normalized by the investment cost) and the demographics of the region

Index		Population	Population Density	Median Income	Unemployment Rate	Number of POIs	Investment Cost
Trip patterns	Trips generated	0.22*	0.023	0.11	-0.033	0.1	-0.077
	Trips generated during morning rush hours	0.17	-0.016	0.058	-0.068	0.096	-0.1
Visits to healthcare	Number of people visiting healthcare	-0.017	-0.025	-0.16	0.014	0.063	0.038
	Number of people visiting healthcare from outside ZCTAs	-0.019	-0.026	-0.16	0.015	0.062	0.038
Healthcare investment	Number of healthcare establishments	0.099	0.039	-0.03	0.11	0.1	0.014
	Number of small healthcare establishments	-0.014	0.017	-0.039	0.0033	0.076	0.005

Notes:
Red numbers have a p-value<0.3.
Blue numbers have a p-value<0.15.
Green numbers have a p-value<0.1.
*implies p-value<0.1.
**implies p-values<0.05.
***implies p-value<0.01.

and potential impact on the region's transportation system, the transportation needs of the region's population and can also highlight the positive effects of transportation investments on the region's economy, such as job creation and increased economic activity.

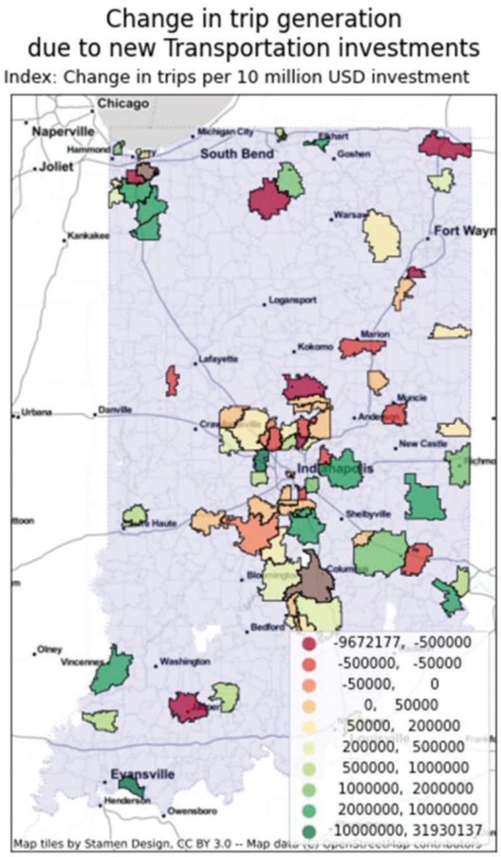
We examine the impact of transportation investments on the change in trips generated from each ZCTA in 2021, measured per $10 million of transportation invested in Figure 5.9. The analysis reveals that the suburbs of Indianapolis, Evansville, and Gary showed the highest increases in trip generations, while some suburban areas of Indianapolis and Bloomington experienced a decrease in trip generations due to transportation investments. Overall, the net change in trips generated resulting from investing $2.77 billion in 75 ZCTAs was 22,424,587.

Further analysis revealed that investing $10 million in new transportation construction resulted in a change in trips of 1,435,500 per zip code on average. These findings demonstrate the significant impact of transportation investments on trip generation and provide valuable insights for policymakers and planners in terms of making informed decisions about transportation infrastructure investment. The results also underscore the importance of carefully considering the unique characteristics of each ZCTA when making transportation investment decisions.

Figure 5.10 indicates a significant positive correlation between the net change in trip generation per $10 million of transportation investment and population. This means that as the population of a ZCTA increases the net change in trip generation resulting from a given transportation investment also tends to increase. The strength of this correlation suggests that population is a critical factor in predicting the impact of transportation investments on trip generation.

The observed positive correlation between population and net change in trip generation can be attributed to several factors. For example, larger populations may create a higher demand for transportation services, which could lead to an increase in trip generation resulting from transportation investments. These findings have important implications for transportation planning and infrastructure investment decisions. They suggest that investments in transportation infrastructure are likely to have a more significant impact on trip generation in areas with larger populations. Therefore, policymakers and planners should take population into account when making decisions about transportation infrastructure investments and consider the potential impact on trip generation. By doing so, they can help to ensure that transportation investments are targeted effectively and efficiently, and that the needs of the population are adequately addressed.

Our analysis revealed that there is an insignificant correlation between the net change in trip generation resulting from transportation investment per $10 million of investment and the median income of a ZCTA. However, we did observe significant differences in the net change in trip generation resulting from transportation investment per $10 million between the poorest and richest regions. Specifically, in low-income regions, the overall net increase in trip generation resulting from investing $366 million in 10 ZCTAs was found to be 2,450,483. This translates to an average increase in trips of 1,247,179 per zip code resulting from



Note: The suburbs of Indianapolis, Evansville, and Gary showed the highest increases in trip generations, while some suburban areas of Indianapolis and Bloomington experienced a decrease in trip generations due to transportation investments.

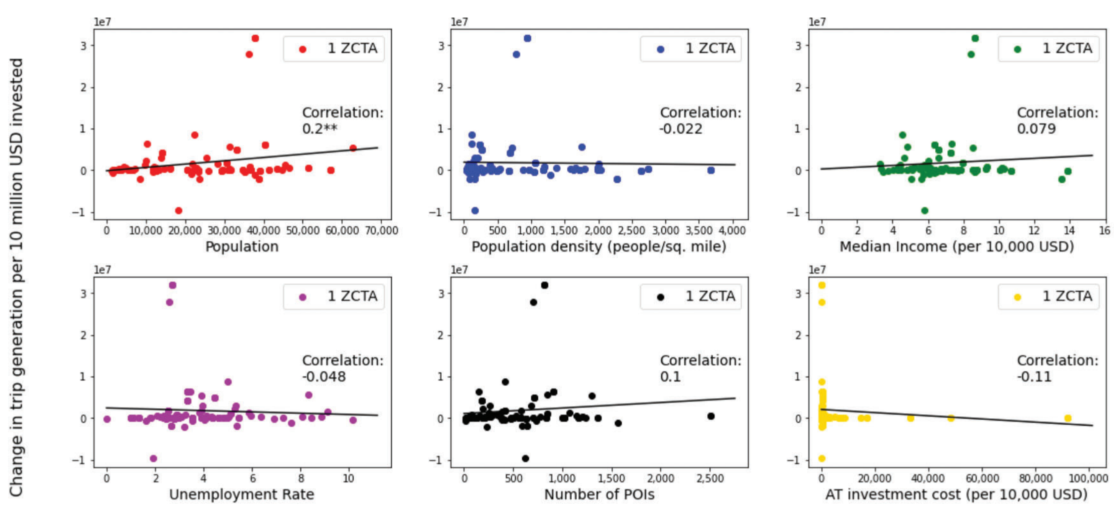
Figure 5.9 The impact of transportation investments on change in trips generated from each ZCTA in 2021, measured per $10 million of transportation invested.

investing $10 million in new transportation construction. In contrast, in high-income regions, the overall net decrease in trip generation resulting from investing $22 million in 4 ZCTAs was found to be -696,421. This translates to an average decrease in trips by 438,901 per zip code resulting from investing $10 million in new transportation construction.

The observed differences in the net change in trip generation between low and high-income regions may be attributed to several factors. For example, in low-income regions, transportation investments may have a more significant impact on trip generation due to a higher dependence on transportation services, limited access to alternative modes of transportation, and a greater need for transportation infrastructure improvements in comparison to the high-income regions.

The unique characteristics and needs of different income regions when making decisions about transportation infrastructure investments should be considered. By doing so, they can ensure that transportation investments are targeted effectively and efficiently, and that the needs of all regions are adequately addressed.

5.2.2.2.2 Trip generation during morning rush hours. Analyzing trip generation during morning rush hours due to new transportation investments is important because it provides insights into the impact of transportation investments during peak travel times, which are typically associated with the highest levels of traffic congestion and travel demand. Morning rush hour periods are often characterized by high levels of commuter traffic, as people travel from their homes to work or school, making it an important time to assess the effectiveness of transportation investments. For this analysis in Indiana, the morning rush hours were considered as 6:30 AM–9:30 AM.

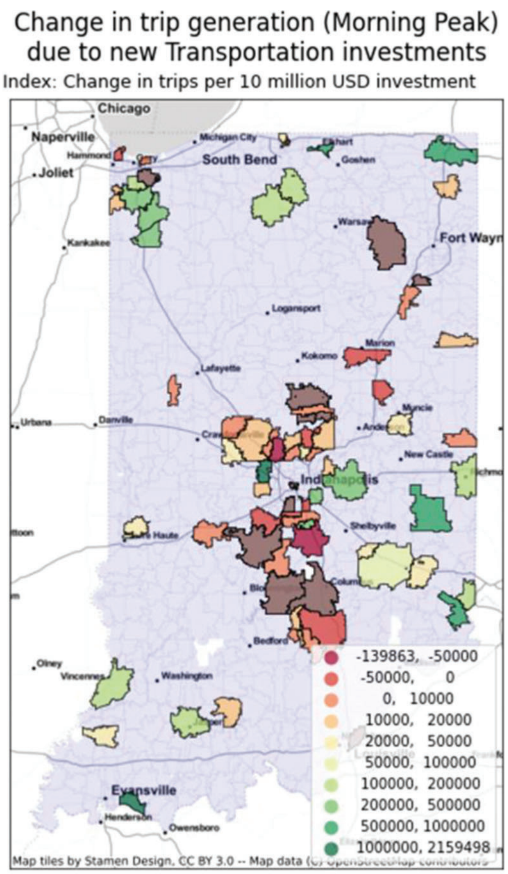


Note: Each data point on the scatter plot corresponds to a unique ZCTA. The analysis revealed a positive correlation between the population of the ZCTAs and the net change in trip generation per $10 million of transportation investment.

Figure 5.10 The correlation analysis between the demographic characteristics of ZCTAs and the net change in trip generation per $10 million of transportation investments.

While analyzing trip generation for the whole day can be useful for understanding overall travel patterns and demand, it may not capture the specific impact of transportation investments during peak travel times, such as morning rush hour. By analyzing trip generation during morning rush hours, transportation planners can gain a better understanding of how transportation investments are affecting travel behavior during peak demand periods. This information can help guide future transportation investment decisions, such as whether to focus on improving transit service during morning rush hour periods or investing in additional road infrastructure to reduce congestion during peak periods.

Figure 5.11 investigates the impact of transportation investments on changes in trip generation during morning rush hours, measured per $10 million of investment, across various ZCTAs in 2021. Our findings show that the suburbs of Gary and Evansville experienced the highest increase in trip generation during morning rush hours due to transportation investments. Conversely, some suburban areas of Indianapolis and Bloomington experienced a decrease in trip generation during morning rush hours due to transportation investments. Overall, the analysis reveals a significant net change in trip generation during morning rush hours, resulting in 1.26 million trips due to investing $2.778 billion in 75 ZCTAs. The average change in trips per zip code resulting from investing $10 million in new transportation construction is found to be 133,350 trips. However, there exist regional discrepancies in the trip generation across regions.



Note: The suburbs of Gary and Evansville experienced the highest increase in trip generation during morning rush hours due to transportation investments. Conversely, some suburban areas of Indianapolis and Bloomington experienced a decrease in trip generation during morning rush hours due to transportation investments.

Figure 5.11 The effect of transportation investments on changes in trip generation during morning rush hours, measured per $10 million of investments across ZCTAs in 2021.

These results suggest the importance of considering specific timeframes, such as morning rush hours, when assessing the impact of transportation investments on trip generation. Such analysis can aid in the development of targeted transportation investment strategies aimed at maximizing the benefits of transportation investments during peak travel periods while minimizing their negative impacts.

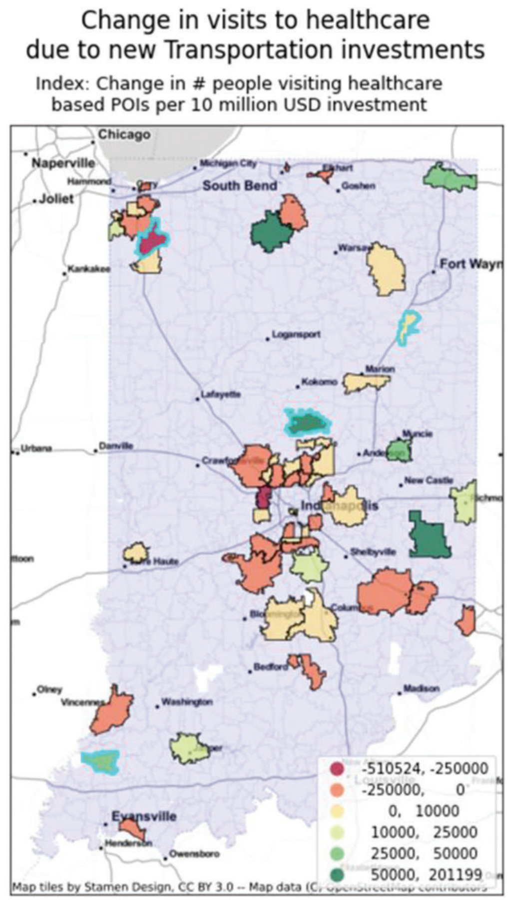
We explore the correlation between changes in trip generation during morning rush hours due to transportation investment, measured per $10 million of investment, and population size in various ZCTAs. Our analysis reveals a significant positive correlation between changes in trip generation and population size, as earlier. Specifically, transportation investments in areas with larger populations result in a greater net change in trip generation during morning rush hours. These findings are of critical importance for transportation planners as they seek to maximize the effectiveness and efficiency of transportation investments. By considering population size as a key factor in transportation investment decision-making, policymakers can develop targeted strategies that address the specific transportation needs of different communities, thus enhancing the overall impact of transportation investments on trip generation during morning rush hours.

We also investigate the relationship between changes in trip generation during morning rush hours due to transportation investment and median income of the region. Our analysis reveals an insignificant correlation between the net change in trip generation during morning peak hours and median income of the region. However, we observe differences in the net change in trip generation due to transportation investment per $10 million of transportation investment between the poorest and the richest regions. Specifically, the poorest regions experienced an overall increase in trips by 144,500 due to investing $366 million in 10 low income ZCTAs. This translates to an increase of 95,500 trips per zip code on average due to $10 million invested in new transportation construction. Conversely, the richest regions experienced an overall decrease in trips of 101,000 as a result of investing $22 million in 4 high income ZCTAs. This translates to a decrease of 21,100 trips per zip code on average due to a $10 million investment in new transportation construction in high income regions. This could inform policy decisions on where and how to allocate transportation funding.

5.2.2.3 Visits to healthcare-based POIs. In this section, we analyze the impact of transportation investments on the number of visits to healthcare-related points of interest (POIs) in a given region. These POIs include physicians, dentists, health practitioners, care centers, laboratories, home services, ambulatory services, surgical hospitals, substance abuse hospitals, specialty hospitals, nursing facilities, and pharmacies and drug stores. To measure changes in the frequency of visits, we utilize cell phone location data, and extract valuable insights into how transportation investments can affect the usage of healthcare services.

5.2.2.3.1 Number of people visiting healthcare related POIs. Analyzing the change in the number of people visiting healthcare-related POIs due to transportation investments is useful to assess the impact of transportation investments on healthcare growth in a region. Healthcare-related POIs are essential for providing necessary healthcare services to the population, and an increase or decrease in visits to these POIs can indicate changes in healthcare accessibility and utilization. By analyzing this metric, it is possible to determine whether transportation investments have contributed to improving or worsening access to healthcare services in a region. This information is valuable for policymakers and stakeholders who are interested in promoting the growth of healthcare services and improving the health outcomes of the population.

Figure 5.12 studies the impact of transportation investments on changes in number of people visiting healthcare-related POIs, measured per $10 million of investment, across ZCTAs in 2021. It shows that the transportation investments may not necessarily lead to an increase in the number of people visiting healthcare-related POIs in all regions, and the effectiveness of such investments may vary depending on the region's characteristics. The statistically significant increase in the number of people visiting healthcare-related POIs in more rural and suburban parts of the state highlights the importance of transportation investments in providing improved access to healthcare services in these areas. The observed increase in visits to healthcare-related POIs around Evansville, Indianapolis, Fort Wayne, and South Bend could be attributed to transportation investments that improved connectivity to healthcare facilities in these areas. However, the majority of regions are experiencing a decrease in the number of people visiting healthcare-related POIs. This may be because transportation investments may lead to the relocation of healthcare-related POIs to more accessible areas, which resulted in a decline in visits to facilities in other regions. This also suggests that transportation investments alone may not be enough to address the complex factors that affect healthcare utilization, such as socioeconomic factors, health literacy, and cultural beliefs. For instance, interventions that address the transportation



Note: There is a statistically significant increase in the number of people visiting healthcare-related POIs only in more rural and suburban parts of the state, as indicated by the cyan boundary. In contrast, the majority of regions observe a decrease in the number of people visiting healthcare-related POIs.

Figure 5.12 The impact of transportation investments on changes in the number of people visiting healthcare-related POIs, measured per $10 million of investments across ZCTAs in 2021.

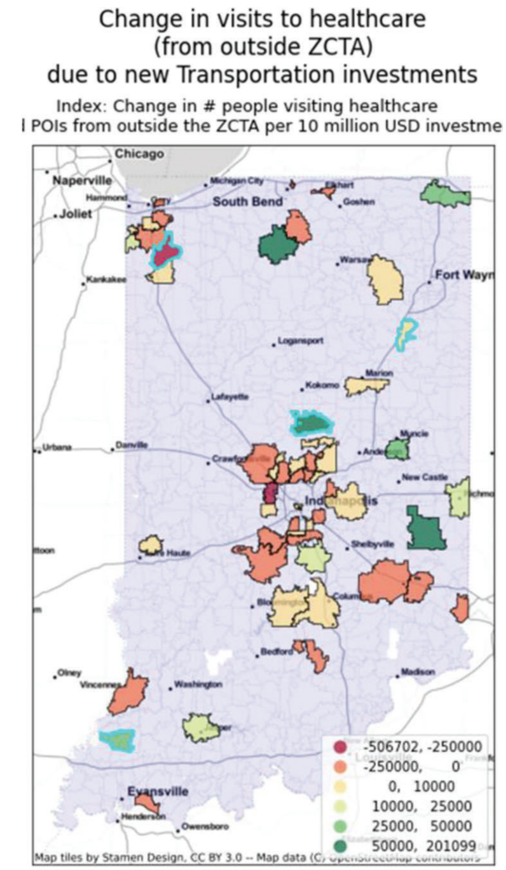
barriers faced by rural and suburban populations may be different from those required for urban populations. The net increase in the number of people visiting healthcare-related POIs resulting from investing $2.575 billion in 75 ZCTAs is 36,768 people for the year 2021. Investing $10 million in new transportation construction results in a decrease in the number of people visiting healthcare-based POIs of 11,110 per zip code on an average in 2021. These results highlight the importance of carefully assessing the impact of transportation investments on healthcare-related POIs to maximize the benefits of such investments. Our findings may help guide policymakers and healthcare professionals in making informed decisions about transportation investments and developing region-specific interventions to improve healthcare access and utilization.

We observe a negative correlation between transportation investments and changes in visits to healthcare-related POIs in relation to the median income of the ZCTAs. Specifically, we found that in low-income ZCTAs, investing $346 million in transportation resulted in a net increase of 66,245 people visiting healthcare-based POIs in 2021. On average, investing $10 million in new transportation construction led to an increase of 40,400 people visiting healthcare-based POIs per zip code in low-income regions. In contrast, in high-income ZCTAs, there was a net decrease of 18,210 in the number of people visiting healthcare-based POIs in 2021 as a result of investing $22 million in transportation. On average, investing $10 million in new transportation construction resulted in a decrease of 8,630 people visiting healthcare-based POIs per zip code in high-income regions.

These findings suggest that in high-income ZCTAs, factors such as existing transportation infrastructure, availability of alternative modes of transportation, or proximity to healthcare facilities play a significant role in healthcare utilization patterns in affluent areas. On the other hand, in low-income ZCTAs, transportation investments may be more effective in improving access to healthcare and increasing visits to healthcare-related POIs. These results highlight the need for targeted strategies and tailored interventions based on the income level of the ZCTAs when considering the impact of transportation investments on healthcare utilization.

5.2.2.3.2 Number of people from other regions visiting healthcare related POIs. Assessing changes in the number of people from other regions visiting healthcare-related POIs due to transportation investments is important because it helps us understand the impact of transportation on the accessibility of healthcare services in a particular region. When people from other regions visit healthcare-related POIs, it can indicate that the transportation investments have improved the connectivity and accessibility of the region to these services. This can lead to increased economic activity, improved health outcomes, and better quality of life for the people in the region. On the other hand, the overall changes in the number of people visiting healthcare-related POIs due to transportation investments provides a more general picture of the impact of transportation on healthcare accessibility. This metric shows how many people are visiting healthcare-related POIs after the transportation investments, regardless of their origin. However, it may not highlight the impact on the accessibility of healthcare services in the region. Therefore, analyzing changes in the number of people from other regions visiting healthcare-related POIs due to transportation investments provides a more nuanced understanding of the impact of transportation on healthcare accessibility.

Figure 5.13 depicts the changes in the number of people visiting healthcare-related POIs from outside the ZCTA due to new transportation investments in 2021, measured per $10 million of investment. The analysis



Note: There is a significant increase in these visits in more rural and suburban areas of the state, as denoted by the cyan boundary. However, the majority of the regions exhibit a decrease in the number of people visiting healthcare-related POIs. These findings are consistent with the previous metric, but this measure specifically considers the changes due to people from outer regions.

Figure 5.13 The changes in the number of people visiting healthcare-related POIs from outside the ZCTA because of new transportation investments in 2021 (measured per $10 million of investment).

shows a statistically significant increase in these visits in rural and suburban areas of the state, as indicated by the cyan boundary. This suggests that transportation investments can lead to improved access to healthcare services for people living in rural and suburban regions. However, the majority of regions observed a decrease in the number of people visiting healthcare-related POIs, indicating that transportation investments alone may not be sufficient to improve healthcare access for all regions.

The findings from this analysis highlight the importance of considering the impact of transportation investments on healthcare access for people from outer regions. This measure is different from the overall changes in the number of people visiting healthcare-related POIs as it specifically focuses on the changes due to people from outer regions. The net change in the number of people visiting healthcare-related POIs from outside the ZCTA was 36,815, as a result of investing $2.575 billion in 75 ZCTAs in 2021. Investing $10 million in new transportation construction resulted in a decrease of 10,950 people visiting healthcare-related POIs from outside the ZCTA on an average per zip code in 2021. These findings highlight the need for targeted investments and strategies to improve healthcare access in areas where transportation investments may not be sufficient. Overall, this underscores the importance of considering the impact of transportation investments on healthcare access in both urban and rural regions.

The changes in the number of people visiting healthcare-related POIs from outside the ZCTA as a result of new transportation investments are similar to the changes in the number of all people visiting healthcare-related POIs. This suggests that the transportation investments are not having a significant impact on attracting new people to visit healthcare-related POIs from within the ZCTA. Instead, it could be the case that the transportation investments are mainly benefiting the non-local population from outside the ZCTAs, in terms of accessing healthcare facilities. The transportation investments, therefore, may not be effectively addressing the healthcare needs of the local population. Instead, these investments may primarily benefit those who are visiting from outside the ZCTA. Policymakers may need to consider additional strategies, such as increasing healthcare accessibility for local residents, to better address the healthcare needs of the community. Policymakers can work on increasing healthcare accessibility for local residents by focusing on active transportation investments in the local area. Another strategy is to improve public transit options, such as increasing bus routes and frequencies or implementing bike share programs. This can provide residents with more convenient and affordable transportation options to reach healthcare facilities.

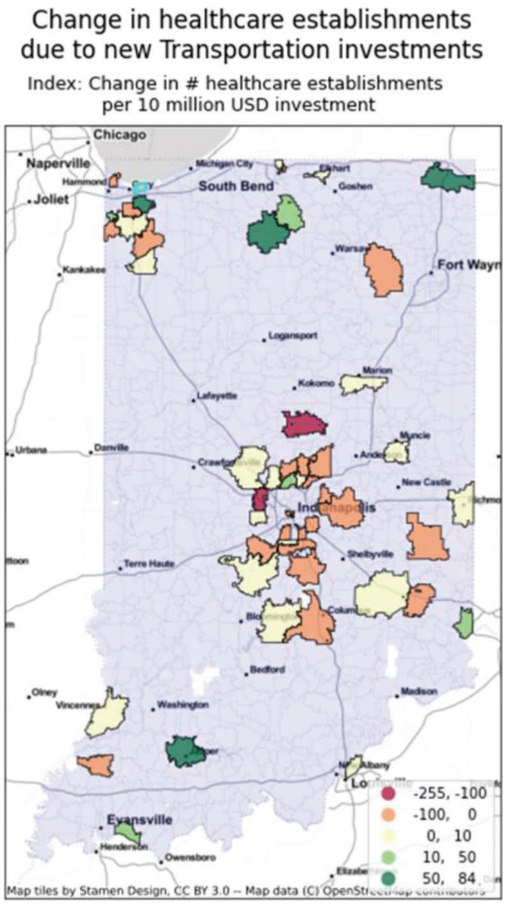
We find a negative correlation between the changes in the number of people visiting healthcare-related POIs from outside the ZCTA due to transportation investments, measured per $10 million of investment, across ZCTAs in 2021, with median income of the ZCTA. Specifically, in low-income regions, a $10 million investment in new transportation construction results in an average change of 40,350 people visiting healthcare-based POIs from outside the ZCTA in 2021. In contrast, in high income regions, the average change is a decrease of 8,630 people visiting healthcare-based POIs from outside the ZCTA per $1 million investment. The net change in the number of people visiting healthcare-based POIs from outside the ZCTA is 66,150 as a result of investing $346 million in 6 low-income ZCTAs and a decrease of 18,150 as a result of investing $22 million in 4 high-income ZCTAs. This suggests that, in low-income regions, transportation investments can attract non-local populations to visit healthcare-related POIs, which can lead to an increase in economic activity and better healthcare outcomes for the local population. However, policymakers need to ensure that transportation investments in high-income regions do not have a negative impact on local residents' access to healthcare facilities. To this end, targeted investments in public transportation and active transportation infrastructure, such as bike lanes and sidewalks, can enhance healthcare accessibility for local residents in both high and low-income regions.

5.2.2.4 Healthcare investments

5.2.2.4.1 Number of healthcare businesses. Assessing the changes in the number of healthcare establishments due to transportation investments is important when examining the relationship between transportation investment and healthcare growth because it provides insight into the effectiveness of transportation investments in promoting healthcare growth. If transportation investments are successful, then they should lead to an increase in the number of healthcare establishments. On the other hand, if transportation investments are not effective, then they may not result in significant growth or even lead to a decrease in healthcare establishments. By analyzing the changes in the number of healthcare establishments, policymakers and practitioners can better understand the impact of transportation investments on healthcare growth and make informed decisions on future investments about how to allocate resources and prioritize investments to promote healthcare growth and accessibility.

Figure 5.14 observes the analysis on the impact of transportation investments on healthcare establishments in 2020. Most ZCTAs around Indianapolis and Bloomington have experienced a decrease in the number of healthcare establishments due to transportation investments suggesting that there could be underlying issues with the effectiveness of these investments in promoting healthcare growth in these areas. Policymakers should therefore consider alternative approaches to transportation investments, such as targeted investments in healthcare infrastructure and resources, to support healthcare growth in these regions. On the other hand, the few ZCTAs surrounding South Bend, Evansville, and Gary that experienced an increase in healthcare establishments due to transportation investments provide an opportunity for policymakers to learn from the successes and replicate them in other regions. They could study the factors contributing to these successes, such as community engagement, healthcare provider incentives, or strategic transportation planning, to develop targeted policies that can support healthcare growth in other areas.

We observe that investing $10 million in new transportation construction results in a decrease in the number of healthcare establishments by 2 per zip code on an average. This highlights the need for policymakers to carefully consider the return on investment (ROI) when making transportation investment decisions. Policymakers need to weigh the potential benefits of transportation investments against the cost of other



Note: The majority of ZCTAs, particularly those around Indianapolis and Bloomington, have witnessed a decrease in the number of healthcare establishments. However, a few ZCTAs surrounding South Bend, Evansville, and Gary have experienced an increase in healthcare establishments due to transportation investments. The ZCTAs with statistically significant changes in establishments are represented by cyan-colored boundaries.

Figure 5.14 The impact of transportation investments on healthcare establishments in 2020, measured per $10 million of investments.

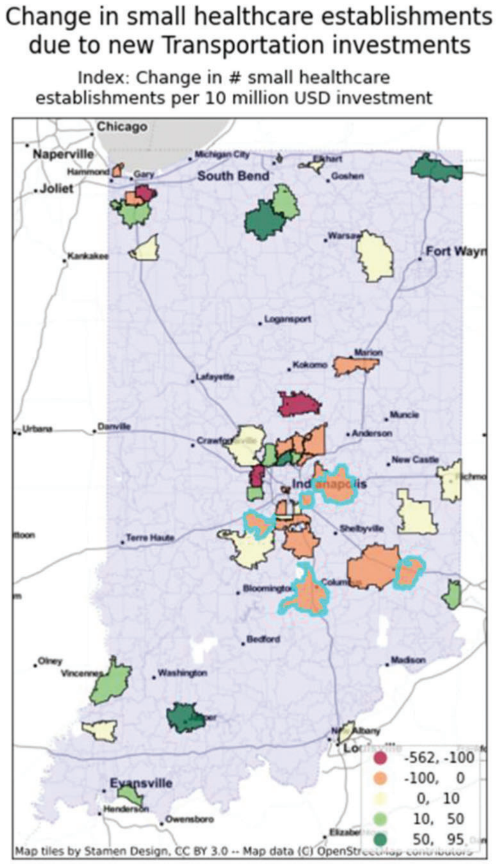
interventions that could potentially yield higher ROI in promoting healthcare growth.

The correlation between the changes in the number of healthcare establishments due to transportation investments, measured per $10 million of investment, across ZCTAs in 2021 with the median income of the ZCTA is found to be statistically insignificant. This implies that the median income of the ZCTA does not significantly influence the relationship between transportation investments and healthcare establishment changes. The net change in the number of healthcare establishments is -3, as a result of investing $351 million in 7 low-income ZCTAs. This indicates that despite transportation investments, there has been a decrease in healthcare establishments in these low-income regions. Investing $10 million in new transportation construction results in an increase in the number of healthcare establishments by 1 per zip code on average for low-income regions. This suggests that the impact of transportation investments on healthcare establishment changes in low-income regions is relatively modest. In contrast, the net change in the number of healthcare establishments is 9, as a result of investing $22 million in 4 high-income ZCTAs. This indicates an increase in healthcare establishments in these high-income regions due to transportation investments. Investing $10 million in new transportation construction results in a change in the number of healthcare establishments of 5 per zip code on average for high-income regions. This suggests that transportation investments have a more significant impact on healthcare establishment changes in high-income regions compared to low-income regions.

Policymakers should consider the nuances of income levels and their impact on the relationship between transportation investments and healthcare establishment changes. In low-income regions, additional measures may be needed to enhance the effectiveness of transportation investments in promoting healthcare growth, such as targeted healthcare interventions or resources. In high-income regions, transportation investments may be a more effective means to promote healthcare growth, and policymakers could prioritize such investments to further improve healthcare accessibility and availability in these areas. Overall, these findings contribute to a better understanding of the complex interplay between transportation investments, income levels, and healthcare establishment changes, which can inform evidence-based policy decisions for promoting healthcare accessibility and equity.

5.2.2.4.2 Number of small healthcare businesses. Assessing changes in the number of small healthcare establishments due to transportation investments is important because it provides a more detailed understanding of the impact of transportation investments on healthcare growth. Small healthcare establishments, such as clinics and primary care facilities, play a crucial role in providing access to healthcare services, particularly in underserved areas. Moreover, these businesses play an important role in job creation, innovation, and community development. Therefore, changes in the number of small healthcare establishments can have a significant impact on the accessibility, quality of healthcare services and economic growth of the region. While assessing changes in the number of overall healthcare establishments due to transportation investments can provide valuable insights, they may not necessarily capture the specific impact on small healthcare establishments or the accessibility of healthcare services in underserved areas.

Figure 5.15 examines the impact of transportation investments on small healthcare establishments in different ZCTAs. The results indicate that suburban and rural ZCTAs surrounding South Bend, Evansville, Gary, and Indianapolis have experienced a positive



Note: Suburban and rural ZCTAs, especially surrounding South Bend, Evansville, Gary, and Indianapolis have experienced an increase in healthcare establishments due to transportation investments. Many ZCTAs in the suburbs of Indianapolis and Bloomington have witnessed a decrease in the number of healthcare establishments. The ZCTAs with statistically significant changes in establishments are represented by cyan-colored boundaries.

Figure 5.15 The impact of transportation investments on small healthcare establishments in 2020, measured per $10 million of investments.

impact on the number of healthcare establishments due to transportation investments, while many ZCTAs in the suburbs of Indianapolis and Bloomington have witnessed a decrease in the number of healthcare establishments. The net increase in the number of small healthcare establishments is 5, as a result of investing $2.575 billion in 75 ZCTAs. This suggests that transportation investments can have a positive impact on small healthcare establishments in certain areas but may not be effective in other areas. Investing $10 million in new transportation construction results in a decrease in the number of small healthcare establishments by 13 per zip code on an average. This implies that transportation investments may have a negative impact on small healthcare establishments in some areas, which policymakers need to consider when making decisions about transportation investments. Overall, these findings suggest that transportation investments can have a complex impact on small healthcare establishments in different ZCTAs, and policymakers need to carefully evaluate the potential effects of transportation investments on small healthcare establishments before making decisions.

The findings suggest that there is no significant correlation between changes in the number of small healthcare establishments across ZCTAs due to transportation investments, and median income. This indicates that transportation investments may not have a significant impact on small healthcare establishments in low and high-income areas. However, it is noteworthy that the net change in the number of small healthcare establishments in low-income areas is negative, with an investment of $345 million in 5 ZCTAs resulting in a decrease of 8 establishments. On the other hand, the net change in the number of small healthcare establishments in high-income areas is positive, with an investment of $22 million in 4 ZCTAs resulting in an increase of 30 establishments. Investing $10 million in new transportation construction results in a change in the number of small healthcare establishments of 1 per zip code on average for low-income regions while the change in high-income regions is observed to be 14 establishments per zip code on average. This implies that transportation investments may have a minimal effect on small healthcare establishments in low-income regions, but a substantial effect in high income regions.

These findings highlight the need for targeted policies that focus on promoting the growth of small healthcare establishments in low-income areas, which may require different strategies than those employed in high-income areas. The study's results indicate that such policies should be customized based on the specific needs and conditions of each ZCTA.

5.2.2.5 Takeaways. We analyze the transportation investments' impact on various aspects of trip generation and healthcare utilization providing valuable insights for making informed policy decisions. The findings reveal that transportation investments have significant effects on trip generation, both in terms of overall trips and during morning rush hours. While the correlation between trip generation changes and median income is insignificant, there are substantial differences between low and high-income regions. Transportation investments have a positive impact on healthcare utilization, with increases in visits to healthcare-related points of interest in rural and suburban areas, especially around Evansville, South Bend, and Gary. However, the effectiveness of these investments varies, and there's a need to consider the nuanced impact on local populations. Healthcare establishment changes, particularly small healthcare businesses, also vary with transportation investments, indicating that tailored strategies are necessary for different income regions. These findings suggest that transportation investments can enhance access to healthcare services and promote economic growth, especially in underserved areas, but the unique characteristics of each region need to be carefully considered in policy planning to maximize their impact.

6. INTEGRATION

The economic attractiveness of several industries, especially finance, manufacturing, agroforestry, and essential healthcare services, can be influenced based on the analysis of active transportation features and overall transportation metrics. It is evident from our analysis that a guided action plan can be designed for each county in improving the transportation infrastructure especially active transportation system which would foster an alternate mode of transportation thereby reducing vehicular congestion, ease of accessibility, improved quality of life.

Analyzing the population growth over the years till 2030 can help in determining the population density distribution. Further this population density or growth expansion can be related to quantifiable healthcare facilities requirement and how a targeted investment is required in these identified counties. This can enable the economic attractiveness for healthcare industry value chain to better their decision-making process of identifying locations of building healthcare establishments and covering the gap in catering desired requirement of the emergency services like number of ambulatory services, bridging the gaps in the number of healthcare employment, number of healthcare firms. Further, deep dive demographic analysis of population expansion can be conducted in checking for the designated (mostly higher) age groups at the county level and how transportation authorities can facilitate future projects in improving the ease of accessibility in the counties based on demographic needs.

Based on determinants and correlation equations captured for the active transportation benefits on economic attractiveness and addressing the healthcare business growth, a modeling framework can be analyzed for future transportation projects and gauged the difficulties, challenges in achieving objectives and amount of investment needed for successful implementation. The scale at which the overall transportation industry operates, such data driven modeling approach can significantly result in few million dollars cost savings.

Our analysis revealed that active transportation investments have a positive impact on the growth of industries like professional, scientific, and technical services, educational services, healthcare, and hospitality and recreation. This impact is more pronounced in low-income areas compared to high-income regions. Specifically, a $10 million investment in healthcare facilities leads to the establishment of 6 more healthcare businesses in an average ZCTA, and 11 more in a low-income ZCTA. However, for overall transportation investment, we found that in an average ZCTA, $10 million investment leads to a decrease of 2 healthcare establishments, and only 1 additional healthcare establishment in a low-income ZCTA. This indicates that in medium and low-income ZCTAs, active transportation investments are more effective in attracting healthcare businesses. In contrast, in high-income ZCTAs, $10 million transportation investments lead to 14 more healthcare establishments, whereas $10 million active transportation investments only lead to 2 more healthcare establishments.

However, the money or length of investment in active transportation is not necessarily linked with more healthcare establishments. We observed the correlation between the change in number of establishments for healthcare industry due to $10 million of active transportation investment and cost of investment to be significant and negative. The investment in active transportation may not be the only factor that influences the growth of healthcare establishments. This suggests that transportation investments should be made strategically to target specific areas with a need for healthcare facilities, rather than assuming that more investment in active transportation will automatically lead to the growth of healthcare facilities.

Furthermore, we found that bike lanes are the most effective type of active transportation investment for attracting healthcare businesses, followed by trails and sidewalks. Specifically, in low-income areas, an investment in constructing 10 miles of bike lanes can attract up to 27 new healthcare businesses, which is a significant gain. In an average ZCTA, this investment can attract up to 4 new healthcare businesses. Similarly, investing in 10 miles of trails and sidewalks can result in the attraction of 7 and 6 new healthcare businesses respectively in low-income areas. However, the effect of trails and sidewalks on average ZCTA and high-income ZCTA is either negative or minimal in relation to attracting healthcare establishments. Thus, targeted policies should be developed to promote the growth of healthcare facilities and improve healthcare access in low-income areas through investment in active transportation, especially bike lanes.

Such data driven planning and strategy development can not only enable economic attractiveness for industrial value chains like finance, manufacturing, healthcare but also aid the Indiana Department of Transportation in capturing cost savings. This also requires efficacious coordination between the targeted industry participants like the healthcare industry and transportation department. Further cost savings can be achieved through collaborating with healthcare industry participants in assessing the forecast results and including healthcare determinants in transportation project planning right from the beginning.

7. RECOMMENDATIONS

Drawing inferences from the Pareto analysis, we observe that there are a few counties which are included in the top 30% with respect to GDP and population but

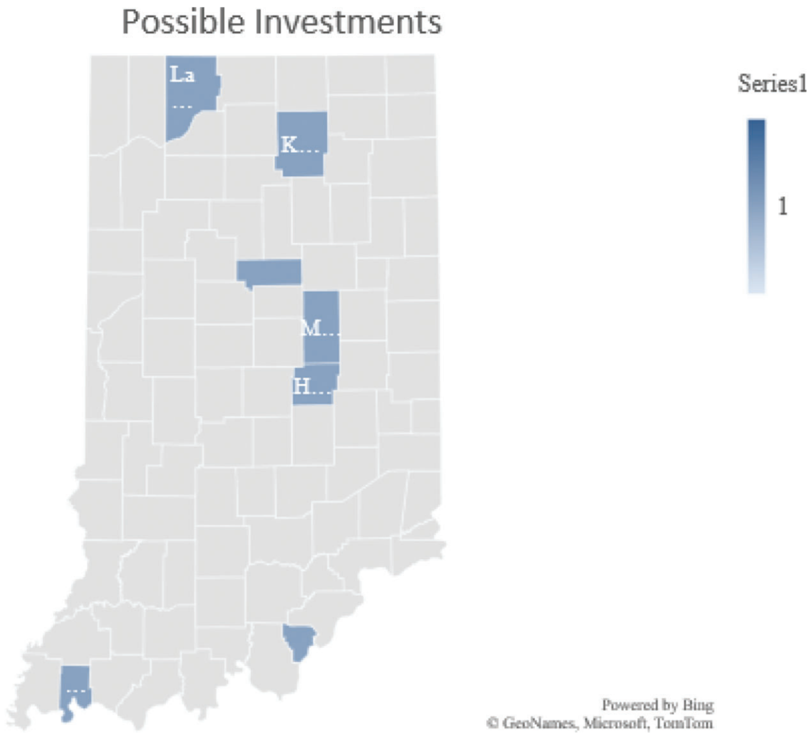


Figure 7.1 Possible investments.

not in terms of active transportation infrastructure presence.

Investments are possible in the following counties: Vanderburgh, Kosciusko, LaPorte, Howard, Madison, Hancock, and Floyd (Figure 7.1). Since these counties have a comparatively higher GDP and population, investing a portion of GDP into active transportation could serve to improve the economy of the counties further.

By examining the geographic and economic features of these counties, INDOT may decide to pursue investments in these counties.

Additionally, we've concluded that manufacturing, finance, and real estate industries are strongly related to active transportation. Thus, investing in active transportation would enable these industries to grow in the regions.

The determinants discussed in the study for healthcare industry follow the population growth trends and the transportation metrics influence the population expansion drives. For instance, the transportation infrastructure development, ease of accessibility, sustainable active transportation features, economic transit options, all contribute towards the decision-making process of population expansion across different counties. Key takeaway for the transportation department is to focus on population growth and their preferences across the counties to achieve short term goals of improving the accessibility for healthcare facilities. This approach can eventually transform to better framework of incorporating long term healthcare economic attractiveness goals upon standardizing the transportation department investment strategies based on the population growth influencing the healthcare industry.

It is recommended to utilize correlation equations in building mathematical and data models for future transportation projects prior to direct implementation. This shall help in assessing the challenges, impact on the target objective and estimating the dollar value investment required at the county level.

Data accuracy in addition to accessibility of relevant data to continuously append the mathematical regression summary table can result in continual improvement for transportation department in staying resilient against the dynamic changes in the economic scenario of healthcare industry especially in emergency situations like pandemic.

The following are a few notable findings from the micro-view causal analysis that can be prominent in decision making of INDOT.

1. The active transportation influenced significant growth in the industries of healthcare, education, hospitality, and recreation. This was consistently observed for low-income regions also. INDOT should prioritize active transportation investments in low-income regions to encourage growth in these industries. This can lead to economic development and better access to essential services for residents of these areas. Additionally, targeted policies and programs should be developed to support the growth of these industries in low-income regions, such as providing financial incentives for healthcare providers to establish clinics and hospitals in these areas.
2. To promote hospitality and recreation in low-income areas or professional, scientific, and technical services

establishments in low/middle income areas, a recommended policy approach is to prioritize investments in trails. This has the highest potential reward according to our analysis.

3. To promote healthcare or education services in low-income or average middle-income areas, priority should be given to investments in bike lanes.
4. Huge investments in active transportation may not necessarily lead to growth and profits. A negative correlation was observed between the net change in service and healthcare establishments due to active transportation investment and the investment costs in the region. Therefore, we suggest that marginal investments be made, and future investments be reviewed periodically based on the current needs of the people.
5. Overall transportation investments are more effective in attracting healthcare businesses in high-income areas. Furthermore, small businesses tend to benefit more in terms of growth and establishment in high-income areas due to these transportation investments. Thus, targeted transportation investments can be useful for economic growth of the region.
6. Our findings suggest that the impact of overall transportation investments on visits to healthcare facilities is primarily driven by non-local visitors, especially in low- and middle-income areas. Therefore, the transportation needs, and accessibility of non-local visitors should be considered including prioritizing transportation infrastructure that improves accessibility for non-local visitors, such as public transit or improved road connections, and considering the unique transportation patterns and behaviors of non-local visitors when designing transportation solutions for healthcare facilities in these areas.

The present study provides several important recommendations. Specific policy suggestions for each metric are detailed in Section 6, along with the corresponding empirical findings. Our analysis is based on data from 2019–2021, but due to the dynamic nature of the environment and human behavior, we recommend that these metrics be periodically updated to reflect changes in the elasticity of growth resulting from both active transportation and overall transportation investments. In addition, our research focuses on the short-term effects of investments (i.e., immediately after the investment is made). However, it is also crucial to examine the long-term effects of these investments on growth, as growth tends to show an exponential increase after the initial few years.

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APPENDICES

Appendix A. Active Transportation Datasets

Appendix B. Healthcare Industry Dataset

Appendix C. Active Transportation Analysis Tables

Appendix D. Healthcare Analysis

APPENDIX A. ACTIVE TRANSPORTATION DATASETS

Table A.1 Sample data table for county-wise employment

County	Total Miles	Total Employment			
	2019	2017	2018	2019	2020
Adams	11	21,002	21,359	21,202	19,762
Allen	219	241,265	246,422	250,512	237,719
Bartholomew	42	61,237	61,956	62,220	57,872
Benton	0	3,851	3,936	3,816	3,603
Blackford	1	4,680	4,624	4,364	4,090
Boone	53	41,217	42,384	44,825	47,215
Brown	210	5,563	5,517	5,588	5,097
Carroll	17	8,164	8,370	8,594	8,328
Cass	32	18,820	19,197	19,241	18,073
Clark	113	68,370	68,635	69,421	67,359
Clay	4	10,895	11,027	11,062	10,521
Clinton	5	14,786	14,975	15,155	14,374
Crawford	31	3,352	3,292	3,260	3,134
Daviess	4	17,661	18,196	18,596	18,016
Dearborn	11	20,106	20,246	20,682	19,373
Decatur	6	17,562	17,866	18,308	17,084
DeKalb	10	27,942	28,096	28,531	26,523
Delaware	46	60,316	60,091	60,082	57,648
Dubois	39	35,680	35,839	35,925	34,256
Elkhart	147	162,358	166,134	162,215	152,140
Fayette	11	8,843	9,012	8,735	8,062
Floyd	10	41,596	42,698	43,220	40,407
Fountain	15	6,591	6,911	6,966	6,433
Franklin	42	8,135	7,824	7,963	7,763
Fulton	13	9,504	9,763	9,799	9,188
Gibson	4	24,661	25,093	25,506	24,458
Grant	22	35,032	35,353	35,183	33,782
Greene	30	10,820	10,868	10,919	10,352
Hamilton	413	205,773	211,677	216,489	207,488
Hancock	22	34,375	35,670	37,467	35,806
Harrison	122	15,987	16,052	16,077	15,029
Hendricks	112	92,569	96,915	99,597	98,899
Henry	39	17,601	17,818	18,008	17,157
Howard	20	49,734	48,870	48,258	45,507
Huntington	34	18,472	18,355	18,400	17,444
Jackson	76	26,076	26,475	26,906	25,908
Jasper	12	16,171	15,787	15,755	15,038
Jay	10	10,470	10,527	10,331	9,462

Jefferson	19	16,646	16,675	16,854	16,019
Jennings	18	10,230	10,531	10,655	10,213
Johnson	54	74,335	77,731	80,415	77,545
Knox	11	22,393	22,691	22,473	21,622
Kosciusko	29	49,389	50,615	50,793	47,815
Lagrange	15	22,670	23,375	23,057	21,478
Lake	188	245,414	247,504	249,849	233,174
LaPorte	37	53,171	53,278	53,548	50,633
Lawrence	41	19,384	19,706	19,806	18,679
Madison	27	53,768	54,112	54,490	51,790
Marion	242	752,647	762,101	775,757	728,049
Marshall	13	24,829	24,476	24,720	23,313
Martin	15	8,791	8,927	9,456	9,553
Miami	40	13,336	13508	13,379	12,477
Monroe	171	89,671	91,155	93,049	89,385
Montgomery	16	20,456	20,552	20,469	19,636
Morgan	17	25,081	24,755	24,806	23,356
Newton	6	4,952	4,980	4,957	4,754
Noble	49	24,065	24,588	24,779	22,623
Ohio	2	2,044	2,061	1,996	1,729
Orange	73	10,286	10,180	10,416	9,454
Owen	31	7,449	7,775	8,075	7,660
Parke	24	5,766	5,755	5,802	5,557
Perry	82	8,629	8,667	8,710	8,237
Pike	25	4,648	4,193	4,216	4,194
Porter	136	81,573	83,952	85,552	79,043
Posey	32	11,784	12,086	12,281	11,756
Pulaski	39	6,428	6,550	6,624	6,326
Putnam	33	18,779	18,796	18,972	17,306
Randolph	8	9,737	9,644	9,553	9,208
Ripley	49	16,512	16,657	17,148	16,048
Rush	1	7,581	7,684	7,723	7,166
St. Joseph	31	161,012	163,126	165,424	152,409
Scott	11	10,530	10,765	1,0673	10,074
Shelby	24	24,178	24,435	24,410	22,595
Spencer	176	9,828	9,815	9,852	9,078
Starke	12	7,205	7,145	6,852	6,453
Steuben	55	20,738	21,109	21,611	20,009
Sullivan	22	7,814	7,822	8,009	7,520
Switzerland	1	3,419	3,554	3,547	3,045
Tippecanoe	106	112,196	114,487	116,469	110,435
Tipton	0	6,562	7,471	7,735	7,177
Union	18	2,294	2,377	2,437	2,258

Vanderburgh	38	132,681	133,898	134,047	125,552
Vermillion	1	6,060	6,008	5,978	5,864
Vigo	55	61,295	61,062	60,655	57,179
Wabash	51	16,305	16,276	16,514	15,434
Warren	5	3,132	3,165	3,194	3,021
Warrick	49	24,250	24,803	25,376	24,522
Washington	43	9,991	10,076	10,127	9,380
Wayne	43	38,728	39,226	39,172	36,971
Wells	21	14,503	14,644	14,674	14,092
White	7	12,450	12,709	12,773	12,263
Whitley	18	16,936	17,447	17,820	17,123

Table A.2 Sample data table for industry-wise county-wise GDP

GeoName	Miles	Table Name	Industry Classification	Description	Unit	2017	2018	2019	2020
Adams, IN	11	CAG DP2	–	All industry total	$ B	1.72	1.76	1.86	1.87
Adams, IN	11	CAG DP2	–	Private industries	$ B	1.58	1.60	1.69	1.70
Adams, IN	11	CAG DP2	11	Agriculture, forestry, fishing and hunting	$ B	0.18	0.19	(D)	0.11
Adams, IN	11	CAG DP2	21	Mining, quarrying, and oil and gas extraction	$ B	0.00	0.00	0.00	0.00
Adams, IN	11	CAG DP2	22	Utilities	$ B	0.00	0.00	(D)	0.00
Adams, IN	11	CAG DP2	23	Construction	$ B	0.17	0.18	0.19	0.19
Adams, IN	11	CAG DP2	31–33	Manufacturing	$ B	0.69	0.67	0.80	0.85
Adams, IN	11	CAG DP2	321, 327–339	Durable goods manufacturing	$ B	0.46	0.45	0.44	0.42
Adams, IN	11	CAG DP2	311–316, 322–326	Nondurable goods manufacturing	$ B	0.22	0.23	0.36	0.43
Adams, IN	11	CAG DP2	42	Wholesale trade	$ B	0.07	0.07	(D)	0.06
Adams, IN	11	CAG DP2	44–45	Retail trade	$ B	0.09	0.09	0.09	0.10
Adams, IN	11	CAG DP2	48–49	Transportation and warehousing	$ B	(D)	(D)	0.04	(D)
Adams, IN	11	CAG DP2	51	Information	$ B	0.04	0.05	0.04	0.04
Adams, IN	11	CAG DP2	52, 53	Finance, insurance, real estate, rental, and leasing	$ B	0.15	0.15	0.15	0.15
Adams, IN	11	CAG DP2	52	Finance and insurance	$ B	0.04	0.04	0.04	0.04
Adams, IN	11	CAG DP2	53	Real estate and rental and leasing	$ B	0.11	0.11	0.10	0.10

Adams, IN	11	CAG DP2	54, 55, 56	Professional and business services	$ B	(D)	(D)	0.04	(D)
Adams, IN	11	CAG DP2	54	Professional, scientific, and technical services	$ B	(D)	(D)	(D)	(D)
Adams, IN	11	CAG DP2	55	Management of companies and enterprises	$ B	(D)	(D)	(D)	(D)
Adams, IN	11	CAG DP2	56	Administrative and support and waste management and remediation services	$ B	0.02	0.02	0.02	0.03
Adams, IN	11	CAG DP2	61, 62	Educational services, health care, and social assistance	$ B	0.06	0.06	0.06	0.06
Adams, IN	11	CAG DP2	61	Educational services	$ B	0.01	0.01	0.02	0.01
Adams, IN	11	CAG DP2	62	Health care and social assistance	$ B	0.04	0.04	0.05	0.04
Adams, IN	11	CAG DP2	71, 72	Arts, entertainment, recreation, accommodation, and food services	$ B	0.02	0.02	0.02	0.02
Adams, IN	11	CAG DP2	71	Arts, entertainment, and recreation	$ B	0.00	0.00	0.00	0.00
Adams, IN	11	CAG DP2	72	Accommodation and food services	$ B	0.02	0.02	0.02	0.02
Adams, IN	11	CAG DP2	81	Other services (except government and government enterprises)	$ B	0.03	0.03	0.03	0.03
Adams, IN	11	CAG DP2	–	Government and government enterprises	$ B	0.15	0.16	0.17	0.17
Adams, IN	11	CAG DP2	11, 21	Natural resources and mining	$ B	0.19	0.20	(D)	0.11
Adams, IN	11	CAG DP2	42, 44–45	Trade	$ B	0.15	0.16	(D)	0.16
Adams, IN	11	CAG DP2	22, 48–49	Transportation and utilities	$ B	(D)	(D)	(D)	(D)
Adams, IN	11	CAG DP2	31–33, 51	Manufacturing and information	$ B	0.73	0.72	0.84	0.89
Adams, IN	11	CAG DP2	–	Private goods-producing industries 2/	$ B	1.04	1.05	(D)	1.14
Adams, IN	11	CAG DP2	–	Private services-providing industries 3/	$ B	0.54	0.55	(D)	0.55

Table A.3 Sample data table for county-wise population

County	Population (Millions)		
	2019	2020	2021
Adams, IN	0.04	0.04	0.04
Allen, IN	0.38	0.39	0.39
Bartholomew, IN	0.08	0.08	0.08
Benton, IN	0.01	0.01	0.01
Blackford, IN	0.01	0.01	0.01
Boone, IN	0.07	0.07	0.07
Brown, IN	0.02	0.02	0.02
Carroll, IN	0.02	0.02	0.02
Cass, IN	0.04	0.04	0.04

Table A.4 Sample data table for county wise trails

SEGMILES	SEGNAME	STATUS	COUNTY	TRAILNAME
0.121679	Winchester Road Rail-Trails connector	Open	Adams	River Greenway Trails
0.189702	Rainbow Bottoms/Paved	Open	Adams	Rainbow Bottoms Trail
0.191813	Kekionga Trail Hospital Spur	Open	Adams	River Greenway Trails
0.240353	Worthman Field Track	Open	Adams	Adams County Parks Trails
0.258294	Woodcrest to Rail-Trail	Open	Adams	River Greenway Trails
0.313161	Woods Trails	Open	Adams	Belmont Pond Trails
0.358006	Winchester to Rivergreenway	Open	Adams	River Greenway Trails

Table A.5 Sample data for active transportation investment

Work Type	Project Status	County	CN Estimate & Inflated Amount	Letting Date
New Road Construction	Active	Morgan	126663110.9	11/14/2019
Road Reconstruction (3R/4R Standards)	Active	Morgan	18491868.37	1/29/2020
New Road Construction	Active	Johnson, Marion, Morgan	147747723.8	11/18/2020
Pavement Repair or Rehabilitation	Active	Bartholomew	1752840	4/3/2019
Pavement Repair or Rehabilitation	Active	Bartholomew	2843000	1/13/2021
Added Travel Lanes	Active	Vigo	5048441.7	3/4/2020
Intersection Improvement	Active	Delaware	87849.5	7/10/2019
Br Repl, Precast 3-Sided Culvert	Active	Clinton	5471868.5	12/11/2019
Bridge Deck Overlay	Active	Clinton	565995.34	5/9/2019

APPENDIX B. HEALTHCARE INDUSTRY DATASET

Table B.1 Sample county wise data set for Healthcare budget (2019)

County	Healthcare Budget 2019	Population 2019	Budget per Capita 2019
Adams	$393,910.00	35,777	$11.01
Allen	$5,419,019.00	379,299	$14.29
Bartholomew	$1,677,742.00	83,779	$20.03
Benton	$67,571.00	8,748	$7.72
Blackford	$191,391.00	11,758	$16.28

Table B.2 Sample county wise data set for Medicare refunds from CMS data source (2019)

HBA	BENE_GEO_LVL	BENE_GEO_DESC	BENE_GEO_CD	BENE_AGE_LVL	TOT_MDCR_PYMT_PC ($ value per capita)
2019	County	IN-Adams	18001	All	10,179.38
2019	County	IN-Allen	18003	All	9,614.61
2019	County	IN-Bartholomew	18005	All	10,009.17
2019	County	IN-Benton	18007	All	11,261.58
2019	County	IN-Blackford	18009	All	11,508.26

Table B.3 Sample county wise data set for Medicare refunds from DART data source (2019)

Geo_Name	Population	Year	Cohort	Eventname	Adjusted_Rate ($ value per capita)
IN-Adams County	3,086	2019	Payment	pmt_total	9,817.86
IN-Allen County	21,702	2019	Payment	pmt_total	9,565.76
IN-Bartholomew County	9,122	2019	Payment	pmt_total	10,178.95
IN-Benton County	1,204	2019	Payment	pmt_total	10,962.67
IN-Blackford County	2,126	2019	Payment	pmt_total	11,185.22

Table B.4 Adams County cash and investment statement - Healthcare sector (2021)

	Local Fund Number	Local Fund Name	Beg Cash & Inv Bal Jan 1, 2021	Receipts	Disbursement	End Cash & Inv Bal Dec 31, 2021
Governmental Activities	0	Clerk of the Circuit Court	$252,212.38	$2,394,796.68	$2,384,102.83	$262,906.23
	00	Inmate Trust Fund 2	$28,303.90	$362,693.16	$360,943.56	$30,053.50
	000	Sheriff"s Commissary 2	$33,415.09	$105,219.51	$138,634.60	$0.00
	0000	County Home Residents	$43,174.31	$281,643.58	$301,624.59	$23,193.30
	000000	Treasurer	$1,032,377.34	$802,144.30	$1,032,377.34	$802,144.30
	0000000	Sheriff"s Commissary 3	$0.00	$296,753.07	$286,603.55	$10,149.52

	1000	County General	$6,003,955.86	$13,834,940.34	$13,824,622.43	$6,014,273.77
	1101	Accident Report	$18,068.45	$2,776.00	$0.00	$20,844.45
	1112	LIT - Economic Development	$311,119.19	$2,301,199.01	$2,061,591.60	$550,726.60
	1116	City & Town Court Costs	$2,018.65	$6,473.26	$6,530.35	$1,961.56
	1119	Clerks Perp Fund	$125,885.24	$23,970.06	$10,743.52	$139,111.78
	1122	Comm Corr Home Detention	$20,422.71	$366,669.96	$354,049.40	$33,043.27
	1123	Comm Transitions Program	$36,457.16	$14,125.00	$36,457.16	$14,125.00

Table B.5 Sample county wise data set for healthcare payroll, number of healthcare establishments (2019)

County Name	NAICS	NAICS Description	Firms	Establishments	Employment	Annual Payroll ($1,000)
Adams	446	Health and Personal Care Stores	8	9	116	2,796
Adams	524	Insurance Carriers and Related Activities	21	23	69	2,708
Adams	621	Ambulatory Health Care Services	29	33	368	13,857
Adams	623	Nursing and Residential Care Facilities	7	10	640	14,209
Allen	621	Ambulatory Health Care Services	544	686	13,915	935,793
Allen	446	Health and Personal Care Stores	54	104	1,479	47,646
Allen	622	Hospitals	5	9	10,971	588,561
Allen	524	Insurance Carriers and Related Activities	235	256	5,636	466,328
Allen	623	Nursing and Residential Care Facilities	54	185	6,954	190,954

Table B.6 Sample county wise data set for transportation metrics (2019)

	County Miles	**Local Miles**	**State Miles**	**Total/Road Miles**	**Trail Miles**
Adams	673.85	104.92	100.41	879.18	11.07
Allen	1,327.23	1,305.76	208.82	2,841.81	218.68
Bartholomew	687.75	291.20	108.66	1,087.61	42.10
Benton	660.10	55.47	110.52	826.09	0.39
Blackford	321.81	61.17	43.61	426.59	1.07

Table B.7 Sample county wise data set for Indiana state transportation projects investment (2019)

County Name	**Investment 2019 ($)**	**Investment 2020 ($)**	**Investment 2021 ($)**
Adams	3,423,770.07	4,136,977.24	36,654.24
Allen	41,212,105.68	33,323,004.1	4,708,500.277
Bartholomew	41,275,868.6	65,267,237.88	3,143,000
Benton	3,049,441.675	1,613,818.63	750,757.85
Blackford County	2,132,884.205	7,194,235.535	42,896.11

Table B.8 Sample county wise data set for Population by different age groups (2019)

Population by Age: 2019							
Geography	**Preschool (0 to 4)**	**School Age (5 to 17)**	**College Age (18 to 24)**	**Young Adult (25 to 44)**	**Older Adult (45 to 64)**	**Older (65 plus)**	**Total**
Adams	3,271	7,933	3,017	7,943	7,874	5,650	35,688
Allen	26,727	70,219	34,255	100,381	90,884	56,540	379,006
Bartholomew	5,490	14,593	6,757	22,684	20,653	13,886	84,063
Benton	554	1,655	647	2,023	2,305	1,579	8,763
Blackford	674	1,885	862	2,538	3,250	2,578	11,787

APPENDIX C. ACTIVE TRANSPORTATION ANALYSIS TABLES

Table C.1 Population vs. trail miles regression statistics

Regression Statistics	
Multiple R	0.71
R Square	0.50
F	89.19
Significance F	0.000
t-stat	9.44
p-value	0.000

Table C.2 GDP vs. trail miles regression statistics

Regression Statistics	
Multiple R	0.57
R Square	0.32
F	42.62
Significance F	0.000
t-stat	6.53
p-value	0.000

Table C.3 Employment vs. trail miles regression statistics

Regression Statistics	
Multiple R	0.62
R Square	0.39
F	57.24
Significance F	0.000
t-stat	7.57
p-value	0.000

Regression: Counties with less than 20 miles: with intercept

Table C.4 Counties with less than 20 miles: with intercept: regression statistics

Regression Statistics: miles <20	
Multiple R	0.33
R Square	0.11
Adjusted R Square	0.08
Standard Error	5.79
Observations	39

	Coefficients	Standard Error	t Stat	P-value
Intercept	6.9693956	1.59	4.38	0.000
GDP	0.0000024	0.00	2.11	0.041

Regression: Counties with less than 20 miles: without intercept

Table C.5 Counties with less than 20 miles: without intercept: regression statistics

Regression Statistics: miles <20	
Multiple R	0.79
R Square	0.63
Adjusted R Square	0.60
Standard Error	7.04
Observations	39

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
GDP	0.000006	0.00	8.0	0.000000001

Regression: Counties with more than 20 miles: with intercept

Table C.6 Counties with more than 20 miles: with intercept: regression statistics

Regression Statistics: miles>20	
Multiple R	0.70
R Square	0.49
Adjusted R Square	0.48
Standard Error	49.65
Observations	51

	Coefficients	Standard Error	t Stat	P-value
Intercept	30.34469	8.93	3.40	0.00135783
GDP	0.00001	0.00	6.85	0.00000001

Regression: Counties with more than 20 miles: intercept = 0:

Table C.7 Counties with more than 20 miles: intercept = 0: regression statistics

Regression Statistics: miles>20	
Multiple R	0.83
R Square	0.69
Adjusted R Square	0.67
Standard Error	54.64
Observations	51

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
GDP	0.000013	0.00000	10.49	0.00000000

Regression: Counties with more than 20 miles: with intercept

Table C.8 Counties with more than 20 miles: with intercept after outliers removed: regression statistics

Regression Statistics	
Multiple R	0.81
R Square	0.65
Adjusted R Square	0.64
Standard Error	28.06
Observations	47

	Coefficients	Standard Error	t Stat	P-value
Intercept	31.446667	5.19	6.06	0.0000003
GDP	0.000008	0.00	9.15	0.0000000

Regression: Counties with more than 20 miles: intercept = 0

Table C.9 Counties with more than 20 miles: intercept = 0 after outliers removed: regression statistics

Regression Statistics	
Multiple R	0.89
R Square	0.79
Adjusted R Square	0.77
Standard Error	28.69
Observations	47

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
GDP	0.000010	0.00	13.14	0.00

Table C.10 Total firms vs. trail miles regression statistics

Regression Statistics	
Multiple R	0.72
R Square	0.51
Adjusted R Square	0.51
Standard Error	34.72
Observations	90

	Coefficients	Standard Error	t Stat	P-value
Intercept	23	4.14	5.50	0.00000
Total firms	0	0.00	9.62	0.00000

Table C.11 MFRE GDP vs. trail miles regression statistics

Regression Statistics	
Multiple R	0.64
R Square	0.41
Adjusted R Square	0.40
Standard Error	34.72
Observations	89

	Coefficients	Standard Error	t Stat	P-value
Intercept	20	4.43	4.50	0.00002
MFRE GDP (billion $)	16	2.01	7.73	0.00000

Table C.12 MFRE number of firms vs. trail miles regression statistics

Regression Statistics	
Multiple R	0.72
R Square	0.52
Adjusted R Square	0.51
Standard Error	34.47
Observations	90

	Coefficients	Standard Error	t Stat	P-value
Intercept	22	4.14	5.27	0.00000
MFRE Firms	0	0.00	9.75	0.00000

Table C.13 GDP/capita vs. active transportation investment regression statistics

Regression Statistics	
Multiple R	0.26
R Square	0.07
Adjusted R Square	0.04
Standard Error	9.46
Observations	43

	Coefficients	Standard Error	t Stat	P-value
Intercept	1	3.25	0.27	0.79
GDP/Capita_2019 ($1,000)	0	0.06	1.69	0.10

Table C.14 Population vs. active transportation investment regression statistics

Regression Statistics	
Multiple R	0.35
R Square	0.12
Adjusted R Square	0.10
Standard Error	9.17
Observations	43

	Coefficients	Standard Error	t Stat	P-value
Intercept	3	1.71	2.00	0.05
Population_2019 (million)	20	8.34	2.40	0.02

Table C.15 GDP/capita vs. trail miles regression statistics

Regression Statistics	
Multiple R	0.20
R Square	0.04
Adjusted R Square	0.03
Standard Error	63.68
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	18	15.95	1.16	0.25
GDP/Capita_2019 ($1,000)	1	0.32	1.98	0.05

Pareto Analysis

Table C.16 Top 30% counties with 70% trails

County	Trails	GDP 2020	Population 2020
Hamilton, IN	413	21.15	0.35
Marion, IN	242	95.29	0.98
Allen, IN	219	21.63	0.39
Brown, IN	210	0.30	0.02
Lake, IN	188	22.26	0.50
St. Joseph, IN	176	14.34	0.27
Monroe, IN	171	7.36	0.14
Elkhart, IN	147	16.11	0.21
Porter, IN	136	7.31	0.17
Harrison, IN	122	1.21	0.04
Clark, IN	113	5.57	0.12
Hendricks, IN	112	7.66	0.18
Tippecanoe, IN	106	10.47	0.19
Perry, IN	82	0.72	0.02
Jackson, IN	76	2.52	0.05
Orange, IN	73	0.64	0.02
Vigo, IN	55	4.69	0.11
Steuben, IN	55	1.50	0.03
Johnson, IN	54	6.04	0.16
Boone, IN	53	3.91	0.07
Wabash, IN	51	1.20	0.03
Ripley, IN	49	1.23	0.03
Noble, IN	49	1.94	0.05
Warrick, IN	49	2.42	0.06
Delaware, IN	46	4.25	0.11
Wayne, IN	43	2.86	0.07
Washington, IN	43	0.66	0.03
Bartholomew, IN	42	6.64	0.08

Table C.17 Top 30% counties with 60% GDP

County	Sum of SEGMILES	GDP 2020	Population 2020
Marion, IN	242	95.29	0.98
Lake, IN	188	22.26	0.50
Allen, IN	219	21.63	0.39
Hamilton, IN	413	21.15	0.35
Elkhart, IN	147	16.11	0.21
St. Joseph, IN	176	14.34	0.27
Vanderburgh, IN	38	11.47	0.18
Tippecanoe, IN	106	10.47	0.19
Hendricks, IN	112	7.66	0.18
Monroe, IN	171	7.36	0.14
Porter, IN	136	7.31	0.17
Bartholomew, IN	42	6.64	0.08
Johnson, IN	54	6.04	0.16
Kosciusko, IN	29	6.00	0.08
Clark, IN	113	5.57	0.12
Vigo, IN	55	4.69	0.11
Delaware, IN	46	4.25	0.11
LaPorte, IN	37	4.20	0.11
Howard, IN	20	4.18	0.08
Madison, IN	27	4.03	0.13
Boone, IN	53	3.91	0.07
Gibson, IN	4	3.44	0.03
Hancock, IN	22	3.37	0.08
Floyd, IN	10	3.11	0.08
Posey, IN	32	3.09	0.03
Dubois, IN	39	2.87	0.04
Wayne, IN	43	2.86	0.07
Dekalb, IN	10	2.55	0.04

Top 30% counties with 60% Pop

Table C.18 Top 30 % counties with 60% Pop

County	Sum of SEGMILES	GDP 2020	Population 2020
Marion, IN	242	95.29	0.98
Lake, IN	188	22.26	0.50
Allen, IN	219	21.63	0.39
Hamilton, IN	413	21.15	0.35
St. Joseph, IN	176	14.34	0.27
Elkhart, IN	147	16.11	0.21
Tippecanoe, IN	106	10.47	0.19
Vanderburgh, IN	38	11.47	0.18
Hendricks, IN	112	7.66	0.18
Porter, IN	136	7.31	0.17
Johnson, IN	54	6.04	0.16
Monroe, IN	171	7.36	0.14
Madison, IN	27	4.03	0.13
Clark, IN	113	5.57	0.12
LaPorte, IN	37	4.20	0.11
Delaware, IN	46	4.25	0.11
Vigo, IN	55	4.69	0.11
Howard, IN	20	4.18	0.08
Bartholomew, IN	42	6.64	0.08
Floyd, IN	10	3.11	0.08
Hancock, IN	22	3.37	0.08
Kosciusko, IN	29	6.00	0.08
Morgan, IN	17	1.98	0.07
Boone, IN	53	3.91	0.07
Wayne, IN	43	2.86	0.07
Grant, IN	22	2.48	0.07
Warrick, IN	49	2.42	0.06
Dearborn, IN	11	2.04	0.05

APPENDIX D. HEALTHCARE ANALYSIS

Table D.1 Healthcare payroll versus trail miles regression summary

Fitted Line Parameters		
	Coefficient	**t-stat**
Intercept	0	–
Trail miles	9218	14.69

Regression Statistics	
Multiple R	0.841
R Square	0.710
Adjusted R Square	0.700
Standard Error	436,444
Observations	89

Table D.2 Healthcare payroll versus roadway miles regression summary

Regression Summary (base)	
Multiple R	0.633
R Square	0.401
Adjusted R Square	0.390
Standard Error	1,140,935
Observations	92
t-Stat	7.812

Table D.3 Healthcare payroll versus road miles regression summary for two clusters

Regression Summary (Cluster 1)		Regression Summary (Cluster 2)	
Multiple R	0.849071	Multiple R	0.871962
R Square	0.720921	R Square	0.760319
Adjusted R Square	0.705048	Adjusted R Square	0.721857
Standard Error	44952.43	Standard Error	728033.5
Observations	64	Observations	27
t-Stat	12.75	t-Stat	9.08

Table D.4 Healthcare payroll versus population regression summary

Regression Statistics	
Multiple R	0.945716745
R Square	0.894380163
Adjusted R Square	0.883391152
Standard Error	261549.2572
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
2019 Population	5.276372121	0.190075608	27.75933307	3.3522E-46

Table D.5 Healthcare payroll versus age group (44 to 64) regression summary

Regression Statistics	
Multiple R	0.932411877
R Square	0.869391908
Adjusted R Square	0.858402897
Standard Error	290847.8026
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
Age (44 to 64)	21.45859967	0.871882434	24.6118041	5.34021E-42

Table D.6 Healthcare payroll versus age group (65+) regression summary

Regression Statistics	
Multiple R	0.901579292
R Square	0.81284522
Adjusted R Square	0.801856209
Standard Error	348161.8693
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
Age 65+	34.83762821	1.752364383	19.88035625	7.08428E-35

Table D.7 Healthcare payroll vs. population, road miles, trail miles multi-regression summary

Regression Statistics	
Multiple R	0.971488
R Square	0.943788
Adjusted R Square	0.931289
Standard Error	192,939.3
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
2019 Population	6.893092	0.251653	27.39129	3.83E-45
Road Miles	-250.789	30.57117	-8.20344	1.66E-12
Trail Miles	4.274722	416.0618	0.010274	0.991825

Table D.8 Healthcare payroll vs. age group (44 to 64), age group (65+), road miles, trail miles multi-regression summary

Regression Statistics	
Multiple R	0.974288
R Square	0.949236
Adjusted R Square	0.936142
Standard Error	184,389.6
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
Age (44 to 64)	68.80538	6.280314	10.95572	4.02E-18
Age 65+	-71.1652	11.09474	-6.41432	6.87E-09
Road miles	-135.874	36.77867	-3.69436	0.000382
Trail miles	-851.254	417.1876	-2.04046	0.044302

Table D.9 Number of healthcare firms county wise sample data

County	#Healthcare Firms	PYRL	County Miles
Adams	65	$88,287	879
Allen	892	$4,076,501	2,842
Bartholomew	202	$414,972	1,088
Benton	13	$8,381	826

Table D.10 Healthcare firms versus healthcare payroll, road miles multi-regression summary

Correlation Matrix	#Healthcare Firms	Healthcare Payrolls	County Roadway Miles
#Healthcare Firms	1	0.94	0.89
Healthcare Payrolls	–	1	–
County Roadway Miles	–	–	1

Table D.11 Healthcare firms versus population regression summary

Regression Statistics	
Multiple R	0.984611
R Square	0.969458
Adjusted R Square	0.958469
Standard Error	54.7058
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
2019 Population	0.002137	3.98E-05	53.74467	9.79E-71

Table D.12 Investment vs. healthcare firms per capita regression summary

Regression Statistics	
Multiple R	0.483845961
R Square	0.234106914
Adjusted R Square	0.223117903
Standard Error	22245954.98
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
Healthcare Firms per Capita	6444353.927	1221899.937	5.274043917	8.95416E-07

Table D.13 Investment vs.healthcare firms per capita (excluding outliers) regression summary

Regression Statistics	
Multiple R	0.706728328
R Square	0.49946493
Adjusted R Square	0.487416737
Standard Error	8,765,841.171
Observations	84

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
Healthcare Firms Per Capita	4,719,483.858	518,585.3152	9.100689356	4.1057E-14

Table D.14 Transportation investment vs. healthcare number of firms regression summary

Regression Statistics	
Multiple R	0.58579738
R Square	0.34315858
Adjusted R Square	0.33586034
Standard Error	18,440,252.6
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	4,058,963.94	2,209,009.521	1.837458779	0.06944199
Number of Firms	48,654.7951	7,095.569071	6.857067356	8.5698E-10

Table D.15 Transportation investment vs. healthcare number of firms (excluding outliers) regression summary

Regression Statistics	
Multiple R	0.86517942
R Square	0.74853543
Adjusted R Square	0.74567788
Standard Error	8,154,458.55
Observations	90

	Coefficients	Standard Error	t Stat	P-value
Intercept	1,780,518.24	987,193.276	1.80361666	0.07471347
Number of Firms	54,945.6113	3,394.87584	16.1848662	4.0807E-28

Table D.16 Transportation investment versus number of ambulatory services regression summary

Regression Statistics	
Multiple R	0.576537763
R Square	0.332395793
Adjusted R Square	0.324977968
Standard Error	18,590,716.67
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	4,513,554.513	2,202,699.243	2.049101587	0.04336369
Ambulatory services	75,468.64239	11,273.97471	6.694058158	1.8077E-09

Table D.17 Transportation investment versus number of ambulatory services (excluding outliers) regression summary

Regression Statistics	
Multiple R	0.861213574
R Square	0.74168882
Adjusted R Square	0.738753466
Standard Error	8,264,723.495
Observations	90

	Coefficients	Standard Error	t Stat	P-value
Intercept	2,117,272.259	991374.4803	2.135693728	0.03548207
Ambulatory services	87,977.26827	5534.646299	15.89573453	1.3366E-27

Table D.18 Road miles versus number of ambulatory services regression summary

Regression Statistics	
Multiple R	0.885296
R Square	0.783749
Adjusted R Square	0.781346
Standard Error	238.9047
Observations	92

	Coefficients	Standard Error	t Stat	P-value
Intercept	807.231	28.30634	28.51767	7.5036E-47
Ambulatory Services	2.61659	0.144879	18.06051	1.1179E-31

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

Further information about JTRP and its current research program is available at http://www.purdue.edu/jtrp.

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