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Retrospective Analysis of Impacts of Highway Bypass and Widening Projects

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Civil Engineering

by

Sanjeev Bhurtyal
Tribhuvan University
Bachelor of Science in Civil Engineering 2017

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This thesis is approved for recommendation to the Graduate Council.

Sarah Hernandez, Ph.D.
Thesis Director

Suman Mitra, Ph.D.
Committee Member

Micah Hale, Ph.D.
Committee Member

Mervin Jebaraj, M.P.A.
Ex-Officio Member

Abstract

Community members often worry that highway projects may have negative impacts on their local economies. This is typical for highway bypass and widening projects in small cities (population less than 50,000). It is a challenge for planners to balance public concerns of economic decline with desired project outcomes of mobility and safety. Much of this challenge stems from a lack of information on post-project outcomes related to economic and safety impacts of new construction projects. Thus, there is a need for an evidence-based framework to help planners with the decision-making process and better inform the community on potential outcomes. This study performs retrospective analysis of the economic impacts of highway bypass and widening projects in small towns as a means to provide data-based evidence.

Impact assessment is carried out using both a proprietary economic impact assessment tool (IMPLAN) and statistical analysis (regression methods). Based on the IMPLAN and regression analyses, this work develops simplified methodologies to estimate the impacts of highway bypass and widening projects using fewer variables, non-proprietary software, and more accessible methods. Lastly, this study applies a hedonic price model to estimate the effects on property value resulting from the construction of a highway bypass in small cities to fill a critical research gap by introducing spatial models.

The results from this study can be used in public involvement sessions to better inform community members on potential impacts of planned projects. The simplified model presented in this thesis expands the existing impact assessment methodology with its ability to estimate impacts using fewer variables. The spatial hedonic model presented in this study can be used to guide transportation investment decisions made by state transportation agencies. This will assist planners to make an evidence-based decision for proposed highway improvement projects.

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Sabailai Dhanyabad

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Introduction

Highway improvements are usually carried out with a goal of improving the traffic flow and safety of the users. Highway bypass, widening, interchange, and beltways are few examples of highway projects that aim to achieve this goal. The choice of an appropriate project type depends on several factors such as its function, available budget, project location, and existing and projected traffic volume. For example, an interchange (re)design is appropriate to address traffic congestion caused by flow disruptions at an intersection whereas a beltway is suitable to improve traffic flow through an urban area. The selection of the project type also depends on the potential sociodemographic, environment, and economic impacts of the highway project. For example, during environmental impact assessment, if a project is estimated to have an adverse effect on the wildlife, then it could be given low prioritization. Thus, it is necessary to make a rational decision while it comes to the selection of appropriate project type.

The type of highway improvement in small and mid-sized towns are of particular interest since the selection of project type can have large impact on a smaller local economy. Small towns, defined as having population less than 50,000 (U.S. Census, 2020), through which the interstate and state highway pass relies on local and pass-through related business. Thus, the community members often worry that some highway improvement projects might cause business relocation and in turn decline the economy of the city (Helaakoski et al., 1992). It is a challenge for planners and policy makers to balance community concerns and project outcomes. One of the specific challenges for the planner is to decide on constructing a highway bypass or widening the existing main throughfare through the central downtown area ('widening'). A highway bypass diverts traffic from the city and hence improves traffic safety along the main thoroughfare (Cena et al., 2011). Highway widening, on the other hand, improves the capacity of the highway, but might decrease traffic safety due to increased traffic volumes and interactions with parked cars and pedestrians in a downtown area (Gårder, 2004). Thus, to help planners make informed decisions, an evidence-based framework that identifies and quantifies the impacts of highway bypass and widening projects through retrospective analysis is required.

Past studies have carried out several retrospective analyses to estimate the impacts of highway bypass and widening projects. The study ranges from use of proprietary tools such as IMPLAN (Gaustad et al., 2018) to formulation of statistical models from publicly available data sources (Iacono & Levinson, 2009; Thompson, Miller, & Roenker, 2001). Before and after analysis and matched pair analysis are statistical models that have been widely used in the past to measure the impacts of highway projects. EconWorks' Assess My Project, a publicly available web-based tool produced by the Federal Highway Administration (FHWA), also estimates the economic impact of potential projects based on parameters defined by the users (Economic Development Research Group, 2015). This tool relies on approximately 100 case studies to determine the impacts of a proposed highway project.

Impact assessments of highway projects have considered a number of variables including (i) sociodemographic- population (Thompson et al., 2001) and (ii) economic- income, employment, business establishments, property values (Gaustad et al., 2018), and retail sales (Babcock & Davalos, 2010). Property values are also found to be impacted by transportation infrastructure projects (Palmquist, 1982). Property values are influenced by highway accessibility and are a reasonable proxy for measuring economic impacts (Girouard & Blöndal, 2001; Mohring, 1961). Since small towns have limited time series data related to property values, population, etc., cross sectional studies of property values can be used to measure the impact of a highway bypass.

This thesis performs retrospective analysis to estimate impacts of highway bypass and widening projects. Impact assessment is carried out using both proprietary tool (IMPLAN) and statistical analysis. This work develops simplified methodologies using results from IMPLAN and the FHWA's EconWorks Assess My Project tool that estimates the impacts of highway bypass and widening projects using fewer and publicly accessible variables. This study adopts a hedonic price model to estimate the effects on property value resulting from the construction of a highway bypass in a small city to fill a critical research gap by introducing spatial models.

This thesis is organized as follows. Chapter 1 describes the respective economic impact assessment of highway bypass and widening projects using proprietary and statistical tools. This includes a review of methodologies implemented in past studies, a description of the methodology adopted in this study and its implementation in case studies, and a discussion of the results. This chapter also includes the formulation of a simplified methodology using results from IMPLAN and the FHWA's EconWorks Assess My Project tool. Chapter 2 describes the impacts of a highway bypass on residential property values in Sheridan, a small city in Arkansas. This chapter includes models to estimate impacts of highway projects adopted in past studies, the methodology implemented in this study, and discussion of results. The thesis concludes with a discussion of the study limitations and potential future scope of this research.

References

Babcock, M. W., & Davalos, J. A. (2010). Case Studies of the Economic Impact of Highway Bypasses in Kansas. *Journal of the Transportation Research Forum, 43*(1). doi:10.5399/osu/jtrf.43.1.721

Cena, L. G., Keren, N., Li, W., Carriquiry, A. L., Pawlovich, M. D., & Freeman, S. A. (2011). A Bayesian assessment of the effect of highway bypasses in Iowa on crashes and crash rate. *Journal of safety research, 42*(4), 241-252.

Economic Development Research Group. (2015). EconWorks user's guide. In: American Association of State and Highway Transportation Officials (AASHTO).

Gaustad, V. B., Murray, J., Bardaka, E., Findley, D., Smith, R., & Martin, B. J. (2018). Analysis and validation of Historical Transportation Investments.

Girouard, N., & Blöndal, S. (2001). House prices and economic activity.

Gårder, P. E. (2004). The impact of speed and other variables on pedestrian safety in Maine. *Accident Analysis & Prevention, 36*(4), 533-542. doi:https://doi.org/10.1016/S0001-4575(03)00059-9

Helaakoski, R., Mahmassani, H. S., Walton, C. M., Euritt, M. A., Harrison, C. R., & Andersen, S. J. (1992). Economic effects of highway bypasses on business activities in small cities.

Iacono, M., & Levinson, D. (2009). The economic impact of upgrading roads.

Mohring, H. (1961). Land values and the measurement of highway benefits. *Journal of Political Economy, 69*(3), 236-249.

Palmquist, R. B. (1982). Impact of highway improvements on property values in Washington State.

Thompson, E., Miller, J., & Roenker, J. (2001). The impact of a new bypass route on the local economy and quality of life.

United States Census Bureau. (2020). Latest City and Town Population Estimates of the Decade Show Three-Fourths of the Nation's Incorporated Places Have Fewer Than 5,000 People. Retrieved from https: https://www.census.gov/library/stories/2020/05/america-a-nation-of-small-towns.html

Chapter 1

1. Retrospective Economic Impact Assessment of Highway Improvements on Small Towns in Arkansas using Econometric and Input-Output Models

1.1. Abstract

Community members often worry that highway projects may have negative impacts on their local economies. This is typical for highway bypass and widening projects in small and mid-sized cities (population less than 50,000). It is a challenge for planners to balance public concerns of economic decline with desired project outcomes of mobility and safety. Much of this challenge stems from a lack of information on post-project outcomes related to economic and safety impacts of new construction projects. Thus, there is a need for an evidence-based framework to help planners with the decision-making process and better inform the community on potential outcomes. This study performs retrospective analysis of the economic impacts of highway bypass and widening projects in small towns as a means to provide data-based evidence.

Impact assessment is carried out using both a proprietary economic impact assessment tool (IMPLAN) and statistical analysis (regression methods). Based on the IMPLAN and regression analyses, this work develops simplified methodologies to estimate the impacts of highway bypass and widening projects using fewer variables, non-proprietary software, and more accessible methods. The results from the IMPLAN analysis showed that the economic impact of widening projects was higher compared to that of bypass projects in terms of total effects in employment, labor income, gross domestic product (GDP), and business production. The statistical analysis revealed that there was a decrease in Average Daily Traffic (ADT) along the main road and increase in sales tax, employment, and number of establishments with the

bypassed cities. For cities with widening projects, while there was increase in GDP, there was decrease in sales tax, and ADT along the widened road. The simplified methodology developed in this study estimates impacts of highway improvements based on the length of the project (miles) and annual average daily traffic (AADT).

The results from this study can be used in public involvement sessions to better inform community members on potential impacts of planned projects. The simplified model presented in this thesis expands the existing impact assessment methodology with its ability to estimate impacts using fewer variables.

1.2. Introduction

Impact assessment is an important phase of any highway construction/improvement project. Potential impacts of highway projects are estimated before the construction phase via an Environmental Assessment (EA) process. This includes estimation of impacts on land use, business, residents, the environment, and the economy. Based on an EA, recommendations are provided from a set of proposed alternatives. The major aim of the assessment before the construction is to avoid potential negative impacts that could arise from highway construction project. The assessment of impacts after the completion of the project is carried out using retrospective analysis and is rarely performed. A retrospective analysis attempts to attribute sociodemographic and economic impacts arising after the completion of a project to the highway project. It is usually carried out using before and after analysis where the impact indicator variables in consideration are compared before and after the completion of the highway project.

Several software and database tools exist that assess the impacts of highway project. One of the publicly available tools is the FHWA's Highway Economic Requirements System State Version (HERS-ST) that serves as a benefit/cost optimization framework to develop highway investment programs and policies (Federal Highway Administration, 2002). This tool selects economically desirable improvements based on pavement condition, delays, congestion, and collision rates. This tool does not take sociodemographic variables into account. Also in the public domain is FHWA's Strategic Highway Research Program Phase 2 (SHRP2) EconWorks toolkit. EconWorks is a web-based tool that considers sociodemographic and economic variables while estimating project impacts (Economic Development Research Group, 2015). This tool bases impact estimation on approximately 100 case studies of the economic and development impacts of highway projects sourced from around the US. This tool was designed as a web-based platform to which states can contribute case studies over time. Moreover, the 'Assess My Project' interface provides an estimate of the economic impacts for a planned project based on its length, type, setting, traffic volume, and cost. However, the tool is limited in its geographical scope, in particular, for bypass and widening projects for small cities. The tool has a limited numbers of cases from small and mid-sized communities from which to base estimated impacts of projects in these types of communities. Therefore, there is a need to expand the scope of EconWorks by including projects from small and mid-sized communities.

Another impact assessment tool is IMPLAN, an input-output modeling system, that enables the evaluation of the economic impact of specific activities such as construction or operation of public works projects such as highway improvement (French, 2018). This tool estimates direct, indirect, and induced impacts on number of jobs, income, output, and tax arising from the highway project. A limitation of this tool is that it is proprietary and can be cost prohibitive for a state or local planning agency.

This thesis performs retrospective economic analysis for the projects from small and mid-sized (population less than 50,000) (U.S. Census, 2020) communities located in the state of Arkansas. The case studies developed from this project expands the case studies included in the FHWA's EconWorks database and helps to expand its geographical scope. The major objective of this study is to perform a retrospective impact analysis of highway bypass and widening project and then develop a simplified methodology to help planners make informed decision in the future. This objective is accomplished with the completion of the following:

a. Review of state-of-the-practice methods, a literature review of state transportation agency impact studies, academic research articles, and SHRP 2 EconWorks research reports to provide an understanding on the types of data collected and methodologies implemented for the economic, social, and environmental analyses.

b. Selection of an appropriate methodology for impact assessment, based on the literature review and development of a simplified methodology for ease of adoption by state transportation agencies.

c. Implementation of the methodology for five highway projects and two widening projects located in Arkansas.

The results from this study can be used by planners as an evidence-based framework to make an informed decision. The results can also be presented to the community during public involvement sessions to make them aware of the potential impacts of a planned project. The simplified methodology can be used by planners to estimate the impacts of proposed highway bypass or widening project.

1.3. Background

1.3.1. Highway bypass and widening

A highway bypass diverts pass-through traffic around a city's Central Business District (CBD). They are constructed with a motivation to reduce congestion and improve safety along the main thoroughfare in the city's CBD by shifting through traffic to bypass. Bypasses also help in reducing travel time and noise pollution in the city's CBD. However, it may also reduce the retail sales of the city and hence, negatively impact the city's economy. The community members often worry that the highway related business may relocate from the city.

Highway widening is an improvement of the existing highway by increasing the current lane width or/and adding additional lanes. The major motivation of widening is to increase the capacity of the highway to reduce congestion and improve traffic flow. With higher traffic capacity, there may be additional flow of travelers which positively impact the economy of the city. However, with wider roads, there is safety concern for pedestrians. Along with the safety issues, there might not be enough Right of Way (ROW) for widening without demolishing or damaging existing structure. These issues may deter community members from construction of widening.

Both highway improvement types have their respective advantage and disadvantage. It is a challenge for planners to balance public concerns with desired project outcomes for mobility and safety. Hence, there is a need for an evidence-based framework that can assist planners to make informed decision based on the retrospective analysis of highway projects.

1.3.2. Impacts of highway improvement projects

Past studies have shown mixed impacts of highway improvement projects on sociodemographic and economic impact indicators. Kockelman, Srinivasan, and Handy (2001) reported both positive and negative impacts of highway bypasses on sales and number of establishments of four industrial sectors: retail trade, gas station, food services and service industries. The study showed that the impacts were mostly negative for small cities while there were mixed for medium cities. Gaustad et al. (2018) found that beltways have greater impact on business development, bypasses have positive impacts on residential development, and widening projects have mixed impacts with both business and residential development. The study by Iacono and Levinson (2009) did not find significant effects of highway improvements on property values. Similarly, Souleyrette, Plazak, Albrecht, and Pettit (2009) did not find any positive or negative impact of highway bypasses on the local economy. A quantitative study by Babcock and Davalos (2004) concluded that there was no statistically significant impact of highway improvement on total employment of the town, however a qualitative study revealed that the business owners experienced a decline in employment and sales of travel-related businesses.

The impacts from past studies mentioned above vary with the size of town (small and medium), type of improvement (bypass and widening), impact indicators (population, property value, employment, and business establishments) and industries (retail, services, manufacturing). There is a need for a comprehensive study that examines the impacts based on above mentioned factors.

1.3.3. Methods of impact assessment of highway projects

Several tools and statistical models have been used to assess the impacts of highway improvement projects on a number of variables including (i) demographic – population, (ii) economic – income, employment, business establishments, property value and retail sales. IMPLAN is one of the most widely used models for economic impact assessment. For example, Gaustad et al. (2018) used proprietary tools, IMPLAN and Transportation Economic Development Impact System (TREDIS), to estimate the net direct and indirect economic impacts of bypass, widening and beltway projects. However, IMPLAN is a proprietary tool and there is a cost associated with its use which can be substantial depending on the scale of analysis desired.

Matched pair analysis is one of the most widely used statistical analysis models. For example, Souleyrette et al. (2009) conducted matched pair analysis to compare the trend in number of business establishments and total employment before and after the construction of bypass compared to that of control city. Matched pair analysis was also adopted by Babcock and Davalos (2004) to assess the impacts of highway bypass. The impacts were measured in terms of employment and retail sales. In the study by Thompson et al. (2001), matched pair analysis was used to assess the impacts of highway improvements in terms of employment, population, and retail sales.

One of the challenges with matched pair analysis is the requirement for time series data or at least cross-sectional data before and after the construction of highway improvement projects. However, for small and medium cities, data is often limited to specific years, e.g., US Census estimates. Similarly, some of the data are only available for large geographical regions such as county or state, and not the city level.

Another challenge is the selection of control cities. Control cities are similar to project cities in terms of sociodemographic and economic characteristics but do not have highway improvement projects. Babcock and Davalos (2004) selected the control for their study based on the location of project city, population, employment, and tax data. Thompson et al. (2001) used five key economic measures: distance to the nearest large town, population, employment in mining, employment in manufacturing, and retail capture to find control counties. In the study by Anderson et al. (1992), the selection of a control city was based on the highway district, proximity to a larger city, economic base, magnitude and trend of retail sales, population, and highway network characteristics. Although it is challenging to find the perfect match for a project city, the goal is to find the control city that most closely matches the study city.

The current literature on retrospective impact analysis of highway improvement projects is limited in its scope in the following keyways.

1. The statistical impact analysis methodology requires huge data which are limited for small and mid-sized towns.
2. Proprietary impact assessment tools require usage fee that could be substantial for large scale analysis.

This study fills this critical gap by creating a simplified methodology that is easy to implement as it uses simple regression models, publicly available data, and scales to small and mid-sized cities.

1.4. Methodology

The main objective of this study is to perform retrospective economic analysis and develop and evidence-based framework to assist planners in decision making process. The case studies for this analysis were selected based on guidelines developed for the FHWA's EconWorks toolkit. Economic impact assessment for each of the case study sites was carried out using IMPLAN and matched pair analysis. To perform a matched pairs analysis for each of the selected case study sites, four control cities were identified based on similar sociodemographic, economic, and highway characteristics. Using the results from IMPLAN and EconWorks tools, a simplified methodology was developed. The methodology adopted in this thesis is divided into: (Section 1.4.1) selection of case studies, (1.4.2) selection of control cities, (1.4.3) economic impacts evaluation, and (1.4.4) development of simplified methodology.

1.4.1. Selection of Case Studies

The case studies for the analysis were selected as per guidelines developed by the FHWA's EconWorks' Case Study Design and Development guide. The criteria to be met are as follows:

a. Completed for at least five years.
b. Economic development was a key motivation for the project.
c. Must have a highway component.
d. Fit into one of ten project categories such as bypass, widening, access road, beltway.
e. Contact information of a person knowledgeable about the project.

f. Possess all required project data (project, location, and impact indicators)

1.4.2. Selection of Control Cities

Matched pair analysis requires a set of control cities for each target project cities. Control cities share similar sociodemographic and geographic characteristics as the study sites. As per the literature review, control cities are selected in the ratio of 4:1(Grimes & Schulz, 2005; Hennekens & Mayrent, 1987). Each target city is assigned to four control cities. To determine appropriate control cities, the following characteristics were considered: population, population density, per capita income, and median house value is calculated. All 500 cities in Arkansas were ranked after calculating the percent difference between the study site and each candidate site for each of the abovementioned variables. Due to unavailability of time series data on per capita income and median house value at city level, the average difference is calculated based on year 2000 data. After examining the top ranked candidate cities (e.g., minimum difference between the target/study city and the candidate city), a manual examination was made for the following criteria:

a. *Project setting:* The candidate city is discarded if the project setting (rural or urban), based on the Core Based Statistical Area, does not match with the target city.

b. *Location:* The candidate city is discarded if the city's proximity interstate is dissimilar to that the proximity of the target city to the interstate.

c. *Highway Characteristics:* The candidate city is next considered based on the roadway functional class (e.g., interstate, arterial, local road, etc.). For example, if the target city study segment is classified as a state highway, priority is given to candidate control cities that also contain state highways. However, if the functional class doesn't match, cities are compared based on number of lanes and type of median present for the study segment. For example, if the target segment is a state highway, but the candidate control city is a major collector, then number of lanes and type of median are compared. If both are four lane divided highways, then the candidate city is still considered as a control city.

d. *Data Availability:* As most of the time series data is limited at the city level, priority is given to the control city that has data on sales and use tax collected at city level.

1.4.3. Economic impacts evaluation

Several economic impact assessment tools are available as discussed in section (1.3.3) of this thesis. This study adopted two different methodologies for retrospective analysis. The first method is IMPLAN, a proprietary tool, and the second method is matched pair analysis, a statistical approach.

1.4.3.1. IMPLAN Analysis

The IMPLAN impact analysis for highway projects estimates the impacts of construction expenditures. IMPLAN uses an input-output model to measure the effects of three types of impacts: direct, indirect, and induced (French, 2018). Direct impact consists of employment and purchase of goods in the area resulting from the construction activity. Indirect impact consists of goods and services purchased for the construction activities. Induced impact results from the purchase of goods or services by the employees involved in direct and indirect activities (Demski, 2020). These impacts are measures in terms of employment, labor income, value added, output, and tax generated. Employment and labor income are the number of jobs and income of labor in the county supported by construction activities, respectively. Value added is a measure of the contribution to GDP generated by the construction activities. Output is the total value of a business' production and is the measure of the value added plus intermediate expenditures. Tax generated includes the taxes from employment compensation, production and imports, households, and corporations (Demski, 2020).

For this study, the IMPLAN model was based on the start and completion date of the project at each study site, and the cost of the project. The data on start and completion date were obtained from the documents provided by ARDOT. Cost data was also obtained from ARDOT and included the cost for each phase of construction (preliminary engineering, right of way, utilities, construction, construction engineering) for each job numbers of the project. Job numbers without a work order date were assigned the same date as the earliest work order date of the same project. If the work order date was after September (during the fourth quarter of the year), the work was listed in the next calendar year.

1.4.3.2. Statistical Models

Econometric models are used to relate the impacts of highway project on sociodemographic and economic variables. Matched pair analysis is most widely used methodology to assess the impacts of highway projects (Thompson, Comlavi, & Dimmit, 2011) (**Eq 1.1)**.

$$D(Y_t) = B * D(X_{t-1}) + C * Z_{t-1} + D_t + \in_t \quad \textbf{(1.1)}$$

where,

$D(Y_t)$	=	The difference between the dependent variable for the target city and average value of the dependent variable from the control cities
$D(X_{t-1})$	=	Vector of difference between a set of lagged independent variables for the target cities and average value of their counterpart from the control cities
B	=	Vector of regression coefficients for $D(X_t)$

D_t = 1 for years after the construction/improvement; 0 for before the construction/improvement

Z_{t-1} = Vector of lagged independent variables from the target cities, $X \cap Z = \emptyset$

$\in_t$ = Error term

The goal of this study was to isolate the impacts of highway improvement projects on the economic indicators. For this, conditional marginal effects at means (MEM) (Eq 1.2) (Bartus, 2005) and conditional semi-elasticity **(Eq 1.3)** of the dummy variables were calculated.

$$MEM = \frac{\partial \hat{Y}}{\partial D} | X = \bar{X}, Z = \bar{Z} \quad \textbf{(1.2)}$$

Conditional Semi-Elasticity = $[\frac{\partial \hat{Y}}{\partial D} | (X = \bar{X}, Z = \bar{Z}) \frac{D=1}{\hat{Y}|(X=\bar{X}, Z=\bar{Z})}]$ x 100 **(1.3)**

where,

$\hat{Y}$ = Predicted value of the dependent variable

$\bar{X}, Z =$ Values of other independent variables fixed at their mean

The semi-elasticity indicates the percentage change in the predicted value of the dependent variable when the dummy value changes discretely from zero to 1 conditional on other regressors remaining fixed at their mean values. By running regressions involving a broad set of variables, and alternative specifications of the model and taking the weighted average of these results, we obtain average semi elasticity (**Eq 1.4**) and average p-values (**Eq 1.5**).

$$Average\ Semi\ Elasticity = E = \left[\frac{\sum_{i=1}^{N} \frac{\overline{R_\iota^2}(n-k)_i}{VIF_i} MEM_i \frac{1}{\hat{Y}|(X = \bar{X}, Z = \bar{Z})}}{\sum_{i=1}^{N} \frac{\overline{R_\iota^2}(n-k)_i}{VIF_i}}\right] \text{x100} \quad \textbf{(1.4)}$$

$$Average\ P - values = \left[\frac{\sum_{i=1}^{N} \frac{\overline{R_\iota^2}(n-k)_i}{VIF_i} P_i}{\sum_{i=1}^{N} \frac{\overline{R_\iota^2}(n-k)_i}{VIF_i}}\right] \quad \textbf{(1.5)}$$

where,

N	=	Number of chosen regressions
$\overline{R_i}^2$	=	Adjusted R-square for regression i
(n-k)	=	Measure of degree of freedom
VIF_i	=	Average variance inflation factor regression i

Since, the semi-elasticity calculations only hold the values of the regressor constant at their mean values, the elasticity number represents by how much the difference between the target and the control city changes without effectively putting any restrictions on the control city part of the dependent variable. Therefore, it is necessary to look at the relative movement of the control city and target city component of the dependent variable. Assume $\bar{Y}, \overline{Y^{TR}}, \overline{Y^{CR}}$ and E are mean difference, level mean for target city, level mean for control city dependent variables and the calculated average conditional semi elasticity, respectively. There are four general cases:

Case 1: $\bar{Y} < 0, E < 0$. There will be four subcases:

Subcase 1: If $\overline{Y^{TR}}$ decreases and $\overline{Y^{CR}}$ decreases between before and after construction, $\overline{Y^{TR}}$ falls, compared to $\overline{Y^{CR}}$ at most by the magnitude of the elasticity number E.

Subcase 2: If $\overline{Y^{TR}}$ increases and $\overline{Y^{CR}}$ increases between before and after construction, $\overline{Y^{TR}}$ rises, compared to $\overline{Y^{CR}}$ at least by the magnitude of the elasticity number E.

Subcase 3: If $\overline{Y^{TR}}$ increases and $\overline{Y^{CR}}$ decreases between before and after construction, $\overline{Y^{TR}}$ rises, compared to $\overline{Y^{CR}}$ at least by the magnitude of the elasticity number E.

Subcase 4: If $\overline{Y^{TR}}$ decreases and $\overline{Y^{CR}}$ increases between before and after construction, $\overline{Y^{TR}}$ falls, compared to $\overline{Y^{CR}}$ at most by the magnitude of the elasticity number E.

Case 2: $\bar{Y} < 0, E > 0$. There will be four subcases:

Subcase 1: If $\overline{Y^{TR}}$ decreases and $\overline{Y^{CR}}$ decreases between before and after construction, $\overline{Y^{TR}}$ falls, compared to $\overline{Y^{CR}}$ at least by the magnitude of the elasticity number E.

Subcase 2: If $\overline{Y^{TR}}$ increases and $\overline{Y^{CR}}$ increases between before and after construction, $\overline{Y^{TR}}$ rises, compared to $\overline{Y^{CR}}$ at most by the magnitude of the elasticity number E.

Subcase 3: If $\overline{Y^{TR}}$ decreases and $\overline{Y^{CR}}$ increases between before and after construction, $\overline{Y^{TR}}$ falls, compared to $\overline{Y^{CR}}$ at most by the magnitude of the elasticity number E.

Subcase 4: If $\overline{Y^{TR}}$ increases and $\overline{Y^{CR}}$ decreases between before and after construction, $\overline{Y^{TR}}$ rises, compared to $\overline{Y^{CR}}$ at least by the magnitude of the elasticity number E.

Case 3: $\bar{Y} > 0, E > 0$. There will be four subcases:

Subcase 1: If $\overline{Y^{TR}}$ increases and $\overline{Y^{CR}}$ increases between before and after construction, $\overline{Y^{TR}}$ rises, compared to $\overline{Y^{CR}}$ at least by the magnitude of the elasticity number E.

Subcase 2: If $\overline{Y^{TR}}$ increases and $\overline{Y^{CR}}$ decreases between before and after construction, $\overline{Y^{TR}}$ rises, compared to $\overline{Y^{CR}}$ at least by the magnitude of the elasticity number E.

Subcase 3: If $\overline{Y^{TR}}$ decreases and $\overline{Y^{CR}}$ increases between before and after construction, $\overline{Y^{TR}}$ falls, compared to $\overline{Y^{CR}}$ at most by the magnitude of the elasticity number E.

Subcase 4: If $\overline{Y^{TR}}$ decreases and $\overline{Y^{CR}}$ decreases between before and after construction, $\overline{Y^{TR}}$ falls, compared to $\overline{Y^{CR}}$ at most by the magnitude of the elasticity number E.

Case 4: $\bar{Y} > 0, E < 0$. There will be four subcases:

Subcase 1: If $\overline{Y^{TR}}$ increases and $\overline{Y^{CR}}$ increases between before and after construction, $\overline{Y^{TR}}$ rises, compared to $\overline{Y^{CR}}$ at most by the magnitude of the elasticity number E.

Subcase 2: If $\overline{Y^{TR}}$ increases and $\overline{Y^{CR}}$ decreases between before and after construction, $\overline{Y^{TR}}$ rises, compared to $\overline{Y^{CR}}$ at least by the magnitude of the elasticity number E.

Subcase 3: If $\overline{Y^{TR}}$ decreases and $\overline{Y^{CR}}$ increases between before and after construction, $\overline{Y^{TR}}$ falls, compared to $\overline{Y^{CR}}$ at most by the magnitude of the elasticity number E.

Subcase 4: If $\overline{Y^{TR}}$ decreases and $\overline{Y^{CR}}$ decreases between before and after construction, $\overline{Y^{TR}}$ falls, compared to $\overline{Y^{CR}}$ at most by the magnitude of the elasticity number E.

Following these cases, direction, and magnitude of change of the dependent variables with respect to control city is determined.

1.4.4. Development of Simplified Methodology

The FHWA EconWorks database has limited case studies from small and mid-sized communities which limits its use in estimating impacts of many projects in Arkansas. IMPLAN is a proprietary software and is not publicly available. Statistical models require significant data which can be cumbersome to obtain for small and mid-sized communities and may require propriety software packages to estimate. Therefore, there is a need for a simplified methodology that could estimate the impacts of highway project using basic data such as length and annual average daily traffic and not require a state transportation agency to purchase or use expensive software. The proposed simplified methodology aligns closely with the method used in EconWorks. The following steps are applied to develop the simplified model:

a. Data from the existing EconWorks case studies of bypass and widening projects from all regions are gathered. These case studies are supplemented with the additional projects under consideration.
b. Setting factors for distressed and non-distressed economic conditions are calculated using the median jobs per AADT (**Eq 1.6**) and mean jobs per mile (**Eq 1.7**) of the case studies from step (a). Regions with regional unemployment rate greater than the national unemployment rate are

classified as distressed regions whereas regions with regional unemployment rate lower than the national unemployment rate are classified as non-distressed regions.

$$Setting\ Factor_{type,setting,median} = \frac{Median\ jobs\ per\ AADT\ of\ distressed\ cases}{Median\ jobs\ per\ AADT\ of\ all\ cases} \quad \textbf{(1.6)}$$

$$Setting\ Factor_{type,setting,mean} = \frac{Mean\ jobs\ per\ mile\ of\ distressed\ cases}{Mean\ jobs\ per\ mile\ of\ all\ cases} \quad \textbf{(1.7)}$$

Where,

type = [bypass, widening]

setting = [distressed, non-distressed

c. The number of jobs is estimated using project length, AADT, and the estimated setting factors obtained from step (b) (**Eq 1.8**).

$$Number\ of\ Jobs = Length \times Mean\ jobs\ per\ mile \times Setting\ Factor_{type,setting,mean} + AADT \times Median\ jobs\ per\ AADT \times Setting\ Factor_{type,setting,median} \quad \textbf{(1.8)}$$

d. Calibration factors for each project type and setting are calculated. The calibration factors aim to minimize the average percentage difference between estimated number of jobs obtained from step (c) and the number of jobs estimated from IMPLAN.

e. Number of jobs for project cities is estimated using the calibration factors (**Eq 1.9**).

$$Number\ of\ Jobs = Calibrated\ Factor_{setting,type} \times \left[Length \times Mean\ jobs\ per\ mile \times Setting\ Factor_{type,setting,mean} + AADT \times Median\ jobs\ per\ AADT \times Setting\ Factor_{type,setting,median}\right] \quad \textbf{(1.9)}$$

1.5. Case Study

1.5.1. Selection of Case Studies

Case study locations used in this study were recommended by the ARDOT Research Subcommittee assembled for this thesis (**Figure 1-1**). The five-highway bypass and two highway widening case were selected from seven different cities of Arkansas. All selected projects cities met requirements mentioned in methodology section (**Table 1-1**). Sheridan was an exception as it had not been completed for at least five years at the time of the study.

Table 1-1 Summary of EconWorks Requirements by Project Study Site

Project	**Completion Year**	**Five Years**	**Economic Development as a Key Motivation**	**Highway**	**Project Category**	**Contact Information**
	Requirement (Req.) 1		***Req. 2***	***Req. 3***	***Req. 4***	***Req. 5***
Grady	2009	Yes	Congestion Mitigation	Highway 65	Bypass	Available
Hardy	2005	Yes	Congestion Mitigation	Highway 412	Bypass	Available
Sheridan	2014	No	Congestion Mitigation	Highway 167	Bypass	Available
Vilonia	2012	Yes	Congestion Mitigation	Highway 64	Bypass	Available
Flippin	2008	Yes	Congestion Mitigation	Highway 412	Bypass	Available
Gould	2011	Yes	Congestion Mitigation	Highway 65	Widening	Available
Siloam Springs	2012	Yes	Congestion Mitigation	Highway 412	Widening	Available

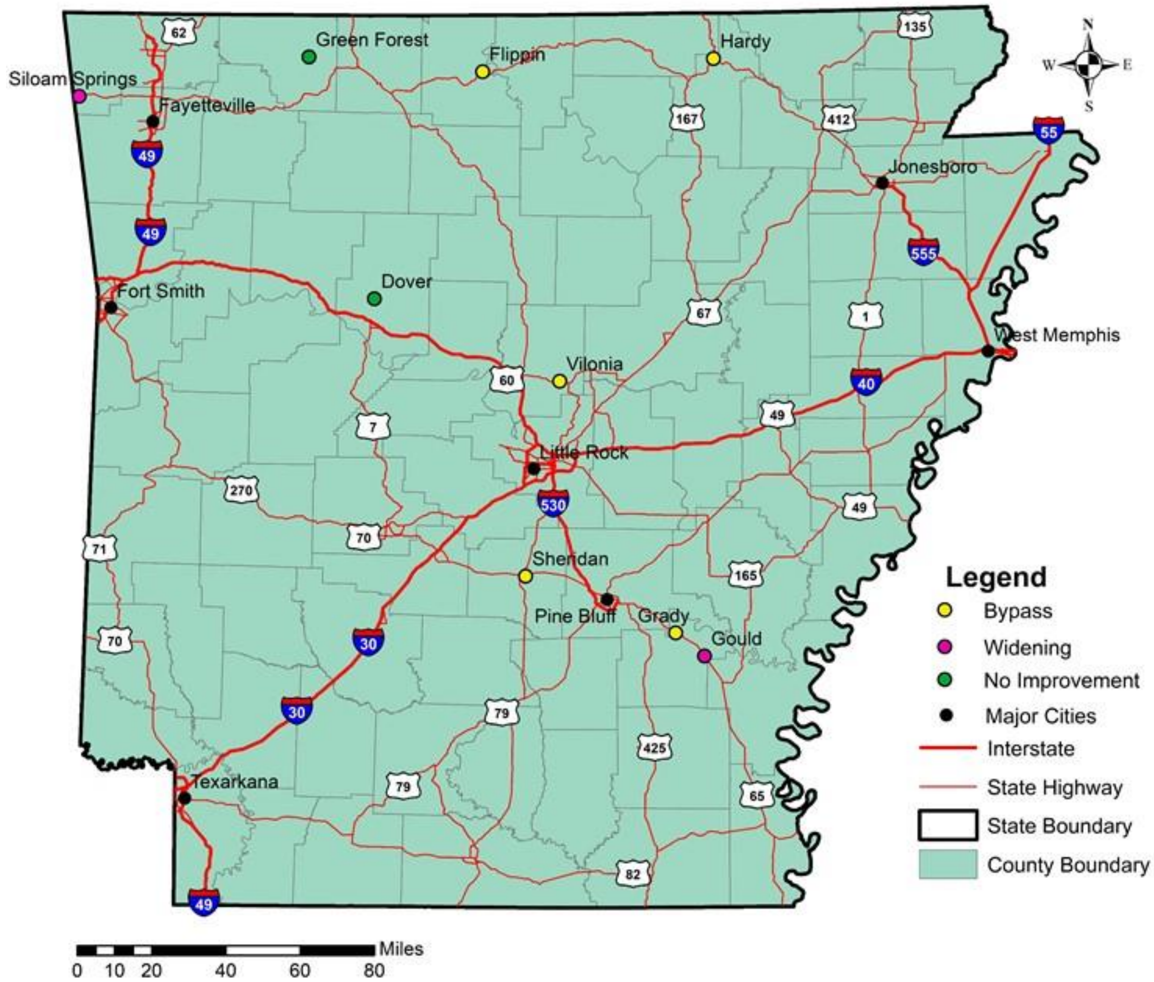

Figure 1-1 Location of Project Cities

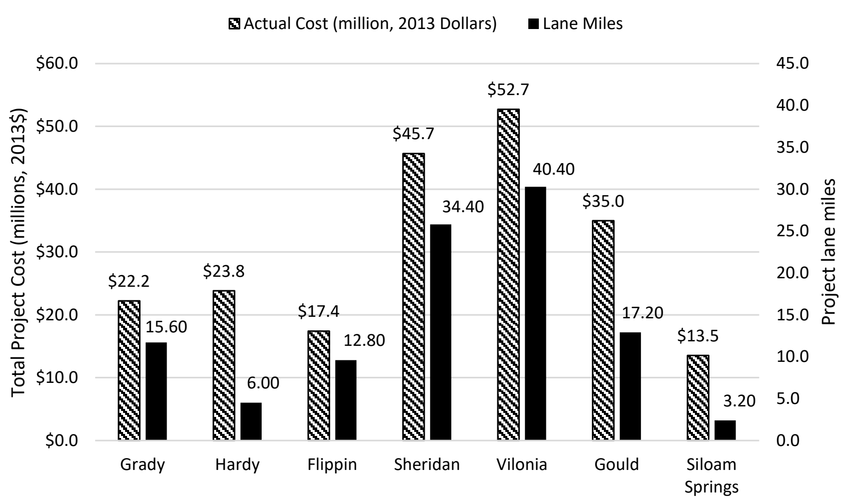

Figure 1-2 Project Characteristics

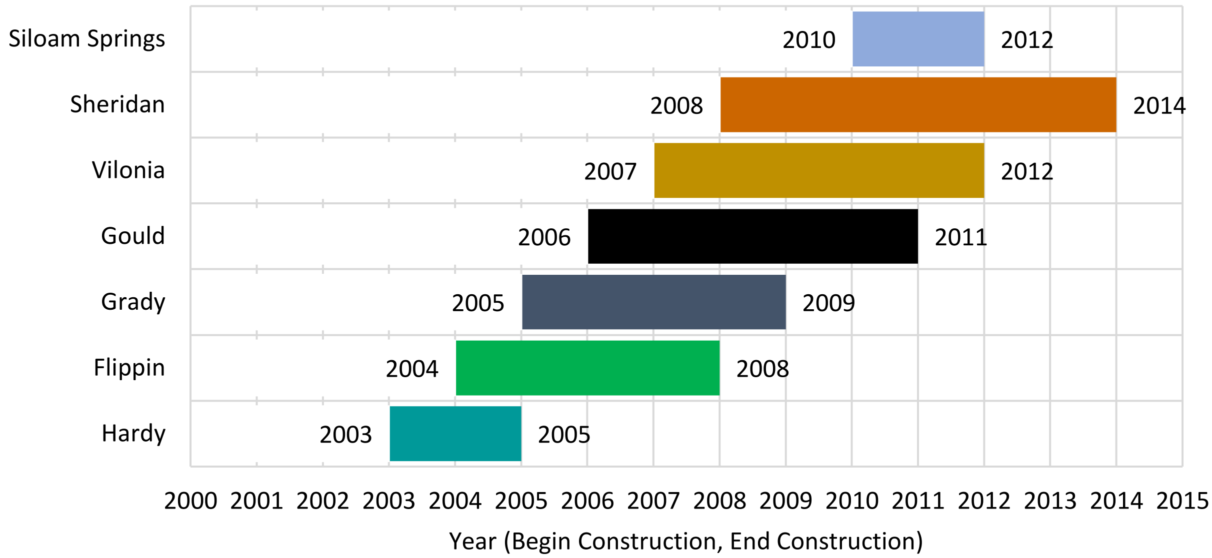

Figure 1-3 Project Construction Timeline

1.5.2. Data and Variable Specifications

As mentioned in section (1.3.3), retrospective analysis is usually carried out to assess the impacts on several impact indicators. Data on sociodemographic indicators was collected for population density which defines the number of people residing per unit sq. miles of the city (**Table 1-2**). Data on economic indicators were collected for number of employees at city, number of establishments at, GDP per capita for agriculture, construction, manufacturing, private services, retail trade, real estate, and transportation utilities industries, home price, sales tax, and value of property transfer variables (**Table 1-2**). GDP for each industry is the value of the goods and services produced by that industry in the city. Home price is the value of single-family homes in the city. This data was obtained from Zillow. Sales tax is the total tax obtained from sale of goods and services in the city. The data was obtained from Arkansas Department of Finance and Administration. Value of property transfer is the total sale amount of all the transfer of commercial properties in the city. The data is publicly available from assessor's office, however for this study, the processed data was obtained from DataScout. Number of employees and establishments at city level, and GDP per capita at city level were augmented from county level data obtained from BLS using **Eq 1.10**. All monetary values were converted to 2018 dollars using a consumer price index as shown in **Eq 1.11**.

$$\text{Augmented city data} = \frac{\text{City Population}}{\text{County Population}} * \text{County Data} \quad \textbf{(1.10)}$$

$$\text{Data on 2018\$} = \frac{\text{Consumer price index in year 2018}}{\text{Consumer price index in year 'i'}} * \text{Data in year 'i'} \quad \textbf{(1.11)}$$

Table 1-2 Data Description

Variable Name	Data Elements	Geography	Data Source
ADT Main	ADT in the Main Road	Highway Section	ARDOT (Arkansas Department of Transportation)
Employees City	Number of employees	City	Augmented from county level data from BLS (U.S. Bureau of Labor Statistics)
Establishments City	Number of establishments	City	
GDPPC AFFH	Gross Domestic Product Per Capita for Agriculture, Forestry, Fishing and Hunting	City	Augmented from county level data from Bureau of Economic Analysis (Bureau of Economic Analysis)
GDPPC ALL	GDP per capita of all sectors of the economy		
GDPPC Construction	GDP per capita of construction industry		
GDPPC Manufacturing	GDP per capita of manufacturing industry		
GDPPC Private Services	GDP per capita of private services industry		
GDPPC Retail Trade	GDP per capita of retail trade industry		
GDPPC RRL	GDP per capita of real estate, rental, and leasing industry		
GDPPC TU	GDP per capita of transportation and utilities industry		
Home Price	Zillow House Value Index for single-family residence		

Table 1-2 Data Description (Cont.)

Variable Name	Data Elements	Geography	Data Source
Population Density	Number of people residing per unit sq. miles	City	American Community Survey (United States Census Bureau), Decennial Census (United States Census Bureau), Arkansas Economic Development Institute (Arkansas Economic Development Institute)
Sales Tax	Tax from sales of goods and services		Arkansas DFA (Arkansas Department of Finance and Administration)
Transfers	Total Sale Amount of all the Transfer of Commercial Properties		Arkansas DFA (Arkansas Department of Finance and Administration) and DataScout (DataScout)

1.5.3. Selection of Control Cities:

As per the literature review, matched cities were selected in the ratio of 4:1. Each of the project cities had four matched (control) cities. There are more than 500 cities in Arkansas, so it was necessary to list the cities in order of similarity. For this, the average of percentage difference in population, population density, per capita income, and median house value were calculated. Due to unavailability of time series data on per capita income and median house value at city level, the average difference was calculated based on year 2000 data. The cities were then ordered in ascending order based on the average difference. The cities were then manually selected based on the criteria mentioned in section (1.4.2) (**Table 1-3**).

Table 1-3 Control Cities

Project City	Matched City	County
Grady	Wilton	Little River
	Taylor	Columbia
	Bonanza	Sebastian
	Amity	Clark
Hardy	Viola	Fulton
	Summit	Marion
	Oppelo	Conway
	Ravenden	Lawrence
Sheridan	Greenwood	Sebastian
	Dardanelle	Yell
	Magnolia	Columbia
	Ashdown	Little River
Vilonia	Pea Ridge	Benton
	Perryville	Perry
	Elkins	Washington
	Gravette	Benton
Flippin	Cave City	Sharp
	Mammoth Spring	Fulton
	Salem	Fulton
	Glenwood	Pike
Gould	Lincoln	Washington
	Gentry	Benton
	Huntington	Sebastian
	East Camden	Ouachita
Siloam Springs	Batesville	Independence
	Searcy	White
	El Dorado	Union
	Paragould	Greene
Dover	Decatur	Benton
	Gravette	Benton
	Foreman	Little River
	Ola	Yell
Green Forest	Hamburg	Ashley
	Murfreesboro	Pike
	Rector	Clay
	Stamps	Lafayette

1.6. Results

Impact assessment was carried out for the case studies selected (see section 1.5.1). The assessment included analysis using IMPLAN and matched pair analysis.

1.6.1. Economic impacts evaluation

1.6.1.1. <u>IMPLAN Analysis</u>

IMPLAN analysis was carried out to estimate direct, indirect, and induced effects in employment, labor income, value added and output. The economic impacts were assessed at the county level and in cases where the project was a part of more than one county, a combination of counties was included in the model. These three types of effects are summed up to obtain total effects of the project (**Figure 1-4**).

Among the projects included in the study, the Gould widening project had the highest per capita total effects in each of the impact categories (employment, labor income, value added, output, and tax generated), whereas the Siloam Springs project had the lowest per capita total effects.

Overall, the average per capita total employment of the bypass projects (15 jobs per 1,000 people or 0.015 jobs per capita) was higher than the average total employment of the widening projects (13 jobs per thousand people). The average per capita total labor income of the bypass projects ($549) was higher than the average for the widening projects ($526). On average, total value added of the bypass projects ($767) was higher compared to the widening projects ($719). The average total output of bypass projects ($2,123) was higher than the average total output of widening projects ($1,910). Average total tax generated by bypass projects ($55) was higher than the widening projects ($52).

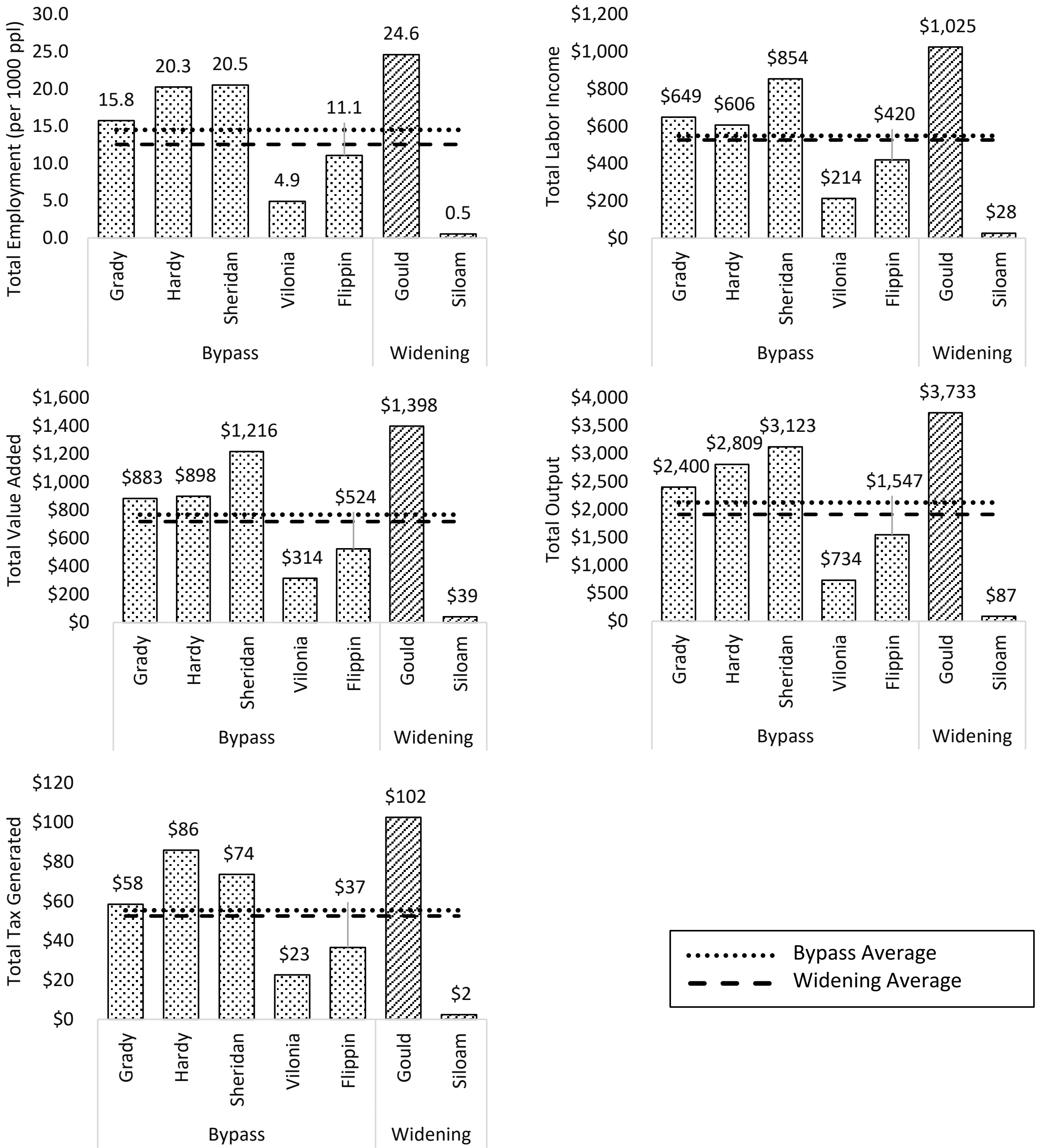

Figure 1-4 Summary of IMPLAN Per Capita Results for Total Effects

Considering the varied sizes of each project, e.g., Vilonia had a 41.6 lane-mile bypass while Siloam Springs had a 3.2 lane-mile widening project, more equitable comparisons among projects may be observed by examining impacts on a per lane-mile basis for bypass and widening projects (**Figure *1-5***). Among the projects in the study, the Hardy bypass had the highest per capita total impacts per lane-mile in employment, labor income, value added, output, and tax generated. Vilonia bypass had the lowest per capita total impacts per lane-mile in each of the impact categories. The impact of bypass projects was higher compared to that of widening in terms of per capita total effects per lane-mile. The bypass projects had higher per capita total employment, total labor income, total output, and total tax generated per lane-mile added compared to the bypass projects.

Overall, the average per capita total employment per lane-mile of the bypass projects (1.2 jobs per 1000 people) was higher than the average per capita total employment per lane-mile of the widening projects (0.8 jobs per 1000 people). The average per capita total labor income per lane-mile of the bypass projects ($41) was higher than the average for the widening projects ($34). On average, per capita total value added per lane-mile of the bypass projects ($58) was higher compared to the widening projects ($47). The average per capita total output per lane-mile of bypass project ($170) was higher than the average total output per lane-mile of widening projects ($122). The average per capita tax generated per mile by bypass ($5) was higher than that by widening project ($3).

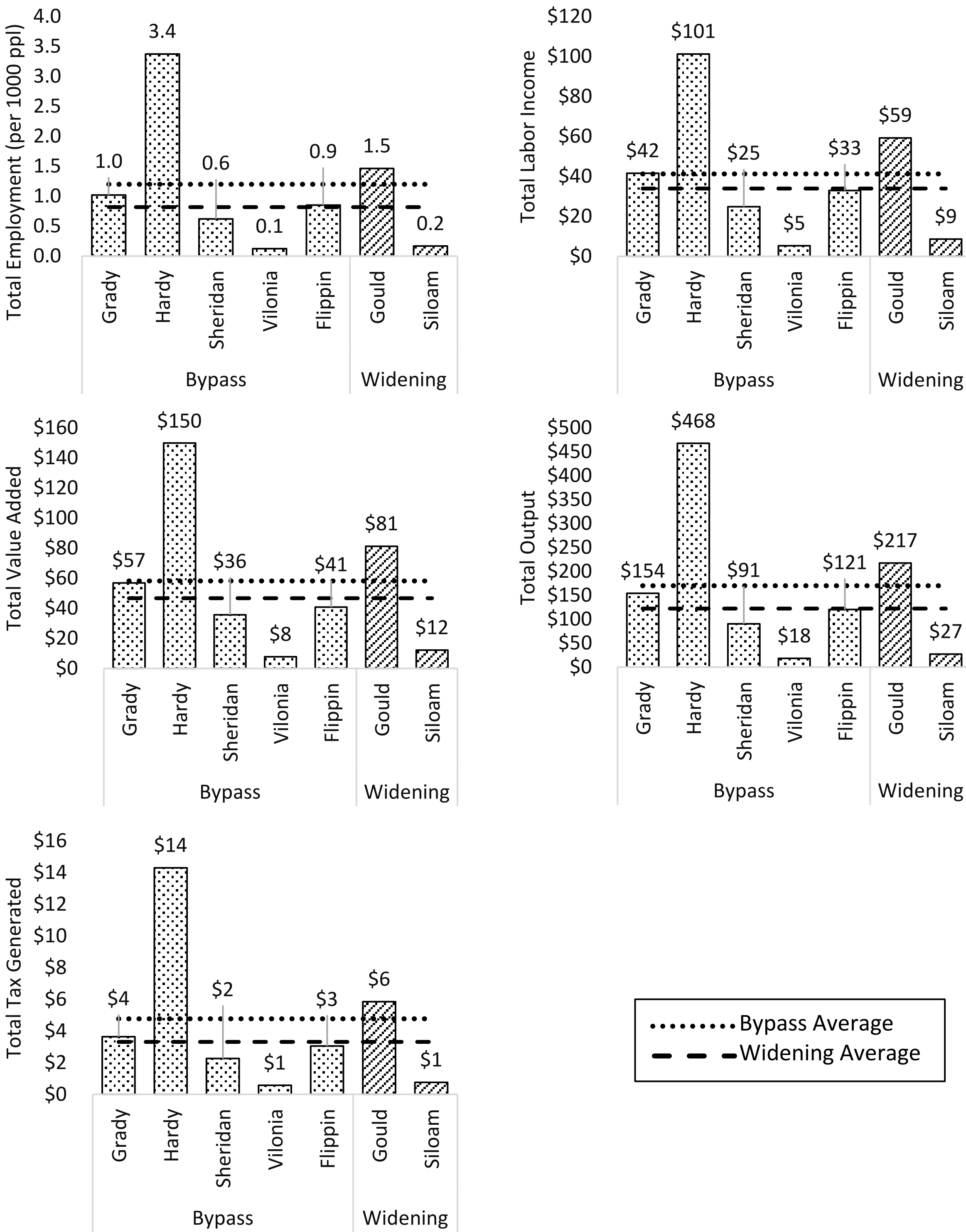

Figure 1-5 Summary of Per Capita IMPLAN Results for Total Impacts per Lane-Mile

1.6.1.2. Econometric Model

Matched pair analysis was carried out for seven project cities with economic indicators mentioned in **Table 1-2** as dependent variables. Results from the analysis indicated that the bypass and widening projects had a significant positive macroeconomic effect on study sites, boosting various types of macroeconomic activities **(Table 1-4 and Table 1-5).**

For bypass cities (**Table 1-4**), increases relative to control cities were found to be significant for per capita GDP for all industries, and specifically for real estate and transportation/utilities ranging from 0.4% for Sheridan to 297.4% for Flippin, sales tax ranging from 22.3% for Hardy to 77.3% for Flippin, city employees ranging from 0.1% for Sheridan to 188.9% for Flippin and city establishments ranging from 0.1% for Sheridan to 66.1% for Vilonia. Decreases relative to control cities were found for ADT along the main road. The lowest decrease of 0.1% was observed in Sheridan whereas the largest decrease of 543.0% was observed in Flippin. There were mixed results for per capita GDP for private services, agriculture, construction, manufacturing, retail, and home prices.

For widening study sites **(Table 1-5)**, increases relative to control cities were found to be significant for per capita GDP for all industries, and specifically for retail, private services, agriculture, and sales tax and ADT. Decreases relative to control cities were found for per capita GDP of manufacturing. There were mixed results for per capita GDP for real estate and transportation/utilities, construction, population density, city employees, city establishment, and home prices.

Table 1-4 Results of Pre and Post Construction Relative to Control Cities for Bypass Study Sites

	Percentage (%) Change				
Measure	**Grady**	**Hardy**	**Sheridan**	**Vilonia**	**Flippin**
ADT Main	(-) ≤ 17.8	(-) ≤ 152.6	(-) ≤ 0.10**	(-) ≤ 197.6	(-) ≤ 543.0
Employees City	(+) ≥ 54.8**	(+) ≥ 172.8	(+) ≥ 0.1	-	(+) ≤ 188.9**
Establishments City	(+) ≥ 85.8*	(+) ≥ 38.4	(+) ≥ 0.1	(+) ≥ 66.1	(+) ≤ 29.8
GDPPC AFFH	(-) ≤ 109.8	(-) ≥ 1.4	(+) ≥ 1.3	-	(-) ≤ 32.4*
GDPPC All	(+) ≥ 25.2	(+) ≤ 151.6	(+) ≥ 29.2	(+) ≥ 6.16*	(+) ≥ 134.7
GDPPC Construction	(+) ≥ 105.8	(+) ≥ 1.6	(-) ≤ 0.5*	(-) ≥ 159.7**	(-) ≤ 123.4
GDPPC Manufacturing	(-) ≤ 21.1	(+) ≥ 0.6	(+) ≥ 0.8	(+) ≥ 0.8**	(+) ≥ 71.0
GDPPC Private services	(+) ≤ 5.6**	(+) ≤ 65.1	(-) ≤ 0.1	-	(+) ≥ 170.6*
GDPPC Retail trade	(-) ≤ 17.2	(+) ≥ 136.6	(+) ≥ 0.2	(+) ≥ 61.5	(+) ≤ 0.2*
GDPPC RRL	(+) ≤ 47.3	(+) ≤ 115.6	(+) ≥ 0.4	(+) ≤ 56.6	(+) ≥ 297.4
GDPPC TU	(+) ≥ 34.2	-	(+) ≥ 0.1**	-	(+) ≥ 142.3
Home Price	(+) ≥ 38.3	(+) ≥ 0.8	(-) ≥ 0.2	(+) ≥ 34.8	-
Population Density	(+) ≥ 503.4*	(+) ≤ 0.3	(+) ≤ 0.0	-	(+) ≥ 24.4*
Sales Tax	(-) ≤ 180.0*	(+) ≤ 22.3	(+) ≤ 2.1*	(+) ≥ 91.0*	(+) ≥ 77.3

1. Cells can be interpreted as: "(-)≤ 152.6" can be read as "the percentage decrease is less than or equal to 152.6%" and "(+) ≥ 172.8" can be read as "the percentage increase is more than or equal to 172.8%".
2. *Not statistically significant. **Statistically significant at 10% level of significance
3. Unless otherwise noted, all the estimation results are significant at 5% level of significance.
4. All the variables are represented as the difference between the control and study cities for the same year.
5. '- 'cells indicate the unavailability of data for the analysis of the respective variable.

Table 1-5 Results of Pre and Post Construction Relative to Control Cities for Bypass Study Sites

	Percentage (%) Change	
Measure	**Gould**	**Siloam Springs**
ADT Main	(+) ≤ 191.1**	(+) ≤ 37.5
Employees City	(-) ≤ 41.1	(+) ≥ 95.1
Establishments City	(-) ≤ 43.4	(+) ≥ 40.5
GDPPC AFFH	(+) ≥ 71.6	(+) ≥ 50.3
GDPPC All	(+) ≥ 15.1	(+) ≤ 100.2**
GDPPC Construction	(+) ≥ 53.6	(-) ≤ 47.3
GDPPC Manufacturing	(-) ≤ 41.4	(-) ≤ 51.1
GDPPC Private services	(+) ≤ 11.3	(+) ≥ 28.2
GDPPC Retail trade	(+) ≥ 25.3	(+) ≥ 156.7**
GDPPC RRL	(+) ≤ 55.8	(-) ≤ 212.8**
GDPPC TU	(+) ≥ 27.3**	(-) ≤ 101.1
Home Price	(+) ≥ 13.6	(-) ≥ 34.3
Population Density	(-) ≤ 116.0	(+) ≥ 69.6
Sales Tax	(+) ≤ 28.5	(+) ≤ 170.4**

1. Cells can be interpreted as: "(-)≤ 152.6" can be read as "the percentage decrease is less than or equal to 152.6%" and "(+) ≥ 172.8" can be read as "the percentage increase is more than or equal to 172.8%".
2. *Not statistically significant. **Statistically significant at 10% level of significance
3. Unless otherwise noted, all the estimation results are significant at 5% level of significance.
4. All the variables are represented as the difference between the control and study cities for the same year.
5. '- 'cells indicate the unavailability of data for the analysis of the respective variable.

1.6.2. Development of Simplified Methodology

Following the steps mentioned in section (1.4.4), a simplified model was developed that estimates the number of jobs based on the type, setting, length, and annual average daily traffic of the highway (**Table 1-6**). The simplified methodology developed in this thesis estimates impact of highway improvement. The model takes length of the project and annual average daily traffic as inputs and estimates number of jobs attributed to the project. The equations mimic the data requirements and format of the methods used in EconWorks.

Table 1-6 Simplified Model Equations for Estimation of Direct Jobs

Improvement Type	Setting	Formula ($Number\ of\ Jobs =$)
Bypass	Non-Distressed	$0.047 \times (Length \times 118 \times 1.00 + AADT \times 0.04 \times 1.35)$
	Distressed	$0.464 \times (Length \times 118 \times 1.54 + AADT \times 0.04 \times 0.92)$
Widening	Non-Distressed	$0.008 \times (Length \times 158 \times 0.63 + AADT \times 0.04 \times 0.31)$
	Distressed	$0.003 \times (Length \times 158 \times 3.22 + AADT \times 0.04 \times 2.27)$

The estimated number of jobs for project cities using the simplified approach was compared to the results obtained from IMPLAN analysis. Since universal calibration factors were applied in the model, there was still minor discrepancy between the IMPLAN, and simplified model estimated number of jobs. The results showed the increased accuracy in estimation using the simplified model (Average Absolute Percent Error, AAPE, of 54%) compared to the EconWorks Assess My Project tool (AAPE of 161%) (**Figure 1-6**). The average absolute percentage difference of simplified model was about one third of the EconWorks Assess My Project tool.

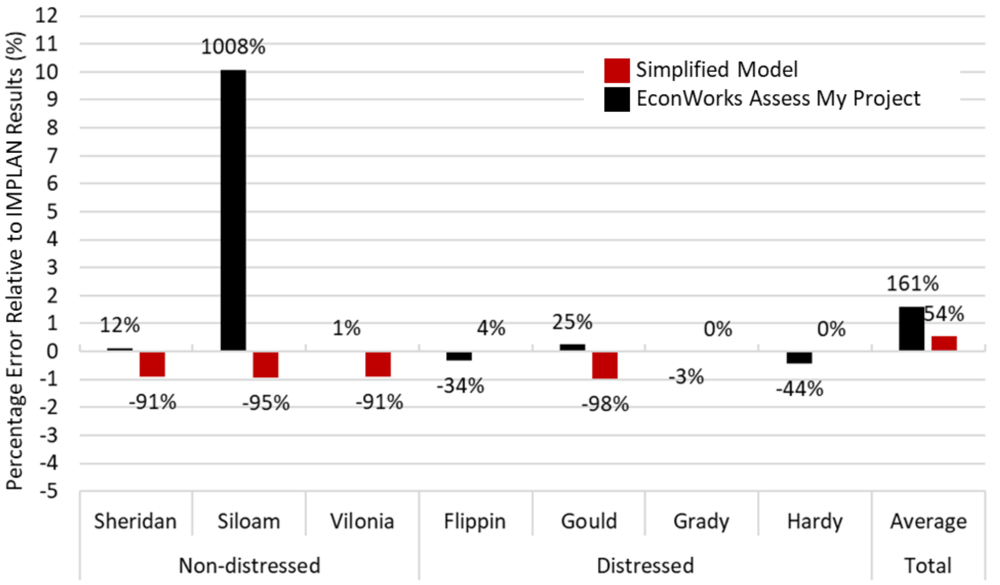

Figure 1-6 Comparison between Simplified Model and Assess My Project Tool Relative to the Results of the IMPLAN Analysis

1.7. Discussion

1.7.1. Economic impacts evaluation

1.7.1.1. <u>IMPLAN Analysis</u>

The results from IMPLAN analysis showed that the Hardy bypass had the highest per lane-mile total effects in each of the impact categories. This can be attributed to Hardy having the relatively higher influx of tourist in the city. The analysis also revealed that, on average, bypass projects had higher impacts per lane-mile compared to widening projects. Bypass projects had higher employment, labor income, output, tax, and value added per lane-mile.

1.7.1.2. <u>Econometric Model</u>

Matched pair analysis revealed for bypass cities, compared to control cities, that there was decrease in ADT in main street. This was an expected outcome since the bypass is constructed with the goal of diverting traffic away from the main street. Souleyrette et al. (2009) obtained similar results in their study of four bypass cities. All the cities in the study by Souleyrette et al. (2009) experienced drop in the average daily traffic after the completion of the bypass. While there was decrease in ADT, the bypass cities experienced an increase in the number of employees, number of establishments, sales tax and per capita GDP for real estate and transportation/utilities industries. This result is consistent with the findings from the study by Gaustad et al. (2018) which concluded that residents in communities with the bypass projects tended to perceive that the bypasses positively influenced economic activity and spurred business growth (Gaustad et al., 2018).

Results from matched pair analysis for widening cities showed that there was increase in average daily traffic attributed to widening projects. This increase in traffic can be attributed to the induced travel resulting from changes in land use development patterns as observed by

Noland & Lem (2002). In addition to daily traffic, there was increase in sales tax, and per capita GDP for retail, private services, and agriculture industries. This can be attributed to the increased economic activity from induced traffic resulting from the widening project. However, there was a decrease in per capita GDP for manufacturing industries. There were mixed results for other impact indicators such as population density, home price, per capita GDP for transportation/utilities, real estate, and construction industries, number of employment and number of establishments.

1.7.2. Development of simplified methodology:

Using the equations in EconWorks, which derive from projects outside the scope and scale of the Arkansas case studies, the error in estimating number of jobs was 139% on average. With the simplified methodology, this error was reduced to 53% on average, representing a reasonable planning level estimate. The results showed that the simplified methodology can be used in conjunction with EconWorks' Assess My Project Tool. While the simplified model had better estimation for bypasses in distressed regions and widening projects in non-distressed regions, the EconWorks Assess My Project tool had better estimation for bypasses in non-distressed regions and widening projects in distressed regions. Hence, the appropriate model can be used based on the economic setting of the location of the highway improvement project. The methodology alleviates data collection and reliance on expensive software while providing a method that is accurate for Arkansas's socioeconomic and project characteristics.

1.8. Conclusion

Impact assessment is an important phase of any highway construction/improvement project. Retrospective analysis assesses the impact of the project after its completion by comparing the economic indicators before and after the project's construction. This analysis can help planners make informed decisions when selecting project alternatives, e.g., choosing between bypass and widening options. This study develops and applies a methodology to perform retrospective analysis and applies the method to five highway bypass and two highway widening projects located in seven cities in Arkansas. The goal of this study is to prepare an evidence-based framework to assist planners in decision making and community engagement. The simplified methodology developed in this study can be used by planners to estimate the impacts of widening and bypass project without the need to perform sometimes costly and time-consuming statistical analyses.

The retrospective impact analysis was carried out using proprietary software, IMPLAN, and a statistical model, matched pair analysis. The results from IMPLAN showed that impact of bypass projects was higher compared to that of widening in terms of total effects in employment, labor income, total value added, total output, and tax generated. The results from matched pair analysis were mixed. For cities with bypass projects, there was decrease in ADT and increase in sales tax, employment, and number of establishments. For cities with widening projects, while there was increase in GDP, there was decrease in sales tax, and ADT. The simplified methodology developed in this study estimate impacts of highway improvement using length of the project and annual average daily traffic. This methodology alleviates data collection and reliance on expensive software.

The major contribution of this study was the impact assessment of highway improvement projects for small and mid-sized cities which helps to expand the FHWA's EconWorks database in scope. By adding Arkansas case studies to the FHWA EconWorks database, this work also helps to expand the geographical coverage of the EconWorks database. In these ways, the EconWorks tools have broader applicability and accuracy across the US and by project type.

The current limitation of this methodology lies in its scope. It is applicable to only bypass and widening projects and cannot be used for other project types such as beltways or interchanges. Furthermore, it was prepared for small and medium cities and is not applicable for larger cities. In future, additional models can be prepared that target variety of project types and geographical region. In addition, the impact results from Assess My Project tool and simplified model were compared to impact results from IMPLAN. Since IMPLAN is also an estimation model, future work will look for additional sources such as surveys or census data to compare the models to empirical data set.

1.9. Acknowledgement

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1.10. References

Anderson, S. J., Harrison, R., Euritt, M. A., Mahmassani, H. S., Walton, M. C., & Helaakoski, R. (1992). Economic Impacts of Highway Bypasses, Report 1247-3F. *Center for Transportation Research, University of Texas, Austin, Texas*.

Arkansas Deparmtent of Transportation. (2019). ARDOT Traffic Count Maps. Retrieved from https://www.arkansashighways.com/System_Info_and_Research/traffic_info/traffic_map.aspx#

Arkansas Department of Finance and Administration. Tax Collection Data. Retrieved from https://www.dfa.arkansas.gov/excise-tax/sales-and-use-tax/local-sales-and-use-tax-information/tax-collection-data

Arkansas Department of Transportation. Average Daily Traffic. Retrieved from https://www.arcgis.com/apps/webappviewer/index.html?id=8deb09579210490bafb97bd03c3c0792

Arkansas Economic Development Institute. Population Estimates and Projections. Retrieved from http://arstatedatacenter.youraedi.com/population-estimates-projections/

Babcock, M. W., & Davalos, J. A. (2004). Case Studies Of The Economic Impact Of Highway Bypasses In Kansas. http://ageconsearch.umn.edu/record/208230/files/2004_EconomicImpact_paper.pdf

Bartus, T. (2005). Estimation of marginal effects using margeff. *The Stata Journal*, *5*(3), 309-329.

Bureau of Economic Analysis. GDP US Bureau of Economic Analysis (BEA). Retrieved from https://www.bea.gov/data/gdp

DataScout. DataScout, LLC. Retrieved from www.datascoutllc.com

Demski, J. (2020). Understanding IMPLAN: Direct, Indirect, and Induced Effects. Retrieved from https://blog.implan.com/understanding-implan-effects

Economic Development Research Group. (2015). EconWorks user's guide. In: American Association of State and Highway Transportation Officials (AASHTO).

Federal Highway Administration. (2002). FHWA Rolls Out New HERS-ST Software. Retrieved from https://www.fhwa.dot.gov/publications/focus/02jul/hersst.cfm

French, T. (2018). What is IMPLAN? Retrieved from https://blog.implan.com/what-is-implan

Gaustad, V. B., Murray, J., Bardaka, E., Findley, D., Smith, R., & Martin, B. J. (2018). Analysis and validation of Historical Transportation Investments.

Grimes, D. A., & Schulz, K. F. (2005). Compared to what? Finding controls for case-control studies. *The Lancet, 365*(9468), 1429-1433. doi:https://doi.org/10.1016/S0140-6736(05)66379-9

Hennekens, C. H., & Mayrent, S. L. (1987). Epidemiology in medicine.

Iacono, M., & Levinson, D. (2009). The economic impact of upgrading roads.

Kockelman, K. M., Srinivasan, S., & Handy, S. L. (2001). Economic Effects of Highway Relief Routes on Small and Medium-Size Communities. An Econometric Analysis.

Noland, R. B., & Lem, L. L. (2002). A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK. *Transportation Research Part D: Transport and Environment, 7*(1), 1-26. doi:https://doi.org/10.1016/S1361-9209(01)00009-8

Souleyrette, R. R., Plazak, D. J., Albrecht, C. P., & Pettit, R. J. (2009). Managing Decisions Regarding Rural Expressway Routes and Associated Highway Bypasses.

Thompson, E., Comlavi, K., & Dimmit, M. (2011). Model for Predicting the Impact Upon Economic Development Resulting from Highway Improvement Projects.

Thompson, E., Miller, J., & Roenker, J. (2001). The impact of a new bypass route on the local economy and quality of life.

U.S. Bureau of Labor Statistics. Quarterly Census of Employment and Wages. Retrieved from https://www.bea.gov/data/gdp

United States Census Bureau. Decennial Census by Decades. Retrieved from https://www.census.gov/programs-surveys/decennial-census/decade.2000.html

United States Census Bureau. Explore Census Data. Retrieved from https://data.census.gov/cedsci/

United States Census Bureau. (2020). Latest City and Town Population Estimates of the Decade Show Three-Fourths of the Nation's Incorporated Places Have Fewer Than 5,000 People. Retrieved from https://www.census.gov/library/stories/2020/05/america-a-nation-of-small-towns.html

Chapter 2

2. Impacts of a Highway Bypass on Residential Property Values in a Small City in Arkansas

2.1. Abstract

Highway bypasses divert through traffic around a city's core in part to improve safety and reduce congestion. In small cities, highway related business along the bypassed highway might lose business, contributing to declining economic conditions in the city. There is a need to measure this negative externality to identify mitigating solutions. An established proxy for economic condition is residential property values. Statistical approaches, e.g., ordinary least squares (OLS), are commonly applied to measure the impact of highway bypasses on property values but fail to capture critical spatial relationships inherent in property values. In this study, we adopt a hedonic pricing model with considerations for spatial dependencies to estimate the effect of a highway bypass on residential property values in a small city (population less than 50,000) in Arkansas. Neighborhood, network accessibility and disamenity variables are considered. The result of a log-log estimation of a spatial autoregressive model with autoregressive disturbances (SARAR) model on 1,751 properties shows that the residential properties closer to the bypass have lower land value compared to properties closer to bypassed highway, e.g., land value per acre of properties closer to the bypass decreases by 40% or by $15,850. This implies that the bypassed highway provides greater accessibility compared to bypass. A log-log OLS model underestimates the impact of the bypass on property values, e.g., land value closer to the bypass decreases by 24%. Estimates of highway bypass impacts can be used to guide transportation investment decisions made by state transportation agencies.

2.2. Introduction

The purpose of a highway bypass is to divert pass-through traffic around a city's Central Business District (CBD). Some motivations for a highway bypass are to reduce congestion and improve safety along the main thoroughfare in the city's CBD by shifting through traffic to the bypass. Historically, bypass projects achieve congestion mitigation and safety goals (Cena et al., 2011) but may contribute to unintended economic impacts for the local cities. For example, highway bypass projects may draw away retail, restaurant, and travel service (fuel, rest stops) businesses from the CBD to the bypass and can have negative effects on business volume (Helaakoski et al., 1992). This effect may be countered by increased local business growth and/or tourism induced by reduced speeds, noise, accidents, and congestion on the main thoroughfare (e.g., the bypassed highway).

Overall, the effects on the local economy resulting from highway bypass construction are dependent on a number of factors including the size of the city, underlying economic conditions, and sociodemographic characteristics (Andersen, Mahmassani, Walton, Euritt, & Harrison, 1992). In larger towns with highway bypasses, businesses may continue to thrive because of the broader diversity and lesser dependency on traffic from the bypass route (Comer & Finchum, 2001). However, in small cities, highway related business along the main thoroughfare such as gas stations, fast food restaurants, and auto repair shops might lose business, contributing to the economic decline of the city (Comer & Finchum, 2001). Moreover, in small and mid-sized towns (population of less than 50,000) (U.S. Census, 2020), business relocations from the CBD to the bypass may adversely affect the quality of life for residents by increasing travel distances to local services (grocery, auto repair, banks). If business along the main thoroughfare close or relocate because of the new bypass, then residential property values may decrease around the thoroughfare.

Due to the possibility of adverse impacts on residents, when state Departments of Transportation (DOTs) present planning studies for bypass projects to communities, residents may be reluctant to approve bypass construction in favor of widening-on-existing (i.e., add capacity to the existing thoroughfare). A challenge for state DOTs is to ensure that selection of a bypass over widening-on-existing will not produce negative externalities, or at least that those externalities are minor and/or short lived. Furthermore, estimation of impacts relative to distance from the bypass can be used by state DOTs to design the bypass alignment, when possible, to reduce negative impacts. For instance, the location of the bypass could be chosen with the goal of minimizing negative impacts on property values.

An added challenge for state DOTs is the unavailability of data at the local level. Local level data is needed to estimate what impacts may be realized should a decision to construct a bypass be made. While time series socioeconomic data is available at the census block level in larger metropolitan areas, it may be aggregated to the county level and/or census tracts that are larger than the city itself for small cities. Thus, methods to compare economic trends in property values such as time series or matched pairs approaches, for example, are limited for small towns when city-level analyses are needed.

Property values have been shown to be influenced by highway accessibility and are a reasonable proxy for measuring economic impacts (Girouard & Blöndal, 2001; Mohring, 1961). Since small towns have limited time series data, cross sectional studies of property values can be used to measure the impact of a highway bypass. Analyses using traditional regression methods, e.g., Ordinary Least Squares (OLS), do not consider the significant spatial effects inherent to property values in the context of highway bypass accessibility. For example, neighboring properties would have similar value relative to property located elsewhere in the same city. Thus, using OLS may lead to misinterpretation of estimated coefficients and goodness of fit measures, ultimately misguiding investment and policy decisions made in response to such models (Anselin & Griffith, 1988). The presence of spatial effects warrants uses of more complex models. Since the property values usually have spatial dependency, and are influenced by structural, transportation, and neighborhood variables, a hedonic pricing model that considers spatial effects provides more accurate estimation compared to OLS.

This paper uses hedonic pricing techniques with considerations for spatial effects to estimate the impacts of highway bypass projects on the local economy in small towns. This addresses a methodological gap in the economic impact literature regarding capturing spatial effects present in property value data.

The remainder of the paper is organized as follows. A review of prior research related to impact estimation for highway bypass projects is presented followed by an overview of hedonic and spatial modeling methodologies. The results section presents a case study of the proposed approach including a description of the data collected for model development. The discussion section highlights the findings of the case study in terms of the impacts of the presence (distance) of the bypass and other explanatory variables on property value. The final section provides the conclusions and limitations of the paper along with the potential future work.

2.3. Literature Review

2.3.1. Impact assessment for highway capacity expansion projects

Impact assessments of bypass projects consider a number of variables including (i) demographic- population (Gaustad et al., 2018; Rogers & Marshment, 1997), income (Gaustad et al., 2018) and (ii) economic- employment (Babcock & Davalos, 2010; Fricker & Mills, 2009; Gaustad et al., 2018; Souleyrette et al., 2009), business establishments (Babcock & Davalos, 2010; Fricker & Mills, 2009; Gaustad et al., 2018; Souleyrette et al., 2009), property value (Gaustad et al., 2018), property sale value (Iacono & Levinson, 2009). Impacts on property values are of particular interest as they tend to be most impacted by transportation infrastructure projects (Debrezion, Pels, & Rietveld, 2007; Hess & Almeida, 2007; Palmquist, 1982).

Impacts on property values vary according to a number of factors, most importantly the type of project: highway expansion (Siethoff & Kockelman, 2002), beltway (Langley, 1976), bypass (Elias, Hakkert, Penina, & Shiftan, 2006; Gaustad et al., 2018; Iacono & Levinson, 2009), rail (Gatzlaff & Smith, 1993; Ko & Cao, 2010), and toll roads (Boarnet & Chalermpong, 2001). Variables such as median house value, assessed property value, and property sale value are used to capture the impact of highway projects on property value. Of the project types mentioned, bypass projects divert traffic from the CBD potentially causing more direct impacts on residential and commercial properties than other project types. Adding to the complexity of bypass projects, both positive and negative impacts of bypasses have been cited: positive impacts include reduction in heavy truck traffic and negative impacts include increases in sprawl and low density commercial and residential development (Collins & Weisbrod, 2000).

Similarly, for property values, bypass projects have mixed effects that have been shown to be in part related to city size (as measured by population) (Gaustad et al., 2018). Small (population less than 50,000) (U.S. Census, 2020), rural towns may be more prone to negative economic impacts of bypass construction due to a fewer number of businesses within the CBD. If these businesses were to relocate from the CBD to the bypass, local residents may have to travel farther for services, negatively impacting quality of life (Comer & Finchum). This reduced accessibility may be reflected in the property value (Mohring, 1961).

2.3.2. Models to estimate impacts of highway capacity expansion projects

Current economic impact studies for bypass projects are limited in two critical areas: (i) the data used/available for the study and (ii) consideration of distance and other spatial effects within the model specification. In terms of data, a bypass in a small town can range from 2.3 to 10.9 miles in length (Seggerman & Williams, 2014). This may span the incorporated area of the city, traverse an entire county, or extend across multiple counties. This makes selecting an appropriate spatial extent for a study challenging as data may not be publicly available for study variables at all necessary levels of geography, e.g., CBD, city, or county. Ideally, the study area and necessary data should be selected to segregate the impacts of the bypass from those of the surrounding (unaffected) areas. Among the existing studies on the economic impacts of highway bypasses, Gaustad et al. (2018) and Elias et al. (2006) evaluate impacts at the city-level, whereas Iacono and Levinson (2009) is based at the county level considering every highway improvement within the county. The latter study is unable to deduce the impact of bypass from those of other projects or general economic trends in the county.

Considering the ways in which accessibility plays into project impacts, models to estimate impacts should allow the possibility of representing spatial effects. Existing economic impact models aimed at assessing property values include descriptive longitudinal analysis (Elias et al., 2006), multiple sales techniques (Boarnet & Chalermpong, 2001; Gatzlaff & Smith, 1993; Langley, 1976), annual average percentage change (Gaustad et al., 2018), and hedonic price techniques (Boarnet & Chalermpong, 2001; Gatzlaff & Smith, 1993; Iacono & Levinson, 2009; Mikelbank, 2004; Palmquist, 1982). Briefly, hedonic pricing techniques evaluate the value of goods or services based on internal attributes and external factors. The hedonic price can be interpreted as the added or reduced value of goods or services based on these attributes and factors. In the case of property value, hedonic models estimate property value as a function of structural attributes (lot improvement value considering number of bedrooms, etc.), transportation accessibility, and neighborhood characteristics, making it an apt choice for studying the impacts of bypass projects.

While it is assumed that property values maintain a spatial relationship with a highway bypass through measures of accessibility, studies have yet to explore this association using models that specifically account for spatial effects. Spatial models include spatial lag, spatial error, or spatial autoregressive models with autoregressive disturbances (SARAR) models. Mitra and Saphores (2016), and Concas (2013) used SARAR in spatial hedonic modeling to study housing price relative to transportation accessibility. Estimations without consideration of spatial correlation and dependencies lead to biased estimates. However, in terms of spatial effects, the accessibility (distance) of a newly constructed bypass relative to the existing main thoroughfare has not been studied in the literature and therefore it is not clear if distance from the bypass to the property has a positive or negative impact on property values. Thus, in this study we use a hedonic pricing model with considerations for spatial dependencies to estimate the effect of a highway bypass on residential property values in a small city. Uniquely, the accessibility of the bypass relative to the main thoroughfare is taken into consideration to assess and compare the impact on residential property values from both the thoroughfare and the bypass.

2.3.3. Hedonic model specification

For hedonic pricing techniques, data is required in various categories: structural attributes, transportation accessibility, neighborhood characteristics, and disamenity factors. Structural attributes include property characteristics such as lot size, floor area, number of bedrooms, bathrooms, multi/single level, building age, and any other factors that may influence the price of the property (Sirmans, Macpherson, & Zietz, 2005). Some of these data are generally publicly available from the county assessor's office.

Transportation accessibility for residential properties is measured as the distance from the property to a facility of interest. The most common measure of accessibility is network distance from the property centroid to the nearest highway, bus stop, and railway station. The network distance to schools, healthcare facilities, shopping centers and employment areas should also be considered when measuring accessibility (Ko & Cao, 2010; Mitra & Saphores, 2016). Location data are generally publicly available from state GIS offices.

Neighborhood characteristics includes demographic and socio-economic data such as median household income, crime rate, SAT score, and percent of minority population (Boarnet & Chalermpong, 2001; Ko & Cao, 2010; Mikelbank, 2004). Data at the smallest geographic level is desirable. However, it is not always possible to get data at the property level or even block level. The data are generally available from US Census Bureau (United States Census Bureau, 2020), Bureau of Justice Statistics (Bureau of Justice Statistics, 2020), and National Center for Education Statistics (National Center for Education Statistics, 2020).

Although the bypass may positively impact many accessibility measures by decreasing travel times (Burress, 1996), higher speed transportation infrastructure may have negative impacts in noise and air pollution (Langley, 1976). A disamenity variable is generally used to capture noise and air pollution. This can be measured by creating a spatial buffer around railway tracks, bus terminals, highways, and wholesale markets defined by an assumed threshold and determining if property falls within that buffer and thus contribute to noise and air pollution (Mitra & Saphores, 2016).

2.4. Background and Data

2.4.1. Study Area

The hedonic pricing model is applied to a small rural community in the state of Arkansas to estimate the effect of a highway bypass on residential property values. The City of Sheridan is in Grant county and located south of Little Rock in central Arkansas (**Figure 2-1**).With an area of 12.14 sq. mi. and population of 4,857, it is relatively smaller than neighboring cities like Pine Bluff (population of 43,840), Little Rock (population of 198,135), and Hot Springs (population of 36,969) (U.S. Census Bureau, 2019). An 8.6-mile non-limited access highway bypass was constructed between 2008 and 2014. The motivation of the bypass was to reduce congestion in Sheridan by diverting through traffic to the bypass.

Sheridan is selected for this case study for two key reasons. First, Sheridan represents a small, rural community which is currently not well represented in publicly available economic impact assessment toolkits like FHWA's EconWorks. EconWorks (Economic Development Research Group, 2015) is used by state transportation agencies to understand the range of economic impacts of highway projects. It is built on a set of 100 case studies throughout the U.S., and abroad, representing various regions, project scopes, and site characteristics like economic conditions. For smaller towns like Sheridan, limited case studies of similar small projects within the southeast region of the U.S. are available in EconWorks and therefore the Arkansas Department of Transportation (ARDOT) must exercise caution when using EconWorks to measure the impacts of highway capacity expansion projects in many towns in Arkansas. Furthermore, the Sheridan bypass has been opened for five years. EconWorks recommends that highway projects completed for less than five years may not yet have realized all potential impacts (Economic Development Research Group, 2018). Second, although Sheridan is a small, rural community, it has a relatively high number of census block groups (8 block groups) compared to other cities in Arkansas that have had a bypass constructed. For example, Hardy with a population of 648 is divided into 5 groups, Vilonia with a population of 4,491 has 3 groups, and Grady with a population of 288 has 1 group. Division into many census block groups provide necessary variation in neighborhood attributes for the hedonic price model.

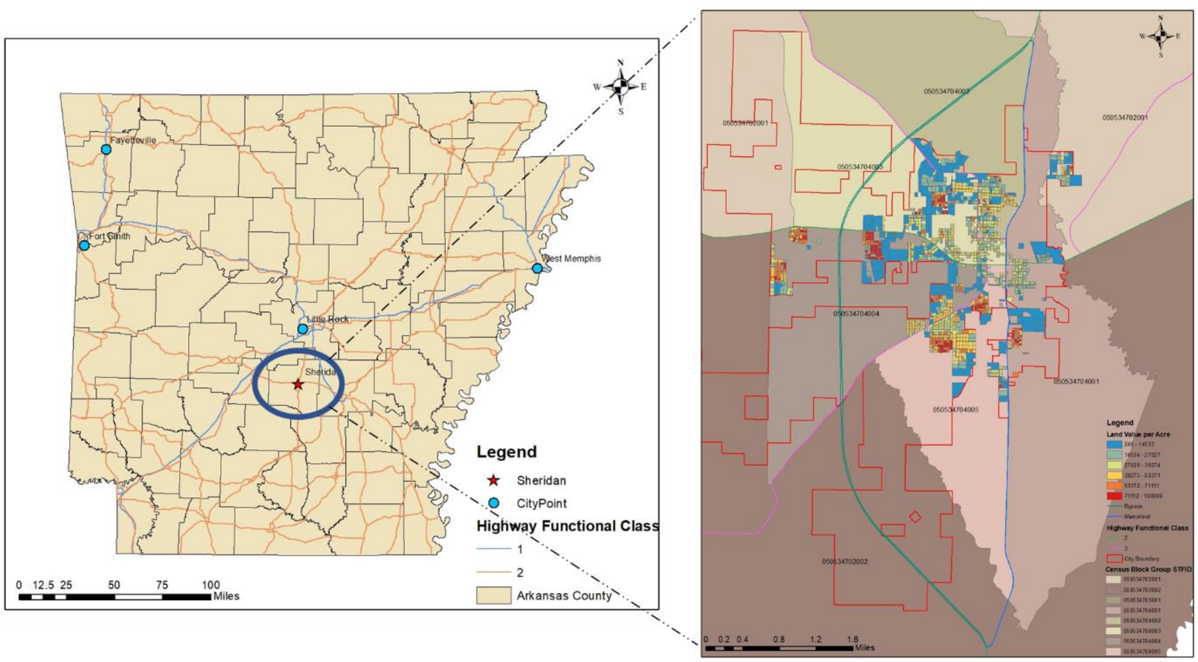

Figure 2-1 Location of Sheridan in Arkansas

2.4.2. Data and Variable Specification for Study Site

Data for model estimation including land values, population density, income, employment rate and distance to the highway bypass, school, airport, parks, health related facilities, and CBD is gathered from publicly available sources (**Table 2-1**). The data from the

Arkansas GIS office are continuously updated. For our study, the data was retrieved on May 30th, 2020. It is important to note that for Sheridan, the number of commercial properties (184 properties) is deemed insufficient to allow estimation of impacts for commercial properties. Thus, commercial property value impacts are not considered in this study. There are 1,862 residential properties in Sheridan, only 1,751 properties are considered in this study after removing the outliers (properties with land value per acre > $100,000, or 4.5 standard deviations above the mean).

To assess the effects of property location relative to the bypass and the main thoroughfare, a binary variable is introduced. The binary variable, closeness to bypass, captures the properties that are closer to the bypass than thoroughfare in terms of shortest network distance. Network distance (distance along the highway) is measured from the centroid of the property to the point of entry along the bypass or thoroughfare following Iacono and Levinson (2009). Around 97% of the properties are less than 3 acres in area. Although most of the residential properties have driveways (visible via aerial imagery) they are not geolocated in the network data and thus could not be readily used for distance calculations. Thus, given the size of the parcels, it is assumed that the network distance calculated from the centroid of the parcel is not expected to differ enough from the driveway calculated distance to have a significant impact on the model results. A binary form of this variable is chosen for two reasons. First, using separate variables for network distance to thoroughfare and bypass leads to multicollinearity. Second, omitting network distance to the thoroughfare leads to omitted variable bias. So, to analyze the impact of the bypass relative to the thoroughfare, relative location (closeness to bypass) of properties is captured. For Sheridan, 323 (18%) of the 1,751 properties are closer to the bypass than the main road.

The data on structural attributes such as number of bedrooms/bathrooms and square footage of heated/cooled space, are not readily available for Sheridan. Therefore, ‘land value’ is used for this study instead of total property value as total property value likely differs based on structural characteristics unlike land value. The land value is normalized by the area of the parcel in acres **(Figure 2-1).** Unnormalized land values range from $500 to $113,000 in Sheridan with the median value of $16,000. Normalized land values range from $246 to $100,000 per acre (**Table 2-1**)

Lastly, demographic, and socioeconomic data including population density, employment rate, and median household income is gathered from the U.S. Census for the block groups defined for Sheridan (**Figure 2-1**). Census data corresponds to the year 2018. The population of Sheridan in 2018 is 4,857. Population density is approximately 409 people per sq. miles and median household income is $49,942. For reference, the population density for the state of Arkansas is 57.5 people per sq. mile and the median household income for the year 2018 is $45,726. Median household income of 2018 is converted to 2019 dollars using Consumer Price Index (CPI) data from Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2020).

For the accessibility variables the shortest network distance to the following land uses is calculated using GIS tools: state maintained or U.S. highway, airport, CBD, hospital related services, parks, and schools. Highways labeled as functional class 1, 2 and 3, corresponding to U.S. Interstates, State Highways, and Collectors are considered. The shortest network distance from the centroid of the property to each highway is calculated as a measure of highway accessibility. For Sheridan, highway accessibility ranges from 0.1 to 1.6 miles with a median of 0.5 miles. Although there is no defined CBD in Sheridan, for the purpose of this study, it is assumed that the area with banks, restaurants, and a retail mall comprises the CBD. The network distance from the centroid of the property to the centroid of the CBD is calculated as the measure of CBD accessibility. For Sheridan, CBD accessibility ranges from 0.1 to 3.2 miles with a median of 1.1 miles. Services such as hospitals, home health agencies, therapy facilities, and any other medical facility are also considered as they may influence property value. The network distance from the centroid of the property to the centroid of the medical establishment is calculated as the measure of health service accessibility. For Sheridan, medical accessibility ranges from 0.1 to 3.5 miles with a median of 1.4 miles. Lastly, both private and public primary, secondary, and post-secondary schools are considered in the study. The network distance from the centroid of the school to the centroid of the property is calculated as the measure of educational accessibility. For Sheridan, educational accessibility ranges from 0.002 to 2.6 miles with a median of 0.8 miles. The network distance to nearest park is calculated as park accessibility. For Sheridan, park accessibility ranges from 0.1 to 2.2 miles with a median of 1.03 miles. The network distance from the centroid of the property to nearest airport is calculated as the measure of airport accessibility. For Sheridan, airport accessibility ranges from 2.6 to 6.3 miles with a median of 4.2 miles.

Langley (1976) found that residents living with within approximately 0.22 miles (350 m) perceived highway noise and air pollution to a greater extent compared to that of residents living farther . Similarly, Mitra and Saphores (2016) used a 0.15 miles (250 m) buffer to capture the negative impacts of highway. Based on these studies, 0.19 miles (300 m) is used in our study as a threshold for pollution buffer variable. In Sheridan, 1,240 (71%) of the 1,751 residential properties are within the defined buffer of a highway.

Table 2-1. Descriptive Statistics for Case Study Application in Sheridan, Arkansas (N=1,751)

Categories	Variables	Description	Mean	Standard Deviation	Minimum	Maximum
Dependent variable	Land Value	Land value per acre (in $, 2019)	39,728	22,019	246	100,000
Neighborhood characteristics	Median household income	Median household income (in $, 2019)	53,476	6,459	45,225	62,962
	Employment rate	Employment Rate (percentage)	94	5	88	100
	Population density	Population Density (people per sq. miles,2019)	377	133	13	537
Transportation accessibility	Highway	Network distance to highway (miles)	0.6	0.4	0.1	1.6
	Airport	Network distance to nearest airport (miles)	4.2	0.7	2.6	6.3
	CBD	Network distance to CBD (miles)	1.1	0.6	0.1	3.2
	Health services	Network distance to nearest health related service facility (miles)	1.4	0.7	0.1	3.5
	Parks	Network distance to nearest park (miles)	1	0.5	0.1	2.2
	Educational	Network distance to nearest school (miles)	0.9	0.6	0.002	2.6
	Closeness to bypass	Binary: 1 if network distance to bypass is less than thoroughfare; 0 Otherwise	0.2	0.4	0	1
Transportation disamenity	Pollution buffer	Binary: 1 if property lies within 300 m of highway; 0 Otherwise	0.7	0.5	0	1

2.5. Methodology

2.5.1. Statistical evaluations for model selection

This paper adopts a hedonic price model (Rosen, 1974) to estimate the effects on property value resulting from the construction of a highway bypass in a small city. The formulation for a hedonic price model is:

$$L = f(S, N, T, e) \qquad \textbf{(2.1)}$$

where,

L = vector of land value per acre

S = vector of structural attributes

N = vector of neighborhood characteristics

T = vector of transportation accessibility/disamenity attributes

e = vector of errors.

Since the impact of infrastructure can be attributed to the difference in the property value, this model has been used extensively to study the impact of transportation infrastructure on property values (Boarnet & Chalermpong, 2001; Iacono & Levinson, 2009; Ko & Cao, 2010; Mikelbank, 2004).

There are several forms of hedonic price models including those that incorporate spatial lag and error autocorrelation. Before selecting the appropriate model, the variables with high multicollinearity can be removed using Variance Inflation Factor (VIF) (Rawlings, Pantula, & Dickey, 2001). To determine the appropriate model formulation, two statistical tests are carried out: (i) Moran's I for spatial dependency, and (ii) the Lagrange Multiplier test for spatial lag and error terms.

Calculation of Moran's I is used to determine if there are spatial dependencies in the data set to be used for modeling (Cliff & Ord, 1981). The weight matrix for the spatial hedonic model is calculated using the following equation:

$$W_{ij} = \begin{cases} d_{ij}^{-\theta} \text{ if distance } d_{ij} \leq d \; (d > 0, \theta > 0) \\ 0 \qquad\qquad\qquad\qquad \text{otherwise} \end{cases} \tag{2.2}$$

where,

W_{ij} = weight matrix

d_{ij} = straight line distance between properties

θ = exponent

The threshold distance 'd' can be obtained from Moran's I correlogram. The distance at which the spatial correlation is significant as expressed in a correlogram can be taken as the threshold distance.

To assess spatial dependencies in the model specification, a Lagrange Multiplier (LM) test is necessary (Anselin, 1988). The LM test assesses if the spatial dependence is reflected in a lag or an error term. If the LM test for spatial lag is significant, and spatial error is insignificant, then the spatial dependence exists in the lag term, and therefore a spatial lag model (**Eq 2.3**) is implemented. However, a spatial error model (**Eq 2.4**) is used when LM error is significant, but LM lag is insignificant. A spatial lag model accounts for the violation of the OLS assumption of independent observation whereas the spatial error model accounts for the violation of the OLS assumption of uncorrelated error terms (Anselin & Griffith, 1988). In the case both LM error and LM lag are significant, a more complex model like a Spatial Autoregressive model with Autoregressive disturbances (SARAR) is used (**Eq 2.5**) (Drukker, Prucha, & Raciborski, 2013).

$$log(L) = \lambda W log(L) + X\beta + u \tag{2.3}$$

where,

L = vector of land value per acre

β = regression slope coefficients

λ = spatial lag parameter

W = spatial weight matrix

X = explanatory variables

u = vector of correlated residuals

$$log(L) = X\beta + u, \quad \textbf{(2.4)}$$

$u = \rho W u + \varepsilon$

where,

L, β, W, u, X are previously defined.

ρ = spatial error parameter

ε = vector of innovations

$$log(L) = \lambda W log(L) + X\beta + u, \quad \textbf{(2.5)}$$

$u = \rho W u + \varepsilon$

where,

L, β, W, u, X, ε, ρ, λ are previously defined

2.5.2. Interpretation of estimated model coefficients

The interpretation of coefficients estimated via a SARAR model differs from that of OLS coefficients. This is because ‘spillover’ effects are represented in SARAR models. The expected value for the dependent variable in an OLS regression is given by a simple linear equation (**Eq 2.6**), whereas the expected value derived from a SARAR model takes into account spatial dependencies (W) (**Eq 2.7**) (Golgher & Voss, 2016).

$$E[y/X] = \alpha i_n + X\beta \quad \textbf{(2.6)}$$

where,

E = expected value for the dependent variable

y = dependent variable

X = explanatory variables

i_n = column vectors of ones

α = intercept coefficient

β = regression slope coefficients

$$E[y/X] = (I - \rho W)^2(\alpha i_n + X\beta) \quad \textbf{(2.7)}$$

where,

E, y, X, i_n, α, and β are previously defined.

ρ = coefficient of endogenous variable

I = unit matrix

W = weight matrix

In the SARAR model in **Eq (2.5)**, the spatial lag term λWlog(L) has off-diagonal matrix elements that create feedback effects between neighboring properties and hence the impact disseminates to the entire system. Therefore, the interpretation of coefficients from the SARAR model is based on the average direct impact (ADI), average indirect impact (AII), and average total impact (ATI) for each variable and given by **Eq**. (**2.8)**, (**2.9)**, and (**2.10)**, respectively (Golgher & Voss, 2016; LeSage, 2008). ADI measures the impact on each observation arising from change in the k^{th} explanatory variable, considering feedback arising from a change in the observed (dependent) variable. AII measures the impact on other observations arising from a change in the k^{th} explanatory variable. Direct effect measures the average impact of a change in explanatory variables on the dependent variable at the same location, whereas the indirect effect characterizes the average impact of a change in the explanatory variables on the dependent variable in different locations (Hwang, Park, & Lee, 2018). ATI measures the total impact given by the sum of ADI and AII. The impact of change in one unit of binary variable on land value (L) is given by (**Eq 2.11**). The significance of ADI, AII, and ATI was calculated following (LeSage, 2008). First, β, λ, ρ, and σ^2 is assumed to be normally distributed. Second, 10,000 simulations are carried out to calculate ADI, AII, and ATI. Finally, the statistical significance is estimated based on the empirical distribution. Average percentage change in land value per acre by changing one unit of binary variable is given by (**Eq 2.12**).

$$ADI_k = \beta_k N^{-1} \sum_{i=1}^{N} V_{ii} \quad \textbf{(2.8)}$$

where,

ADI_k = Average Direct Impact of k^{th} explanatory variable

$V = (I - \lambda W)^{-1}$

β_k, N , I, λ, and W are previously defined

$$AII_k = \beta_k N^{-1} \sum_{i \neq j}^{N} V_{ij} \quad \textbf{(2.9)}$$

where,

AII_k = Average Indirect Impact of k^{th} explanatory variable

β_k, N, V are previously defined

$$ATI_q = \frac{\beta_k}{1 - \lambda} \quad \textbf{(2.10)}$$

where,

ATI_k = Average Total Impact of k^{th} explanatory variable

β_k, λ are previously defined.

$$\Delta\, log(L_i) = \beta_k V_{ij} \quad \textbf{(2.11)}$$

where,

L, β_k, and V are previously defined

$$\left(\frac{\Delta L}{L}\right) = N^{-1} \sum_{i=1}^{N} [exp(\beta_k V_{ii} + 0.5 V_{ii}^2 \sigma_k^2) - 1] \quad \textbf{(2.12)}$$

where,

σ_k^2 = the variance of the distribution of log (β_k)

ΔL = change in land value per acre

L = Land value per acre

N, β_k, and V are previously defined

2.6. Results

The model is estimated using Stata 16. Employment rate, hospital accessibility, and airport accessibility are not included in the final model due to multicollinearity. The variance inflation factor (VIF) for the explanatory variables indicates that multicollinearity is not an issue in the final model as the largest VIF is less than 5 (31). As spatial correlation is found significant up to 0.78 miles (1,250 meters), it is taken as the threshold distance for calculating the weight matrix using **Eq (2.2)**. The value of θ in **Eq (2.2)** is taken as 2. The model gave similar results when repeated with θ as 1. Moran's I test statistic is significant ($p<0.001$) implying the presence of spatial dependency in land value. Since, both LM lag and LM error are significant ($p<0.001$), a SARAR model is estimated via Maximum Likelihood (ML).

Based on Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Akaike, 1974) values, which measure the relative amount of information lost by a model, the SARAR model is a better fit compared to the OLS model. Two data transformations are evaluated for the SARAR and baseline OLS models since multicollinearity is significant in untransformed independent variables. Comparison of a linear-log and log-log transformations (**Table 2-2**) for ML and OLS shows the log-log model outperforms the linear-log model based on AIC and BIC. Thus, the discussion on impacts is based on log-log SARAR model. The spatial lag (λ) and the spatial error (ρ) are strongly statistically significant, large, positive, and between -1 and 1, as required since the spatial weight matrix was row normalized (Kelejian & Prucha, 2010). The positive values of λ and ρ imply that the land value per acre and residuals are positively influenced by the neighboring properties, respectively.

None of the neighborhood variables considered are found to be significant. However, transportation accessibility attributes are found to be strong predictors of land value for the case study application. Among the transportation accessibility variables, highway accessibility, park accessibility, school accessibility, and closeness to the bypass are significant, but the CBD accessibility is insignificant. Based on the direct impacts (**Table 2-3**), a 1% decrease in distance to the nearest highway, park, and school increases the land value per acre by 0.15%, 0.42% and 0.14%, respectively. In monetary value, a 1% decrease in distance to the nearest highway, park, and school increases the land value per acre by $60, $167, and $56, respectively for a property with land value of $39,728 (the average in the sample of this study, N=1,751). Closeness to the bypass is significant and negative, which suggests that the property closer to the bypass than the thoroughfare has lower land value per acre. From **Eq (2.12)**, the land value per acre of property that is closer to the bypass decreases by 40%, which represents $15,853 for a property with land value of $39,728. The pollution buffer variable that indicates if a property is within 0.19 miles (300 m) of highway is insignificant.

2.7. Discussion

Median household income and population density are not significant in the SARAR log-log model. This can be attributed to low variation in median household income ($45,225 to $62,962) at the census block group.

Highway, park, and educational accessibility are significant and have expected negative sign as shown by past studies (Bolitzer & Netusil, 2000; Mitra & Saphores, 2016). It is expected that residential land value will increase if it has good accessibility to highway, parks, and schools. Past studies have shown that people prefer to live in locations where highway, parks, and schools are easily accessible (Fang, 2006; Hamersma, Tillema, Sussman, & Arts, 2014; Kaplan, 1985).

Closeness to bypass is significant and has negative sign. This might be attributed to the fact that there are fewer businesses and developments around the bypass, so the bypass does not offer more accessibility compared to the main thoroughfare. Past studies of small cities found no relocation of business from the thoroughfare to the new bypass route (Rogers & Marshment, 2000). This implies, even after five years of opening the bypass, the bypass has provided less accessibility to residents relative to thoroughfare. Furthermore, the number of trucks is relatively higher along the bypass compared to thoroughfare, hence residents might prefer to live in a peace and quiet place closer to the thoroughfare.

Since there is a lack of time series data, we are limited to comparing property value prior to the construction of bypass. Likewise, it is difficult to find a city of similar characteristics but without a bypass to compare values. This is because property value differs with sociodemographic characteristics, economic conditions, and location of the city. However, EconWorks suggests that the impact of highway improvement could be realized at least 5 years after the completion (Economic Development Research Group, 2018). The results from our analysis, in conjunction with EconWorks statement, implies that even after 5 years, the disparity in property value is significant and the properties closer to the bypass seem to be negatively influenced by bypass.

To capture the variation in estimated impact of the bypass on parcel land values, price elasticities calculated for each parcel (**Figure 2-2**). Although high negative elasticities (land value decreases if a property is close to the bypass) are scattered throughout the city, higher elasticities are concentrated in the northeast and west sides of the city. These findings suggest that the presence of a bypass provides higher negative externalities to the land values of those areas.

The pollution buffer variable is insignificant possibly because of low number of trucks passing through the highways of Sheridan. According to 2019 ARDOT traffic data, annual average daily truck traffic (AADT) along Sheridan highways ranged from 165 to 1,344 trucks per day (Arkansas Deparmtent of Transportation, 2019). Thus, the intensity of noise and air pollution may not be severe enough to deter residents from living near the highway.

Table 2-2. Hedonic Price Model Estimation Results (N=1,751)

Categories	Variables	Linear-Log		Log-Log	
		OLS	SARAR	OLS	SARAR
Neighborhood characteristics	Median household income	17.28***	2.17*	0.71***	0.37
	Population density	6.13***	-1.03	0.13***	-0.04
Transportation accessibility	Highway accessibility	-5.85***	-2.79	-0.15***	-0.15*
	CBD accessibility	11.41***	3.24	0.37***	0.18
	Parks accessibility	-4.30***	-6.06**	-0.26***	-0.41***
	Educational accessibility	1.65	-2.52	-0.01	-0.13**
	Closeness to bypass	-4.74**	-8.90***	-0.28***	-0.50***
Transportation Disamenity	Pollution buffer	-7.44***	-2.42	-0.13***	-0.05
Constant		-181.15	-17.85	1.87	-0.79
Spatial error coefficient (ρ)			*0.82****		*0.84****
Spatial lag coefficient (λ)			*0.75****		*0.67****
AIC		*15,597*	*14,563*	*3,961*	*3,288*
BIC		*15,646*	*14,623*	*4,010*	*3,354*
** Significance at 10%, ** Significance at 5%, *** Significance at 1%*					

Table 2-3 Impact Results of Preferred Model (N=1,751)

Categories	Variables	ML Log-Log			
		Coefficients	ADI	AII	ATI
Neighborhood characteristics	Median household income	0.37	0.38	0.76	1.14
	Population density	-0.04	-0.05	-0.08	-0.12
Transportation accessibility	Highway accessibility	-0.15*	-0.16*	-0.32*	-0.47*
	CBD accessibility	0.18	0.2	0.42	0.61
	Parks accessibility	-0.41***	-0.42***	-0.83***	-1.25***
	Educational Accessibility	-0.13**	-0.14**	-0.28**	-0.42**
	Closeness to bypass	-0.50***	-0.40***	-1.03***	-1.43***
Transportation Disamenity	Pollution buffer	-0.05	-0.04	-0.09	-0.14
Constant		-0.79			
Spatial error coefficient(ρ)		*0.84****			
Spatial lag coefficient (λ)		*0.67****			
** Significance at 10%, ** Significance at 5%, *** Significance at 1%*					

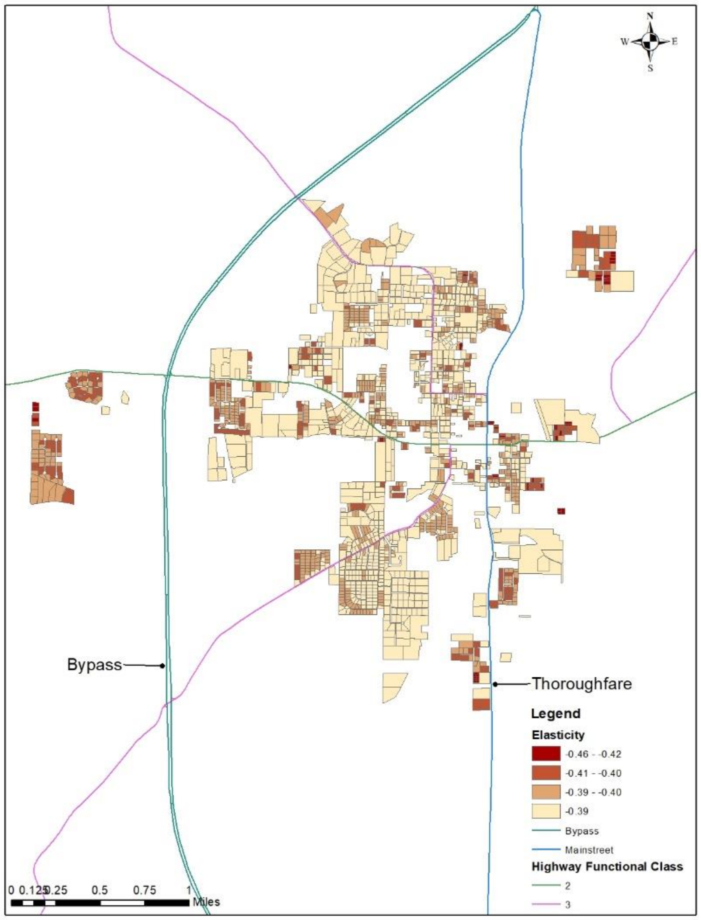

Figure 2-2 Spatial distribution of bypass price elasticities (effects of bypass on land values measured by elasticities)

2.8. Conclusion

This study fills a critical research gap in estimating the impacts of highway bypass projects on local economies in small towns by introducing spatial models that explicitly account for spatial dependencies in property values. Based on a hedonic pricing model framework, a SARAR model is used to incorporate both spatial lag and spatial error observed in the property value data of a small town. Accurate estimation of highway infrastructure projects on small town economies is necessary to guide responsible transportation investments and to inform the public of the magnitude of possible impacts. This study also provides information about where residential property owners would be least impacted due to construction of a bypass. Knowledge of the scope and scale of impacts can help state transportation agencies select optimal geometric alignments and designs for highway bypass such that impact on local economies can be minimized. Case studies targeting small and rural areas, such as that carried out in this paper, provide important context-specific insights, and can be used for public hearing meetings to garner support for proposed project alternatives.

Model variables include neighborhood characteristics, transportation accessibility and transportation disamenity (noise and air pollution). The model is applied to a case study in Sheridan, Arkansas, a rural community, to estimate the impacts of the highway bypass on residential property values. Statistical tests demonstrate the existence of significant spatial dependency among observations as well as spatial error and spatial lag. Alternate transformations including linear-log and log-log are compared for a baseline OLS model and a SARAR model. As measured by AIC and BIC, the log-log SARAR model is the best fit among all models. None of the neighborhood variables are found to be significant. Among the accessibility variables, distance to highways, parks, and schools have a positive effect on land value.

The result of a log-log estimation of a SARAR model on 1,751 properties in Sheridan shows that the residential properties closer to the bypass have lower land value compared to properties closer to bypassed highway. Land value per acre of properties closer to the bypass decreases by 40% or by $15,850 in the context of the average land value. This implies that the bypassed highway provides greater accessibility compared to bypass. A log-log OLS model underestimates the impact of the bypass on property values, e.g., land value closer to the bypass decreases by 24%. Failure to account for spatial dependencies in the data, therefore, can lead to incorrect conclusions about the magnitude of bypass impacts in a small town.

Future extensions of the model framework will investigate the effect of spatial aggregation. For example, a potential limitation of the methodology lies in the lack of neighborhood variables at the census block level. Large urban cities often have the data available at block level, while small cities do not. In Sheridan, there are eight block groups and 268 blocks. More variation in neighborhood characteristics at block levels could have contributed additional explanatory power of the model (Goodman, 1977). Additionally, in the future, if the structural attributes of the property are readily available, they should be used to differentiate price variances. Commercial properties could not be included in the analysis due to the low number of samples. There are only 184 commercial properties included in the shapefile for the study site provided by Arkansas GIS office. This was deemed insufficient to perform statistical regression. Combined model (commercial and residential properties together) could be run but commercial properties demand a separate model specification as suggested by previous hedonic studies (Iacono & Levinson, 2009; Mohammad, Graham, & Melo, 2017). The study on commercial properties is left for the future studies.

2.9. References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE transactions on automatic control, 19*(6), 716-723.

Andersen, S. J., Mahmassani, H. S., Walton, C. M., Euritt, M. A., & Harrison, R. (1992). Traffic and spatial impacts and the classification of small highway-bypassed cities.

Anderson, S. J., Harrison, R., Euritt, M. A., Mahmassani, H. S., Walton, M. C., & Helaakoski, R. (1992). Economic Impacts of Highway Bypasses, Report 1247-3F. Center for Transportation Research, University of Texas, Austin, Texas.

Anselin, L. (1988). Lagrange multiplier test diagnostics for spatial dependence and spatial heterogeneity. *Geographical analysis*, *20*(1), 1-17.

Anselin, L., & Griffith, D. A. (1988). Do spatial effecfs really matter in regression analysis? *Papers in Regional Science, 65*(1), 11-34.

Babcock, M. W., & Davalos, J. A. (2004). Case Studies Of The Economic Impact Of Highway Bypasses In Kansas. http://ageconsearch.umn.edu/record/208230/files/2004_EconomicImpact_paper.pdf

Babcock, M. W., & Davalos, J. A. (2010). Case Studies of the Economic Impact of Highway Bypasses in Kansas. *Journal of the Transportation Research Forum, 43*(1). doi:10.5399/osu/jtrf.43.1.721

Bartus, T. (2005). Estimation of marginal effects using margeff. *The Stata Journal*, *5*(3), 309-329.

Boarnet, M. G., & Chalermpong, S. (2001). New highways, house prices, and urban development: A case study of toll roads in Orange County, CA. *Housing policy debate, 12*(3), 575-605.

Bolitzer, B., & Netusil, N. R. (2000). The impact of open spaces on property values in Portland, Oregon. *Journal of environmental management*, *59*(3), 185-193.

Bureau of Justice Statistics. (2020). Bureau of Justice Statistics (BJS). Retrieved from https://www.bjs.gov/

Burress, D. (1996). Impacts of highway bypasses on Kansas towns.

Cena, L. G., Keren, N., Li, W., Carriquiry, A. L., Pawlovich, M. D., & Freeman, S. A. (2011). A Bayesian assessment of the effect of highway bypasses in Iowa on crashes and crash rate. *Journal of safety research, 42*(4), 241-252.

Cliff, A. D., & Ord, J. K. (1981). Spatial processes: models & applications: Taylor & Francis.

Collins, M., & Weisbrod, G. (2000). Economic Impact of Freeway Bypass Routes in Medium Size Cities. *Excerpt from Economic Impact of I-73 Alignments on Roanoke, 163*.

Comer, J. C., & Finchum, G. A. (2001). Business impacts of highway bypasses.

Concas, S. (2013). Accessibility and housing price resilience: Evidence from limited-access roadways in Florida. *Transportation research record, 2357*(1), 66-76.

Debrezion, G., Pels, E., & Rietveld, P. (2007). The Impact of Railway Stations on Residential and Commercial Property Value: A Meta-analysis. *The Journal of Real Estate Finance and Economics, 35*(2), 161-180. doi:10.1007/s11146-007-9032-z

Demski, J. (2020). Understanding IMPLAN: Direct, Indirect, and Induced Effects. Retrieved from https://blog.implan.com/understanding-implan-effects

Drukker, D. M., Prucha, I. R., & Raciborski, R. (2013). Maximum likelihood and generalized spatial two-stage least-squares estimators for a spatial-autoregressive model with spatial-autoregressive disturbances. *The Stata Journal, 13*(2), 221-241.

Economic Development Research Group. (2015). EconWorks user's guide. In: American Association of State and Highway Transportation Officials (AASHTO).

Economic Development Research Group. (2018). EconWorks Case Study Design. In: American Association of State and Highway Transportation Officials (AASHTO).

Elias, W., Hakkert, S., Penina, P., & Shiftan, Y. (2006). The influence of a bypass road on urban development and safety.

Fang, Y. (2006). Residential satisfaction, moving intention and moving behaviours: A study of redeveloped neighbourhoods in inner-city Beijing. *Housing studies, 21*(5), 671-694.

Federal Highway Administration. (2002). FHWA Rolls Out New HERS-ST Software. Retrieved from https://www.fhwa.dot.gov/publications/focus/02jul/hersst.cfm

French, T. (2018). What is IMPLAN? Retrieved from https://blog.implan.com/what-is-implan

Fricker, J. D., & Mills, J. B. (2009). Effects of Bypasses.

Gatzlaff, D. H., & Smith, M. T. (1993). The impact of the Miami Metrorail on the value of residences near station locations. *Land Economics*, 54-66.

Gaustad, V. B., Murray, J., Bardaka, E., Findley, D., Smith, R., & Martin, B. J. (2018). Analysis and validation of Historical Transportation Investments.

Girouard, N., & Blöndal, S. (2001). House prices and economic activity.

Golgher, A. B., & Voss, P. R. (2016). How to interpret the coefficients of spatial models: Spillovers, direct and indirect effects. *Spatial Demography, 4*(3), 175-205.

Goodman, A. C. (1977). A comparison of block group and census tract data in a hedonic housing price model. *Land Economics, 53*(4), 483-487.

Grimes, D. A., & Schulz, K. F. (2005). Compared to what? Finding controls for case-control studies. *The Lancet, 365*(9468), 1429-1433. doi:https://doi.org/10.1016/S0140-6736(05)66379-9

Gårder, P. E. (2004). The impact of speed and other variables on pedestrian safety in Maine. *Accident Analysis & Prevention, 36*(4), 533-542. doi:https://doi.org/10.1016/S0001-4575(03)00059-9

Hamersma, M., Tillema, T., Sussman, J., & Arts, J. (2014). Residential satisfaction close to highways: The impact of accessibility, nuisances and highway adjustment projects. *Transportation Research Part A: Policy and Practice, 59*, 106-121.

Helaakoski, R., Mahmassani, H. S., Walton, C. M., Euritt, M. A., Harrison, C. R., & Andersen, S. J. (1992). Economic effects of highway bypasses on business activities in small cities.

Hennekens, C. H., & Mayrent, S. L. (1987). Epidemiology in medicine.

Hess, D. B., & Almeida, T. M. (2007). Impact of proximity to light rail rapid transit on station-area property values in Buffalo, New York. *Urban studies, 44*(5-6), 1041-1068.

Hwang, J., Park, J., & Lee, S. (2018). The impact of the comprehensive rural village development program on rural sustainability in Korea. *Sustainability, 10*(7), 2436.

Iacono, M., & Levinson, D. (2009). The economic impact of upgrading roads.

Kaplan, R. (1985). Nature at the doorstep: Residential satisfaction and the nearby environment. *Journal of Architectural and Planning Research*, 115-127.

Kelejian, H. H., & Prucha, I. R. (2010). Specification and estimation of spatial autoregressive models with autoregressive and heteroskedastic disturbances. *Journal of econometrics, 157*(1), 53-67.

Ko, K., & Cao, X. J. (2010). Impacts of the Hiawatha light rail line on commercial and industrial property values in Minneapolis.

Kockelman, K. M., Srinivasan, S., & Handy, S. L. (2001). Economic Effects of Highway Relief Routes on Small and Medium-Size Communities. An Econometric Analysis.

Langley, C. J. (1976). Adverse impacts of the Washington beltway on residential property values. *Land Economics, 52*(1), 54-65.

LeSage, J. P. (2008). An introduction to spatial econometrics. *Revue d'économie industrielle*(123), 19-44.

Mikelbank, B. A. (2004). Spatial analysis of the relationship between housing values and investments in transportation infrastructure. *The Annals of Regional Science, 38*(4), 705-726.

Mitra, S. K., & Saphores, J.-D. M. (2016). The value of transportation accessibility in a least developed country city–The case of Rajshahi City, Bangladesh. *Transportation Research Part A: Policy and Practice, 89*, 184-200.

Mohammad, S. I., Graham, D. J., & Melo, P. C. (2017). The effect of the Dubai Metro on the value of residential and commercial properties. *Journal of Transport and Land Use, 10*(1), 263-290.

Mohring, H. (1961). Land values and the measurement of highway benefits. *Journal of Political Economy, 69*(3), 236-249.

National Center for Education Statistics. (2020). National Center for Education Statistics (NCES) Home Page, a part of the U.S. Department of Education. Retrieved from https://nces.ed.gov/

Noland, R. B., & Lem, L. L. (2002). A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK. *Transportation Research Part D: Transport and Environment, 7*(1), 1-26. doi:https://doi.org/10.1016/S1361-9209(01)00009-8

Palmquist, R. B. (1982). Impact of highway improvements on property values in Washington State.

Rawlings, J. O., Pantula, S. G., & Dickey, D. A. (2001). Applied regression analysis: a research tool: Springer Science & Business Media.

Rogers, C. L., & Marshment, R. (1997). Methodology for determining the impact of highway bypasses in Oklahoma.

Rogers, C. L., & Marshment, R. (2000). Measuring highway bypass impacts on small town business districts. *Review of Urban & Regional Development Studies, 12*(3), 250-265.

Rosen, S. (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy, 82*(1), 34-55.

Seggerman, K., & Williams, K. (2014). Managing the Indirect Impacts of Bypasses on Small and Medium-Sized Communities in Florida. *Transportation Research Record: Journal of the Transportation Research Board, 2453*(1), 46-53. doi:10.3141/2453-06

Siethoff, B., & Kockelman, K. (2002). Property Values and Highway Expansion: Timing, Size, Location, and Use Effects. *Transportation Research Record, 1812*, 191-200. doi:10.3141/1812-24

Sirmans, S., Macpherson, D., & Zietz, E. (2005). The composition of hedonic pricing models. *Journal of real estate literature, 13*(1), 1-44.

Souleyrette, R. R., Plazak, D. J., Albrecht, C. P., & Pettit, R. J. (2009). Managing Decisions Regarding Rural Expressway Routes and Associated Highway Bypasses.

Thompson, E., Comlavi, K., & Dimmit, M. (2011). Model for Predicting the Impact Upon Economic Development Resulting from Highway Improvement Projects.

Thompson, E., Miller, J., & Roenker, J. (2001). The impact of a new bypass route on the local economy and quality of life.

U.S. Bureau of Labor Statistics. (2020). Consumer Price Index (CPI) Databases : U.S. Bureau of Labor Statistics. Retrieved from https://www.bls.gov/cpi/data.htm

U.S. Census Bureau. (2019). *2014-2018 American Community Survey (ACS) 5-Year Estimates*. Retrieved from https://www.socialexplorer.com/tables/ACS2018_5yr

United States Census Bureau. (2020). Census.gov. Retrieved from https://www.census.gov/

United States Census Bureau. (2020). Latest City and Town Population Estimates of the Decade Show Three-Fourths of the Nation's Incorporated Places Have Fewer Than 5,000 People. Retrieved from https://www.census.gov/library/stories/2020/05/america-a-nation-of-small-towns.html

Conclusion

The thesis performs retrospective analysis to assess the impacts of highway improvement projects in small cities. The goal of the thesis is to help planners make data driven decisions using the results from past projects as evidence to compare and prioritize planned project alternatives. The results of the study provide a resource for community outreach performed by state transportation agencies regarding project planning. The study adopts retrospective impact assessment using proprietary tools and statistical analysis. In addition, the study presents a spatial model that asses the impacts of highway improvement projects in property value of small cities.

To perform the retrospective impact analysis two methodologies were implemented: IMPLAN and matched pair analysis. The methodologies were then applied to case study locations in Arkansas. IMPLAN analysis estimated direct, indirect, induced, and total impacts of construction project using the data on start and completion year and cost of each phase of the project. The impacts were assessed at the county level. Matched pair analysis was performed at the city level where the impacts of highway improvement projects in a city was estimated by comparing the economic indicators with its respective control city group. The economic indicators included both sociodemographic and economic variables.

The results from IMPLAN showed that impact of bypass projects was higher compared to that of widening in terms of total effects in employment, labor income, total value added, total output, and tax generated. Matched pair analysis revealed that for cities with bypass projects, relative to control cities, significant increases were attributed to the project for per capita GDP, sales tax, employment, and number of establishments. There was a decrease in ADT along the main road in bypassed cities. There were mixed results for home prices, and per capita GDP of private services, agriculture, construction, manufacturing, and retail. Among the widening study sites, while there was increase in per capita GDP, there was decrease in per capita GDP of manufacturing sector, sales tax, and ADT.

Future extension of the model includes the addition of more project types such as beltways and interchanges. Since the current simplified model is limited in its scope to assess impacts of projects within Arkansas, it could be replicated for other states as well. However, the focus on small and mid-sized cities is critical as other available tools, like the FHWA EconWorks tools, do not have adequate coverage for such settings.

In addition to the econometric and input-output models, the study adopted a hedonic pricing model with considerations for spatial dependencies (e.g., SARAR, or Spatial Autoregressive model with Autoregressive Disturbances) to estimate the effect of a highway bypass on residential property values. The method was applied to a small city in Arkansas. Neighborhood, network accessibility and a disamenity variable were considered in the SARAR model. The results from the model showed that the residential properties closer to the bypass have lower land values compared to properties closer to bypassed highway, e.g. the main route through the town. Land value per acre of properties closer to the bypass decreased by 40%. This implies that the bypassed highway provides greater accessibility compared to bypass.

Future extensions of the model framework will investigate the effect of spatial aggregation. Additionally, in the future, if the structural attributes of the property are readily available, they should be used to differentiate price variances. The limitation of this study lies in the exclusion of commercial properties due to data limitations for the study site. In the future, the model can be used in the cities with higher number of commercial properties to assess the impacts of highway improvement in those properties.

This thesis contributes to the field of transportation by expanding the methods and applications or retrospective impact assessment. The models developed in this work can be used by planners to estimate the impacts of proposed highway improvement projects. Similarly, the results from this study can be used in public involvement sessions to better inform community members on potential impacts of the projects. The simplified model presented in this thesis expands the existing impact assessment methodology with its ability to estimate impacts using fewer variables. The spatial hedonic model presented in this study can be used to guide transportation investment decisions made by state transportation agencies. This will assist planners to make an evidence-based decision for proposed highway improvement projects.