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# A Methodological Framework to Evaluate Community Perceptions of Economic and Safety Impacts Attributed to Highway Bypass and Widening Projects

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A Methodological Framework to Evaluate Community Perceptions of Economic and Safety  
Impacts Attributed to 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

Karla Diaz-Corro  
University of Arkansas  
Bachelor of Science in Civil Engineering, 2018

December 2020  
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

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## ABSTRACT

Transportation practitioners have proposed the construction of highway bypass and widening projects in rural communities to address traffic-related problems that include noise pollution and congestion, among others. In the past, the construction of bypass projects has led community residents to raise concerns about potential decreases in business activity for businesses located along the bypassed road. For transportation organizations, it is essential to understand the economic, social, and safety impacts of transportation projects in terms of public perceptions as public input is a required part of the project planning phase. Moreover, it is recommended that agencies perform retrospective analyses of project economic and safety impacts to better inform future project planning. Yet, a step-by-step framework to aid transportation agencies in gathering retrospective public perceptions of project impacts has not been documented. Moreover, for safety analysis, there are few tools and models to identify causes of crashes at planning area levels, as most focus on analyses of specific segments.

This thesis contributes to these methodological gaps by (1) developing and applying a systematic framework to assess the public perceptions of transportation project impacts on local economies and highway safety; and (2) quantifying the factors attributed to crash occurrence at a zonal level. The components of the framework include (i) design of a semi-structured phone interview survey protocol with data-driven questions; (ii) methods to select participants, and (iii) survey content analysis. While typical crash studies examine crash causal factors at a segment level, understanding the factors at a larger zonal level more closely aligns with the needs for performance-based planning required by federal transportation legislation. Specifically, in this work, a Random Effect Negative Binomial model (RENB) model is developed to estimate the effect of crash causal factors on crash count at the Traffic Analysis Zone (TAZ) level. By

accounting for serial and spatial correlation in longitudinal crash data, the impact of various factors like weather conditions, roadway characteristics, and built-environment can be assessed. Then, planners, engineers, and other traffic safety professionals can identify what countermeasures and programs may be most appropriate for mitigating crashes in a zone.



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## List of Published Papers

### Chapter 2:

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## **Introduction**

For transportation infrastructure investments, community perceptions of the economic and safety impacts of the project play a particularly important role in the assessment of a project's success. The Economic Development Research Group (2018) acknowledged in their handbook for practitioners that the American Association of State Highway and Transportation Officials (AASHTO) have increased the requirements for retrospective economic and public perception analyses in transportation projects. Moreover, the social, economic, and safety impacts derived from a transportation project need to be predicted and defined in the preliminary stage of project planning to ensure that any negative effects are mitigated so that public acceptance can be gained. For example, consider a highway bypass project where a new highway route is built to reroute through traffic around a busy Central Business District (CBD). The motivation for such a project may be to reduce congestion, reduce noise, and increase safety in the CBD. However, the public may perceive the project as potentially taking away customers from the CBD. Retrospective analyses using historical pre- and post-project data on economic conditions and crash occurrence, can shed light on the realized impacts of a project and be used in future projects to educate the public on possible impacts to their community.

Studies have shown that often the lack of support from community members in favor of the construction of highway projects can shift after project completion (Petit, 2007). This can be attributed to a lack of evidence available to present to the community during pre-planning stages to show realized effects of other transportation projects in a community similar to their own. Of various types of highway infrastructure projects, there is notable concern about the economic impacts of highway bypass projects, especially in small and mid-sized towns (Sabol, 1996). The issues that impact community perceptions of highway bypasses can be grouped into six



fundamental issues: (1) reduced traffic volumes in terms of reduced customer bases, (2) improved speed and reliability of freight movements, (3) design to encourage pass through traffic to take the bypass route, (4) decreasing economic business development, (5) inducing shorter travel distances between areas, and (6) declining property values and occupancy rates (Seggerman and Williams, 2014; Sabol, 1996). These concerns should be addressed in the decision-making process when seeking public input and approval. *This thesis looks at systematic ways of gauging public perceptions of highway projects after project completion for the purpose of providing retrospective analyses of project impacts for future public outreach.* Particular attention is placed on highway bypass and widening projects in small and mid-sized communities in rural areas.

The methods to quantify and compare the social and environmental impact in previous studies can be divided into four main categories such as qualitative case studies, pre and post-completion surveys, related factors, and statistical analyzes listed in order of increasing difficulty (Srinivasan and Kockelman, 2002). Each of these approaches is commonly used to gauge social impact, measure the impact of the bypass on the local economy, examine the economic conditions in a controlled area and the study area, and isolate the marginal influence of a bypass route from other factors, respectively.

Mills and Fricker (2009) propose that through the implementation of econometric analyzes, it is possible to reach a comprehensive interpretation of the changes that a city experiences due to the construction of a bypass. Their method looks to explain a relationship between the presence of a bypass route and the changes in the city's economy. Then, the results are correlated to the claims made by the residents of the area.

Forckenbrock and Weisbrod (2001) develop a guidebook for measuring public perceptions of the economic impacts of diverse transportation projects. A detailed description of creating surveys is included in the guidebook. Similarly, Thompson, Miller, and Roenker (2001) measure the overall impact of bypass construction with surveys as a metric to assess the community attitudes toward transportation projects. Some of the community changes evaluated in their surveys included a change in congestion, pollution, land usage, and value of properties before-and-after the completion of the bypass project. The pre- and post-surveys were implemented as part of their method to present more exact results on the quality of life in the communities due to the construction of a bypass road.

Selection of an appropriate assessment method is dependent on the available project data. According to the Economic Development Research Group (2015), a sample list of local, regional, and national data necessary to perform public perception impact assessments include the unemployment rate, population size, and population density, per-capita income, etc. These publicly available data can be used to gather anecdotal evidence regarding the impacts of a project on a community. Iacono and Levinson (2009) list currently available tools that estimate the economic impact of transportation projects. These tools are classified into two types: project-level analysis suitable for highway evaluation of independent impacts, and a regional economic impact assessment for estimating direct and induced economic impacts for the region.

Based on the current findings, the availability of data-driven, frameworks to assess the public perception impacts of transportation projects is limited. *To address this need, the primary objective of this thesis is to develop a framework to estimate community perceptions of the economic and safety impacts of highway bypass and widening projects.* This is accomplished

through the development and implementation of semi-structured phone interviews with community members and leaders.

The framework developed in the thesis is applied to nine cities in Arkansas with populations of less than 17,000 (small communities). The framework was built upon the NCHRP guidance with the added value of applying the framework to the nine case study areas in Arkansas. The framework in this thesis expands on that developed by Thompson et al. (2001) by considering bypass and widening projects. The results from this study can be used by transportation practitioners at public hearing meetings for projects of similar scope and location to better educate the public on realized impacts.

Besides assessing the public perceptions on impacts in small and medium communities due to the implementation of a transportation treatment, transportation agencies are also interested in identifying potential public safety concerns and causal factors of accidents. In NCHRP Report 456, Forkenbrock et al. (2001) suggests that the safety effects of a transportation project should be considered when estimating the benefit-cost ratio before-and-after the implementation of a transportation treatment.

Safety impact assessment requires data on the geometric characteristics of the segment under study, crash, and traffic volume. Forkenbrock et al. (2001) estimate safety effects as the number of crashes per unit of time, based on crash rates and forecasts of traffic volumes measured as Annual Average Daily Traffic (AADT). They suggest that crash rates be examined by functional class and injury type as it has been shown that upgrading a road to a higher functional class or expanding the road system capacity can affect crash occurrence and severity. *To support transportation planning organizations, the second objective of this thesis is to identify and estimate the impact of factors that influence crash occurrence within a Traffic*

*Analysis Zone (TAZ) by accounting for serial and spatial correlation in longitudinal crash data.* With U.S. federal legislation requiring performance-based planning, it is increasingly important to be able to estimate safety performance measures, like crash occurrences, at the same spatial resolution used for mobility, accessibility, and other performance measures.

This work expands the methodology outlined in NCHRP Report 456 by examining weather conditions, roadway characteristics, and the built-environment factors that could potentially lead to the cause of crash incidents. Causal factors are associated with roadway network attributes; thus, helping planners, engineers, and other traffic safety professionals design and plan safer roads (Pawlovich, 1998; Mukoko, 2019).

Based on the current findings, the development of a framework to assess the public perception and safety impacts of transportation projects is a topic of interest for planners and researchers that are looking for ways of measuring the most common impacts of a highway capacity project, especially in the early-stage of project planning. However, the publicly available literature is limited in many aspects. For example, most models measure the socio-economic effects after the construction of transportation treatments.

This thesis is organized as follows. Chapter 1 describes the data-driven framework developed to assess the public perceptions of the economic impacts after the completion of a transportation treatment. This includes a review of previous studies, and the methodology to develop the framework. This chapter also presents a full implementation of the framework. Chapter 2 presents an assessment of crash occurrence using historical crash data and a Random Effect Negative Binomial model. Lastly, the thesis concludes by underlining significant findings, remarking limitations, and recommending future enhancements to the processes developed.

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## Chapter 1

### 1. A Framework to Evaluate the Community Perceptions of Economic and Safety Impacts Attributed to Highway Bypass and Widening Projects

#### 1.1. Abstract

In Arkansas, communities have had to decide what is best for their area regarding state highways constructed through their downtowns. Some of the aspects that communities desire the most is a reduction in the level of noise and traffic congestion experienced on the main thoroughfare. Oftentimes alternatives to mitigate these negative effects for small and medium communities (i.e., towns with a population ranging between 1,000 and 50,000 people) include the construction of a bypass or widening on an existing road. There is a perception among community members that bypasses may negatively impact economic growth in the main downtown area. There is a lack of available evidence to show community members the realized impacts of bypassing and widening projects for towns like their own. Given accurate and comparative evidence of the community perception of the economic and safety impacts, community members can make more informed decisions about the correct treatment for their towns.

Community perception is recorded as a qualitative measure based on implementation of semi-structured phone interview. The interview directs respondents to describe the perceived and observed impacts of the construction of a bypass or widening project in terms of impacts on the local economy and safety. This thesis develops an interview protocol that includes development of a questionnaire, sample frame, and responses analysis.

This part of the thesis work consisted of the following main approaches. First, a literature review was carried out to explore the best practices in measurement techniques for community perceptions of economic and safety impacts. Second, a framework was developed to gauge community perceptions of economic and safety impacts that resulted from the construction of bypass and widening projects in small communities. Third, the framework was applied to nine communities in Arkansas. This work created a repeatable approach to measure community perceptions of economic and safety impacts of past highway capacity improvement projects.

## 1.2. Introduction

Planners perceive the construction of a relief route (i.e., segment of a highway that moves traffic around the central business district of a city, or bypass) to accommodate high speed (low congestion) intercity travel. Although bypasses in small communities lessen congestion, pollution, and accident occurrence, the impacted community may raise concerns about potential negative impacts on the local economy and future growth of the town. Hence, to make well-educated decisions about what is best for a community regarding changes to transportation infrastructure, the identification and quantification of the economic and safety impacts are needed.

Potential impacts derived from a transportation project should be well defined during preliminary stages of planning, assessed before the project is constructed, and then reassessed after completion. For transportation investments, economic and safety impacts are used to estimate the benefits of a project needed to perform benefit-cost (BC) analyses. BC analyses then guide the prioritization and selection of projects. While BC analyses are created before a project is constructed, there is value in looking back at the realized impacts after a project is constructed, e.g., retrospective analysis. In fact, the American Association of State Highway and Transportation Officials (AASHTO) recommends revisiting project impacts after project completion (EDC, 2018). Together, BC and retrospective impact analyses encourage planning agencies, e.g., state, or local Departments of Transportation (DOTs), to assess the effects of transportation projects on communities and estimate impacts that transportation projects investments have on local, regional, and statewide economies.

Several software tools exist to assess the economic impact of transportation treatments. Among those, EconWorks is a web-based tool designed to help planners incorporate economic



analysis during early-stage planning. This tool is the product of the Strategic Research Highway Program (SHRP2) Economic Analysis Tool projects, namely Transportation Project Impact Case Studies (C03) and Tools for Assessing the Wider Economic Benefits of Transportation (C11). EconWorks relies on a set of 100 case studies to estimate the potential economic impacts of future transportation projects, based on planning level data, e.g., projected Annual Average Daily Traffic (AADT), length, economic setting. Planners can compare proposed transportation treatments based on estimated economic impacts in terms of jobs, wages, and economic implications. EconWorks case studies include bypass and widening projects for different project settings (rural, urban, or mixed; region; economic distress, etc.). Even though several DOTs have contributed case studies to EconWorks, there is a need to expand the case study portfolio to include projects within small and mid-sized communities and in rural areas. By doing so, the EconWorks tool will be more applicable to states like Arkansas. Currently, most projects in the EconWorks case study database are beyond the scope of many highway bypass and widening projects in Arkansas' rural communities.

This project develops a method to gather retrospective insights from community members and project planners about the impacts of a transportation infrastructure project. This compliments other efforts to quantify and qualify project impacts post-completion and serves to meet the goals of AASHTO in reassessing project impacts post-completion. This project also serves to expand the EconWorks case study database with Arkansas case studies. The case study database requires that case studies include interviews with community members and planning agency staff.

The main objective is to develop a framework to quantify the community perceptions of economic and safety impacts of transportation treatments. This *community perception framework*

included the design of a semi-structured phone interview survey protocol, including methods to select participants, design targeted data-driven questions, and analyze and synthesize responses.

These objectives were accomplished by completing three major efforts:

- (1) *Review of best practices*, this work reviewed studies performed by other states regarding the methods to evaluate and measure community perceptions of economic and safety impacts as a result from the construction highway projects.
- (2) *Develop a framework*, based on established best practices and insights from available data, this work developed a framework to estimate community perceptions of the economic and safety impacts highway projects through the development and implementation interviews of community leaders.
- (3) *Framework implementation*, the framework was applied to nine study sites in Arkansas (**Table 1.3**). Five of the study sites are bypass locations, two are widening projects, and two are cities in which the decision for a bypass or widening could not be reached. All projects are in small and mid-sized rural communities. The effectiveness of the framework was assessed by determining sections where gaps exist in terms of data and methods and suggested alternate data and methods when needed.

The results from this study can be used to support the efforts of transportation planning organizations to hone the communication exchange between community and officials when it comes to making decisions that impact the future transportation system.

### 1.3. Background

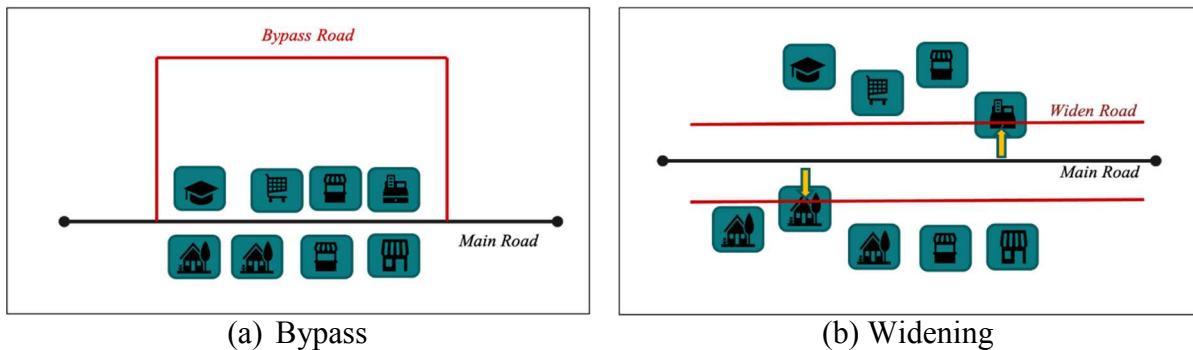
Highway infrastructure projects considered in the FHWA's EconWorks tool include access roads, bypasses, connectors, beltways, bridges, interchanges, widening, freight terminals, and transit/rail operational and infrastructure improvements (stations, new lines, etc.). Of these types of projects, highway widening, and bypass projects have been shown to have significant effects of local economies (Kanaroglou, P. S., et al., 1998). Moreover, the impacts of projects can be more significant in rural areas and small to mid-sized towns than in larger metropolitan areas (Babcock, M. W., et al. 2010). The focus of this thesis is thus on the impacts of highway bypass and widening projects in small to mid-sized communities in rural areas. This fits within the context of projects in the State of Arkansas, which has many small communities in rural areas.

#### *1.3.1. Highway Bypass and Widening Projects*

For several years, transportation planning organizations have proposed the construction of bypass and widening projects in rural communities to solve traffic-related problems that include noise pollution and congestion. A bypass is a road or a section of a roadway that enhances thru-traffic mobility in cities, without compromising local traffic (**Figure 1.1.a**). Bypass projects are a means of transportation believed to reduce congestion and provide safer roads, which leads to improving the quality of life in the downtown area. On the other hand, as part of a solution to alleviate the higher traffic volumes, planners may choose to widen the existing main road through the town (**Figure 1.1.b**).

Community members may perceive bypass projects as economic, social, and safety threats since travelers now may bypass the entire downtown area potentially impacting revenues of their local businesses and/or producing a decline in construction of new business along the main roadway. Moreover, there is a concern that a bypass may affect safety since bypasses have

higher posted speeds. In some cases, agreements between planners, officials, and the community cannot be reached.



**Figure 1.1 Transportation Treatment Considered in The Study**

In the past, the construction of bypass projects has led community residents to raise concerns about potential decreases in local business activity (Srinivasan, S., et al., 2002). Overall, the literature suggests that a bypass or widening project can positively impact a community (Thompson, E. C., et al. 2001; Mills, J.B., et al., 2011). For transportation agencies, it is essential to understand the impacts of transportation projects in terms of safety and the local economy to create more cost-effective policies aligned with the community preferences. **Table 1.1** shows a summary of the remarks found in the literature that relate the construction of a transportation treatment to the economic and safety impacts.

**Table 1.1 Literature of the Economic and Safety Impacts of Bypass and Widening Projects**

<b>Impact</b>	<b>Year</b>	<b>Authors</b>	<b>Title</b>	<b>Remarks</b>
<b>Economic</b>	2009	Iacono, M., & Levinson, D.	The economic impact of upgrading roads	The analysis of the economic impact of highway improvements through the analysis of property values yielded mixed results in terms of observable changes to the local economy associated with the construction of a new highway
	2002	Srinivasan, S., & Kockelman, K. M.	The impacts of bypasses on small-and medium-sized communities: an econometric analysis	Results show that bypassed towns suffered a loss in per capita sales in all four industrial sectors considered (i.e., Total retail, gasoline services, eating and drinking places, and service receipts)
	2011	Mills, J. B., & Fricker, J. D.	Integrated analysis of economic impacts of bypasses on communities: Panel data analysis and case study interviews	Evidence from the best statistical fit of the models developed in this study show that bypasses have economic impacts at the county level and the impacts change over time. Industry sectors included total employment (positive), manufacturing (negative), retail trade (negative), eating and drinking places (negative), wholesale trade (positive)
<b>Safety</b>	2001	Forkenbrock, D. J., & Weisbrod, G. E.	Guidebook for assessing the social and economic effects of transportation projects	The study suggests that crash rates be examined by functional class and injury type as it has been shown that upgrading a road to a higher functional class or expanding the road system capacity can affect crash occurrence and severity
	2011	Cena, L. G., Keren, N., Li, W., Carriquiry, A. L., Pawlovich, M. D., & Freeman, S. A.	A Bayesian assessment of the effect of highway bypasses in Iowa on crashes and crash rate	Bypassed towns are associated with a significant increase in traffic safety both on the main thoroughfare and on the bypass road. These results were obtained through a Bayesian approach to estimating the relationship between crash rates and bypass projects

### *1.3.2. Community Perception of Project Impacts*

Previous studies (Sabol, 1996; Iacono, M., et al., 2009) focused on the evaluation of site-specific impacts (e.g., case studies), while others introduce assessment tools based on synthesizing multiple case studies (Forkenbrock et al., 2001). However, there are limited studies focused on the public perceptions of project impacts. This is an important distinction since real measured impacts in terms of economic growth or crash rates may not be perceived by the public impacted by the project. In other words, what actually happened and what people perceive to have happened can be different. Insights into the public perception of economic and safety impacts of past projects can help inform community members and planners on how best to discuss and present future projects for public meetings.

Evaluating the perception of the community after the construction of a bypass or widening should take into consideration the well-being of the individuals (Geurs, 2009). Community perception on the economic and safety impacts can be explored in terms of the observed effects after the construction of a bypass or widening in comparison with the perceived community opinions before the new road was implemented. These effects can include changes in property values, tourism, traffic volume, business growth, and other factors that compromise the well-being of the community. Studies have shown repeatedly that the lack of support from the community members about the construction of bypass projects changes once the bypass roadway segment gets built (Petit, 2007; Sabol, 1996). For bypass projects in small and medium communities, community members think that redirection of vehicle traffic to the bypass away from the downtown business district will reduce the number of visitors stopping at their businesses. For instance, the Iowa Department of Transportation found that leakage in the economic development of a small community still occurs due to the construction of bypass

projects but it also benefits population growth and increase of per-capita income within the community (Souleyrette et al., 2009).

Key concerns in favor of the construction of bypass through small and medium-sized towns include reducing travel time through the main route in downtown, improving speed and reliability of freight movements, inducing shorter travel distances, and bypass routes leading to safer traffic conditions. On the other hand, key concerns against bypass construction include perceptions of decreased economic business development and declining property values and occupancy rates (Seggerman et al., 2014; Sabol, 1996). The ability to estimate the degree to which these concerns may be realized is a necessary part of the decision-making process carried out by transportation planning organizations. When possible, estimations of impacts are based on case studies of communities with similar demographic and economic characteristics.

### *1.3.3. Methods to Capture Community Perception of Project Impacts*

The selection of appropriate methods to study community perceptions of transportation project impacts depends on the available data. The most common limitation in the study of impacts in small communities is the availability of data to the level where the changes in economic and social sectors can be attributed directly to the implementation of a transportation treatment. Sabol (1996) considered anecdotal and case study observations from over 190 reports to produce a list of measurements of the perceived impacts of highway bypasses on rural and small urban areas. The list includes population, business level (e.g., sales), land-use, land value, employment, traffic, environmental conditions, and financial resources (e.g., project cost). Although increases in total population following the construction of the bypass were observed, most of the studies reviewed in Sabol (1996) did not collect data at a level that would allow for the direct attribution of population changes to the construction of the bypass. In terms of business

activities, using a case-control approach, the authors noted that only 34% of study locations showed higher rates of sales growth when compared to the control area. Again, another major limitation in this category was tying the findings to the construction of the bypass. Employment increased in more than 75% of the studied areas. However, the level of information that was gathered limited the possibility of causally linking employment increase to the construction of the bypass.

Lastly, land-use and value can potentially be impacted by bypass construction due to land access changes. The expectations among all the communities studied showed the amount of land designated as commercial or industrial use increased along both the main road and the bypass. Overall, Sabol (1996) suggests that when impacts may be undesirable, there may be policy-based approaches to reduce anticipated negative effects. For example, interviews with political leaders in bypassed communities showed that negative effects could be mitigated by extending the city boundary, thus its tax base. This attracts and induces new development along the bypass and returns a share of the benefits to the businesses and the residents.

Srinivasan et al. (2002) developed empirical models to quantify the effect of a highway relief route on small and medium communities in Texas. A total of 42 cities were included either as bypass or control cities. Explanatory variables such as traffic volume and demographics were considered. Results showed a negative economic impact in small cities when bypasses were constructed to counter high traffic volumes on the main road if there is significant distance separation between the bypass and the main road. Their model only included the effect of the relief routes (e.g., bypasses) for small communities in terms of the direct effect on the local economy, while the community perception impacts were not considered.



Several comprehensive resources are available to estimate and interpret the community perception of impacts on transportation projects. Forkenbrock et al. (2001) in the NCHRP – Report 456 aimed to assess the community perception of the economic effects of transportation projects. A key component in this document is the development of surveys to identify and assess direct community perception impacts. The report focused on methods to quantify and compare the socio-economic and environmental impact including (listed in order of increasing difficulty): qualitative case studies, pre- and post-completion surveys, related factors, and statistical analyzes. These approaches are used to gauge perceived impacts, measure impacts of a transportation treatment on the local economy, compare economic conditions in a controlled area to the study area, and isolate the marginal influence of a bypass route from other factors. The report also evaluates community networking patterns, also known as community cohesion.

The approach used in this guideline document consists of: (1) defining the study area, (2) collecting information from community leaders and groups active in the community since they can identify the community characteristics that are not apparent to an outsider, (3) visiting the study area to evaluate the community networks and to estimate how a transportation project might affect those networks, (4) estimating the existing level of community cohesion in the form of interviews to gain information about it in the study area, (5) extrapolation of the project's effects on areas of relative cohesiveness to describe how community networking may change in response to the implementation of a transportation project. While this approach seems reasonable, this document only serves as a guideline, and no implementation of the method was provided.

Thompson et al. (2001) developed surveys to assess community attitudes toward transportation projects, specifically bypass construction. The survey, conducted as a pre- and

post-survey, assessed changes in congestion, pollution, land-use, and value of properties before-and-after the completion of a bypass project. The survey was carried out through telephone interviews with a group of six to eight community members in eight different bypass counties in Kentucky. These groups included business owners, political leaders, and media representatives. Thompson et al. (2001) provided insights about hypothetical expectations from the interview responses, and the value of before-and-after surveys to assess the perceived impacts of a transportation treatment. In their study, they found that many of the government officials, media representatives, and businesspeople interviewed were incredibly pleased with the changes observed after the construction of the bypass, which include expanded opportunity for growth, increased land usage, and property values.

Current literature on quantifying the community perceptions of economic and safety impacts due to the implementation of transportation projects (i.e. widening on existing) is limited. Hence, the main contribution of this work seeks to expand the current literature on the methodological framework to evaluate the community perceived impacts after the implementation of a highway capacity project for not only bypass but also for widening projects.

#### **1.4. Methodology**

The main objective of this study is to develop a framework for transportation agencies to apply to assess community perceptions of economic and safety impacts of bypass and widening projects in small towns. The framework proposed in this thesis includes the development of a semi-structured phone interview with community members sampled from a project's original public hearing meetings. The interview transcripts are then subject to review through content analysis. Content analysis tags each response according to keywords that have been mapped to categories of opinions, e.g., positive, negative, and neutral. Examples of questions in the

interview include ‘What happens to the community when it is bypassed by a highway that once went through the main street in town?’; ‘Would the community favor a highway bypass or a widening the second time around?’; and ‘What can be improved?’.

Following the NCHRP Report 456 guidance, an effective community perception evaluation is one that includes the design of the survey instruments, identifies candidates for participation in the study, designs the questionnaire, reviews the information collected and develops a catalog of potential effects, lists the specific concerns voiced by participants, and tailors questions to the sites of interest and collect information about the community in general. Following this scheme, the framework proposed in this thesis is divided into: (Section 1.4.1) survey development; (1.4.2) survey implementation, and (1.4.3) survey content analysis.

#### *1.4.1. Survey Development*

There are numerous survey approaches to gauge public perception including focus groups, mail out surveys, and phone interviews (NCHRP Report 456). The approach selected for this thesis should be low-cost, require minimal or no travel, and be extendable to multiple, possibly distant locations. Focus groups require participants to attend in person and share thoughts as a group. This can be relatively expensive due to the need for the interviewers to travel to sites and rent a space. Mail-out surveys have the limitation of questions potentially being misinterpreted and have low response rates because the participant must mail the survey back. Phone interviews relieve the burden of travel and allow the interviewer to simultaneously contact and interview community members at many sites during the same time period. When developing a perception survey, it is important to assure that the participants can understand the questions being asked, that questions are understood in the same way by all respondents and that respondents are willing and able to answer such questions. A semi-structured phone interview

allows the interviewer to gauge if the participant understood the question and to follow up on insightful responses.

Therefore, for this thesis, semi-structured phone interviews were used. The interviews are used to identify project motivations, supporting policies, and how these policies interacted with the transportation investment to induce impacts, identify additional interview participants, and gather additional documents and resources. Survey question themes centered on business, crash, economic development, property values, tourism, and traffic following recommended question themes provided in EconWorks and defined in **Table 1.2**. **Appendix A** provides the full details on question categories.

**Table 1.2 Key Topics of Interest in the Survey Development Process**

<i><b>Survey Theme</b></i>	<i><b>Description</b></i>
<i>Businesses (i.e. Business Type, Existing, New, And Shoppers)</i>	Changes in businesses along and near the project site. Here, a business is any commercial ventures of any industry, type, or size.
<i>Crash Occurrence</i>	Relate to the participant perception and experience with changes in the crash occurrence that may be a result of the project.
<i>Economic Development Programs</i>	This refers to the process of expanding economic activity in an area to provide more jobs and income for the residents. Economic development programs, led by city leaders, state agencies, or local business groups, may lead to increased productivity and improved competitive position of the city.
<i>Property Value</i>	Consider property values to be the amount of money someone is willing to pay for a property and how much the seller of the property is willing to accept.
<i>Tourism</i>	Potential observable changes in tourism can be attributed to new hotels and business growth, for example. The term tourist refers to someone who travels for pleasure rather than for business.
<i>Vehicular Traffic</i>	This set of questions relates to the participant perception of changes in traffic congestion or volume that may be a result of the project.

The survey includes 29 questions. Interview questions were designed as “fill in the blank” questions that allow the city name, project type, site-specific data, etc., to be inserted into the

question to tailor surveys for each community. **Appendix B** shows all three types of surveys designed for each of the treatment types. For bypass projects, questions focused on gathering information about observed changes on the main road, the bypass road, and if there were any other factors besides the construction of the bypass which could affect changes in the city. For widening projects, questions were phrased to capture perceived changes in the widened road before-and-after its construction. For cities with no treatment implemented, the interview questions were tailored to capture the observed changes before-and-after it was communicated to the public that no project would be put forward.

Examples of questions include:

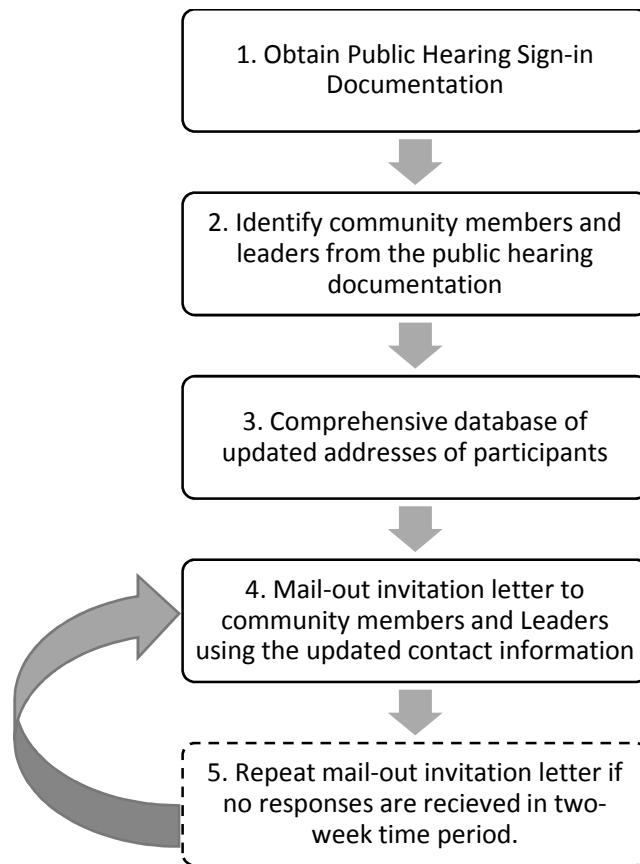
- How do you think *[insert category]* along *[Street Name]* has changed as a result of the *[Project Type]* on *[Project Location]*?
- How do you think *[insert category]* has changed in the area surrounding *[City Name]* as a result of the *[Project Type]* on *[Project Location]*?
- How do you think *[insert category]* has changed due to any other factors since *[Project Completion Date]*?
- Do you have additional insights that would explain the data divergence found on *[Topic]* between the years *[Range of Years]* in *[Project Location]*?
- Do you consider *[Project Type]* on *[Project Location]* a success?

#### 1.4.2. Survey Implementation

The following parties are recommended in the FHWA EconWorks literature to be included in project impact surveys (1) DOT staff, to provide complementary information of the project during its planning and environmental analysis stage; (2) community members, to provide

information on their perception of the impacts of the agency decision to bypass, widen, or decline project treatments in their communities; and (3) business owners, to provide insights on how the decision about the transportation project-affected business growth, investment, and expansion (Weisbrod, G. et al., 2001). Interview participants can be selected based on their physical proximity to the project, snowball sampling (e.g., asking participants in an initial sample frame to identify other potential participants), and those present at the original public hearings that took place before the construction of the highway capacity project.

To select the community leaders and members (**Figure 1.2**), an initial sample frame is created from the public hearing documents produced during the original project planning meetings. Then, considering the age of the projects (10+ years ago in some cases), efforts are made to update the names and addresses of participants gathered from the public hearing documents. This verification process was carried out using the United States Postal Office address lookup to verify the accuracy of the address provided on the public hearing documentation. Fourth, invitation letters are mailed to community members in the initial sample frame. A sample of the invitation letter can be found in **Appendix C**. To increase the response rate, it is recommended to repeat the mailing at least two weeks after the first round of invitation letters is sent. Three weeks after the first round of invitation letters, a follow-up letter was sent to the same group of participants for those that did not respond to the survey the first time. Lastly, throughout the interview process, using snowball sampling, additional interviewees are identified and added to the sample frame. Thus, another round of invitations was sent to the suggested community members from the participants that were being interviewed (snowball sample), and additional contact information from cities where the response rate was zero.



**Figure 1.2 Process to Collect Survey Participants**

*1.4.3. Survey Content Analysis*

For the analysis of qualitative data, open and close coded techniques are recommended for analyzing structured phone interview responses (Bardaka, E. et al., 2018). In the social sciences, coding is an analytical process in which data, in both quantitative forms (such as questionnaire results) or qualitative form (such as interview transcripts), are categorized to facilitate the analysis (Cope, 2010). This quantitative technique is referred to as “content analysis”. One purpose of coding qualitative data is to transform the data into a form suitable for computer-aided analysis. Coding qualitative data helps reduce the content by putting it into smaller themes arranged by topic. Content analysis is a system of identifying terms, phrases obtained from a text document, or audio recording. Cope (2010) mentions two types of codes- descriptive and analytic. According to

their definition, descriptive coding refers to themes or patterns states directly by the research subjects. Meanwhile, the analytic content analysis reflects a theme that is of interest to the researcher. Descriptive content analysis often suggests analytic codes by revealing important themes as the subject responds to the questionnaire.

For this framework, it is recommended to employ an analytic content analysis where the themes are established before interviews are conducted. However, the strength of content analysis is the possibility of adding new connections from the participant responses, e.g. recursive theme generation. Therefore, it is particularly important when developing the survey questionnaire to include a question where the participant can share additional insights that were not touched on during the interview. Thus, expanding the list of themes.

The proposed method for the content analysis of qualitative data is as follows. The first step is to conduct interviews via phone, online, or mail. Then the interviews are transcribed. Next, each response is coded (e.g., a label is applied) using the themes listed in **Table 1.2**. Finally, the frequency of each theme can be summarized for each question across all participants to conclude on the impacts perceived by community members. The codes used in the interviews include:

- **Increase**, example words used by respondents include “more”, “improve”, “positive”
- **Decrease**, example words include “negative”, “less”, “worsen”, “decrease”
- **No change**, example words include “same”, “neutral”, “no change”

### **1.5. Implementation of Framework through Case Study**

The framework to gather community perceptions was applied to nine cities in Arkansas with populations of less than 17,000 people. All nine projects were completed during distinct years,



between 2003-2014. **Table 1.3** shows the description and key project motivations of each of the cities as identified from the project documentation obtained from the transportation planning organization. Three cities are in rural areas, five in metro areas, and one in a mixed area (metro and rural). Each of these communities was presented with the option of decided whether to widen an existing main road (Gould, and Siloam Springs), build a bypass (Grady, Hardy, Vilonia, Sheridan, and Flippin), or do nothing (Dover and Green Forest). The sites are spatially distributed across the state (**Figure 1.3**). The spatial diversity provides an opportunity to evaluate the framework across different regions, contexts, and populations.



**Figure 1.3 Study Sites Locations and Treatment Type**

**Table 1.3 Study Sites Proposed**

<b>Project type</b>	<b>City</b>	<b>Highway location</b>	<b>Project length (miles)</b>	<b>Start-end completion date</b>	<b>Purpose of the project</b>
<b>Bypass</b>	Grady	Hwy 65	4.2	2005-2009	Bypass needed to accommodate for traffic congestion due to local, school, and agricultural traffic.
	Hardy	Hwy 412	1.5	2003-2005	Accommodate high traffic flows from trucks and recreational vehicles.
	Sheridan	Hwy 167	8.13	2008-2014	To eliminate the impediment to the flow of through traffic in Sheridan.
	Vilonia	Hwy 64	10.1	2007-2012	Alleviate the increasing congestion and address safety issues.
	Flippin	Hwy 62	3.16	2004-2008	Reduce traffic impediment and thru traffic.
<b>Widen</b>	Gould	Hwy 65	8.6	2006-2011	For market access for farms, cultural enhancement, and improved healthcare delivery.
	Siloam Springs	Hwy 412	1.6	2010-2012	Relieve increasing traffic congestion, reduce traffic delay, and improve travel safety on highway 412.
<b>None</b>	Dover	Hwy 7	2.7	2011	To improve north-south travel and reduce congestion on highway 7.
	Green forest	Hwy 62	3.0	2012	To improve east-west travel, reduce congestion, and enhance safety.

### 1.5.1 Survey Implementation

The process described in **Figure 1.2** was followed and the following parties were included in the interview and survey process:

- *The local chamber of commerce and community members*: to provide information on how the project affected business growth, investment, and community development; and
- *Private business owners*: to provide information about the role of the investment in economic growth from the perspective of the private sector.

A comprehensive database included individual traceable records of each of the participants based on the availability of the data. These fields included:

- **Round** in which participant was invited, to keep track of the round where the participant was selected as several attempts of contact is recommended.
- **City name**, this corresponds to the city where the project is located.
- **First and last name** of the participant.
- **Address**, this corresponds to the address found in the sign-in documentation as written by the participant.
- **Phone number and email address** (Optional), collecting the participant's phone number and email address is not a requirement to have if the address was collected.
- **Project position** (if available), this column describes the general opinions of the participant at the moment the project was presented during the public hearing.
- **Public hearing date**, if available.
- **Page number** where the participant's name was listed in the public hearing documentation.

226 community members and 93 business leaders were included in the initial sample frame gathered from the public hearing documents. From 319 total selected participants in the initial sample frame, 241 of these were updated using the USPS database. The remaining 78 participants did not have an active address. Through snowball sampling, an additional 14 members and business leaders were added to the sample frame. There were 37 cases where the invitation letter was returned indicating the participant was no longer at the address.

The first round of invitation letters was sent on February 21st, 2020 with several repeat mailings occurring through September 1st, 2020 (**Table 1.4**). Overall, 24 interviews were conducted as of October 20th, 2020, representing a response rate of 14%. This is in line with typical mail out, call back surveys. According to the Pew Research Center, in 2017 and 2018, typical telephone survey response rates fell to 7% and 6%, respectively, according to the Center's latest data (Kennedy et al., 2019). This is due to the increase of spam mails in recent years, which is a justification for the multiple rounds of invitation letters sent.

By city (**Table 1.5**), response rates varied, with several cities not participating. It is suspected that the low response of businesses could be due to the pandemic, e.g., of the 72 invitation letters for businesses, only two responded with interest to complete the surveys. As can be viewed in **Table 1.5**, the Vilonia and Sheridan bypass projects had the greatest percentage of response, while the city of Flippin had the following greatest percentage of community response to the survey invitations. For cities with widening and declined projects, Dover had the greatest response to participate in the interviews with a 29% response from the total invitations sent.

**Table 1.4 Interview Contact Dates and Response Rates**

<b>Date</b>	<b>Letters Sent</b>	<b>Justification</b>	<b>Response Rate (%)</b>
<b>February 21st</b>	241	First rounds of invitations to business (72) and community members (169)	10 (4.1%)
<b>March 12th</b>	158	Follow-up invitations to community members with verified addresses from the first round of invitations	9 (5.7%)
<b>May 17th</b>	68	Expansion of the survey participant database for cities with no response	0 (0%)
<b>June 5th</b>	57	Follow-up invitations to community members with verified addresses from the third round of invitations	3 (5.3%)
<b>September 1st</b>	19	Expansion of the survey participant database for the chamber of commerce and city officials	2 (10.5%)

**Table 1.5 City Response Rate to the Community Members Surveys**

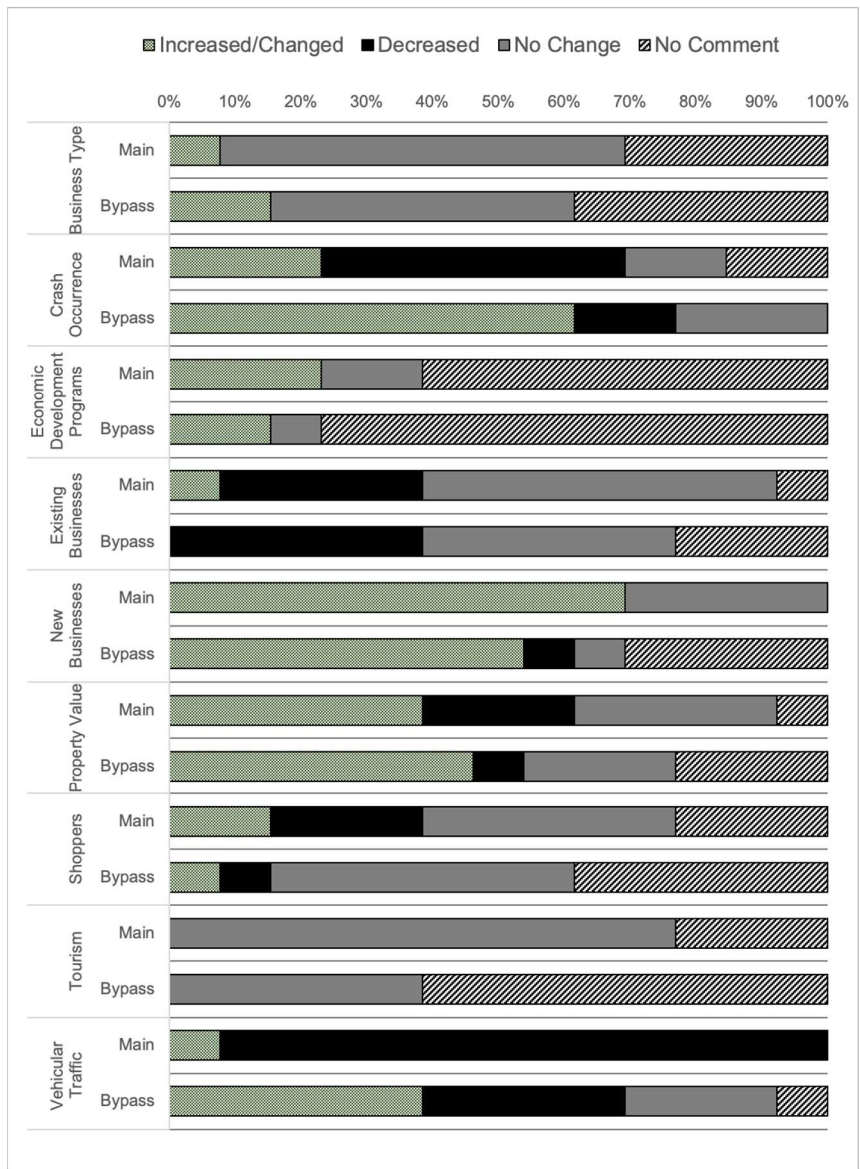
<b>Project Location</b>	<b>No. of Invitations</b>	<b>The proportion of Invitations (%)</b>	<b>Invitation Responses</b>	<b>Response Rate (%)</b>
Grady	13	6%	0	0%
Hardy	23	10%	0	0%
Vilonia	39	17%	7	18%
Sheridan	28	12%	5	18%
Flippin	36	16%	2	6%
Gould	49	21%	1	2%
Siloam Springs	2	1%	1	50%
Dover	14	6%	4	29%
Green Forest	26	11%	2	8%
<b>Total</b>	<b>230</b>	<b>100%</b>	<b>22</b>	<b>14%</b>

### 1.5.2 Content Analysis

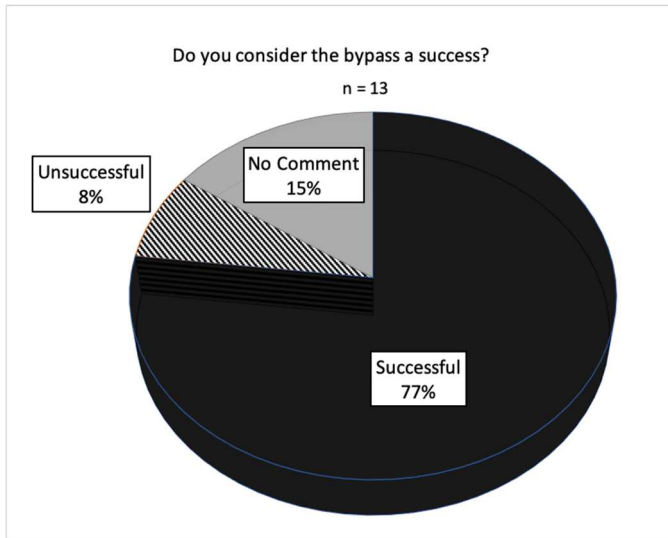
Interviews were audio-recorded, transcribed, and then their content was analyzed by survey theme (**Table 1.2**). Interviews were open coded for extraction of direct quotes, and close coded to quantify themes.

An example of the quantitative results from the survey for the bypass **Figure 1.4** shows a total of thirteen responses which represented an 9.3% response rate. Each response was quantified using keywords from the participants such as increased, decreased, and no change

perceived pre-and-post construction. Then a frequency distribution from the keywords was performed by category. Note that **Figure 1.4** also has a category for “No Comment”. This refers to questions where the participant stated they did not know enough to make an informed remark. At the end of every survey, participants were asked if they consider the project a success. **Figure 1.4** shows the results of this statement for all bypassed towns where 77% considered the project to be successful. A common reason for this being the relief of congestion traffic on the main street. **Figure 1.4** and **Figure 1.5** are available for all individual study sites where surveys were conducted (**Appendix C**).



**Figure 1.4 Community Member Response Summary for All Bypass Projects**



Sample Responses:

*"I do consider it's a success, and it relieved the congestion traffic on Main Street in Vilonia because it took the thru traffic going from East West of Conway"*

*Participant 10*

*"I don't think I would think of it like that, I feel like it was a lot of money put out, and it really hurt our town"*

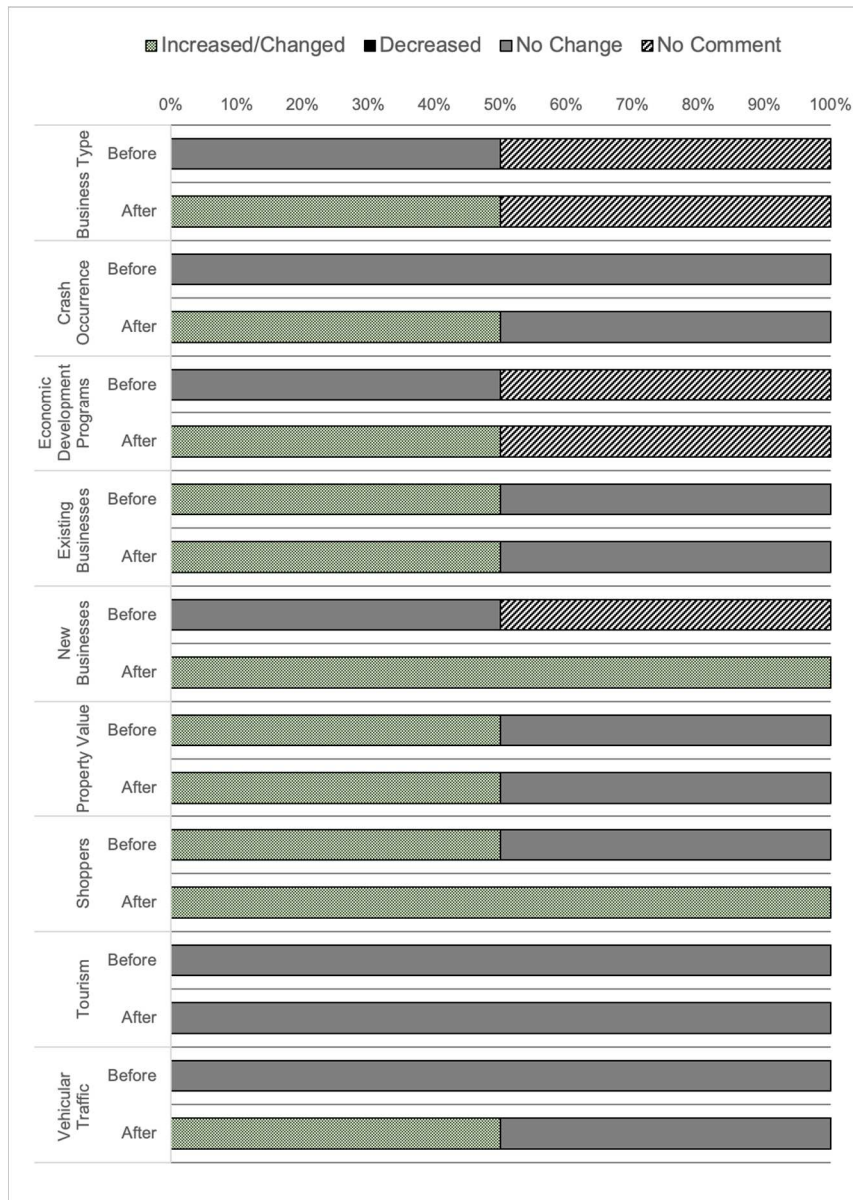
*Participant 16*

**Figure 1.5 Community Member Perception of Project Success for all Bypass Projects**

Another example of the quantitative results from the survey is for the widening projects.

**Figure 1.5** shows a total of two responses which represented an 3.9% response rate. This response rate is lower than the expected for mail-back surveys which typically have a 5% response rate (Kennedy et al., 2019). In comparison with the bypass projects, the results of this statement for all widened roads where that 50% considered the project to be successful. A common reason for this being that the residents near the area of construction were subject to relocation.





**Figure 1.6 Community Member Response Summary for All Widening Projects**

*1.5.3 Results*

Content analysis post- project completion yielded several key insights. For instance, bypass projects were noted to have a substantial effect on traffic reduction on the main road. Many residents expressed that after the construction of the bypass, the truck traffic that used to be extensive on the road through the city has been drastically reduced, improving safety of the main road. Nonetheless, the community reported occasional crashes on the bypass that include large

vehicles such as buses and trucks that sometimes carry hazardous materials. Pointed out by the community was the need for pedestrian overpasses. The lack of proper warning signs to anticipate the approach of two newly installed signal lights, for instance, is a cause for some of the most common accidents to occur in this area based on community perceived observation on crash occurrences. Economically, the bypass was not found to attract new business or relocated businesses. This was often attributed to the lack of proper utility and water/sewer infrastructure along the bypass which limited the ability of businesses to readily location to the bypass.

Interviews with local community members also revealed that on the main thoroughfare many residents have observed an increase in small-and-medium businesses moving into town near the bypass. Some of these businesses include clinics, pharmacies, and gas stations. Further, residents have observed many businesses moving into town and leaving every other month. This phenomenon was attributed to the lessen in traffic in the main thoroughfare.

For widening projects, results showed that a common reason for noting the project a success was because the widening of the main thoroughfare relieved congestion traffic on the main street; thus, ensuring safety. Improvements in safety were noted especially for pedestrians who could now access sidewalks. Also, participants mentioned travel time reductions along the main road.

In summary, a comparison of economic impact measures across all nine case studies suggests all projects likely have some impact on business growth, residential development, and vehicular traffic in the study area. However, bypasses tend to have a greater impact on business growth and residential development; while, widening projects appear to have an even impact across all these measures since traffic utilizing the new infrastructure is perceived to increase when the existing road is widened.

#### *1.5.4 Discussion*

The empirical guide framework to support the efforts of transportation agencies to understand the community perception of the impacts of bypass and widening projects shows promising results because it not only includes step-by-step guidance to perform a community perception of impact analysis but also details the data needed to replicate the framework filling in a current gap in the literature. Recall that current literature focuses on studies of multiple site locations or case studies. Meanwhile, this framework was designed to be applied to individual project sites. The results show that the semi-structured survey protocol captured the opinions of the communities and produced a quantitative analysis to interpret the data and find relationships between the perceived and observed economic and safety impacts because of a transportation treatment.

There are several limitations to this approach. One limitation of the framework is the bias in the sample frame. The sample frame consisted of community members who willingly attended public hearing meetings for the project. Thus, they may be inclined to have strong opinions about the project. To overcome this limitation, it is recommended that the survey sample frame be expanded based on outreach to the local Chamber of Commerce. The Chamber can help distribute survey invitations to obtain more participation from community leaders and to reduce bias in the selection of participants for the surveys and interviews. It is important to note that using public hearing attendance records to generate the sample frame allows the analyst to compare changing opinions over time. In particular, some public hearing documents indicate if the participant was “for” or “opposed to” the project. Using the retrospective interview process, the analyst can see if the respondent’s opinion changed. This can be valuable information to better frame arguments for future public hearing meetings. For example, one respondent, who

was noted as being against the project at the public hearing meeting, noted in the interview that they now think of the project as a success. The most challenging aspect of the content analysis was the interpretation of responses. Because the surveys were designed to be open-ended, participants would not use the same vocabulary to express their opinions. Thus, interpretations during the content analysis process were needed. Therefore, it is recommended to create a list of repeated words among participants to narrow down the most common responses. Then, categorize the responses into a more general group. By following this recommendation, the interpretation of keywords becomes easier to categorize.

Another limitation in this framework is the inherent issue with retrospective analysis, e.g., time. The framework was applied to nine sites in Arkansas with some projects dating more than 10 years in the past. This creates an issue when obtaining updated contact information as the probability that people may move or die increases with older projects. The main issue is that it requires significant effort and time to update and locate the current address of the participants based on the addresses provided in the project documentation and occasionally the project documentation contains unreadable handwritten information. To mitigate this issue in future studies, it is recommended that the framework be applied to more recent projects, for instance three to five years after project completion, or ten years maximum. For example, Sheridan, Vilonia, and Dover were completed in the last ten years and had higher response rates and lower incidence of returned mail (due to undeliverable addresses).

The framework presented can be further improved by conducting site visits to witness the development generated in the vicinity of the transportation treatment. Site visits can help clarify project understanding for the identification of project impacts. It provides an opportunity to see

first-hand what has happened in the vicinity of the transportation investment and will allow the researcher an opportunity for more in-depth discussions with stakeholders.

## **1.6. Conclusion**

Evaluating community perceptions of the impacts of highway infrastructure projects is a key part of project impact analysis. This is especially important for retrospective project analyses. Gauging public perceptions after a project is constructed can help better frame arguments for and against a future project. Moreover, in addition to quantitative measures of project impacts it is necessary to consider the public perceptions of the impacts, as the public is engaged in the planning process and can have a deciding role. This project specifically considered highway bypass and widening projects and their impacts on small and mid-sized rural communities. The goal of this work was to develop a framework that could be applied to analyze public perceptions of highway projects. The framework proposed in this thesis consists of using public hearing documents to generate sample frames for semi-structured phone interviews and then applying content analysis to categorize the interviews and conclude on the perceived impacts. The framework was applied to nine cities in Arkansas to evaluate its effectiveness as a tool.

A semi-structured phone interview was used to synthesize the perceived and observed changes in traffic volumes, crashes, property values, and businesses because of the bypass and widening projects. This served as a measure of community perceptions of the economic impacts after the implementation of a bypass or widening road. As part of the case study, respondents included personnel from ARDOT, local planning agency staff, local chambers of commerce, community members, and private business owners. A total of 226 community members were invited to complete the surveys. The overall rate of response was 14% (22 interviews; Grady (0 responses), Hardy (0), Vilonia (7 responses, 18% response rate), Sheridan (5, 18%), Flippin (2,

6%), Gould (1, 2%), Siloam Springs (1, 50%), Dover (4, 29%), Green Forest (2, 8%).

Interviews were audio-recorded, transcribed, and then their content was quantified by theme.

The main contributions of this work were to introduce a framework to support the efforts of transportation agencies to understand the community's perception of the impacts of bypass and widening projects. The framework was effective in highlighting key concerns and opinions from the community because of the construction of bypass or widening. These key concerns and opinions include reducing travel time through the main route in downtown, improving speed and reliability of freight movements, inducing shorter travel distances, leading to safer traffic conditions, and not affecting business along the main road or the bypass road. Current limitations of the framework include potential sample bias and difficulty in gathering an updated contact information. Future research should further implement and confirm these initial findings by repeating the framework and analyze the results in a larger sample.

The framework presented in this thesis allows agencies like the Arkansas Department of Transportation (ARDOT) to generate insight into perceived project impacts and compare such findings with quantitative evidence of project impacts.

## **1.7. Acknowledgments**

The authors thank the Arkansas Department of Transportation (ARDOT), for providing the public hearing documentation used in this study. The work was performed in part under contract TRC1904 with ARDOT.

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## Chapter 2

### 2. Assessment of Crash Occurrence Using Historical Crash Data and A Random Effect

#### Negative Binomial Model: A Case Study for a Rural State

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#### 2.1 Abstract

The objective of this work is to identify factors that influence crash occurrence within a Traffic Analysis Zone (TAZ) by accounting for serial and spatial correlation in longitudinal crash data. This is accomplished by applying a Random Effect Negative Binomial model (RENB). Unlike commonly used count-models such as Poisson and Negative Binomial (NB), RENB accounts for heterogeneity and serial correlation in crash occurrence. A RENB was applied to 15 years (180 months) of crash data in Arkansas, a relatively rural state, with 1,817 TAZs. RENB estimated impacts were measured using the Incidence Rate Ratio (IRR). The significant causal factors found to contribute to increases in observed crashes include, in order of IRR-estimated magnitude: (i) average precipitation (a one-unit increase in average precipitation results in a 134% increase in total monthly crashes for a TAZ), (ii) average wind speed (16%), (iii) urban designation (7%), (iv) traffic volume (2%), and (v) total roadway mileage (1% for each functional class). Snow depth and days of sunshine were found to decrease the number of accidents by 15% and 2%, respectively. Employment and the total population had no impact on crash occurrence. Goodness-of-fit comparisons show that RENB provides the best fit among Poisson and NB formulations. Model diagnostics confirm the presence of over-dispersion and serial correlation indicating the necessity of RENB model estimation. The main contribution of

this work is the identification of crash causal factors at the TAZ level for longitudinal data, which supports data-driven performance measurement requirements of recent federal legislation.

## 2.2. Introduction

Crash occurrence is an increasing public health concern, compromising the well-being of communities and resulting in serious social and economic losses. Globally, more than 1 million deaths and 20 to 50 million serious injuries are attributed to traffic crash incidents (World Health Organization, 2009). In 2015, an analysis of road crashes per 100,000 population ranked Arkansas, a relatively rural state, in the top five states with the highest fatality rate (17.8) (Sivak, M., et al., 2015). According to the Federal Highway Administration (FHWA), the rapidly growing population is increasing drivers on the road each year, which can result in more exposure to traffic incidents (US Department of Transportation, 2006). In response, traffic safety strategies have been implemented in the U.S., e.g., Vision Zero, safety belt use regulations, and distance-based charges (Yang, D., et al., 2016; Evenson, K, et al., 2018). Policy, operational, and infrastructure solutions for crash mitigation are based on identified risk factors including driver-related factors (i.e., impairment, fatigue, or distractions) and roadway infrastructure (Dingus, T. A., et al., 2016; Papadimitriou, E., et al., 2019; Anastasopoulos, P. C., et al., 2009).

While most crash occurrences are in urban areas, the risk factors of crashes are higher in rural areas (Rakauskas, M. E., et al., 2009). Roadway design elements, narrow shoulders, and higher speed limits can make rural driving conditions more hazardous. Low population density and geographic isolation of rural areas limit the transferability of the identified crash risk factors from urban to rural areas. Hence, there is a need for targeted studies of rural areas to identify crash-contributing factors (Ratcliffe, M., et al., 2016).

With U.S. federal legislation requiring performance-based planning (Fixing America's Surface Transportation Act, 2015), it is increasingly important to be able to estimate safety performance measures, like crash occurrences, at the same spatial resolution used for mobility,

accessibility, and other performance measures. While it is more common to develop crash-prediction models for corridors or specific sites, by estimating or predicting crashes at the Traffic Analysis Zone (TAZ) level (Mitra S., 2009; Pulugurtha, S. S., et al., 2013; Yu, R., et al., 2015) it is easier to tie safety performance measures into long-range transportation planning efforts (Yu, R., 2006). A handful of studies focused on identifying risk factors of crash occurrence using historical data at the TAZ level (Mukoko, K. K., et al., 2019; Zhang, C., et al., 2019). For instance, Wang et al. (2020) showed that at the macrolevel, e.g., TAZ and census tract, traffic flow influenced crash occurrence by using Bayesian models to account for the spatial dependency.

Without accurate estimates of crash-influencing factors, transportation planning agencies will be unable to make informed transportation policy decisions to enhance safety. Therefore, the main contribution of this study is to help fill a critical gap in the transportation safety toolkit regarding the study of historical crash data through modeling approaches suitable for identifying crash causal factors at a macrolevel (i.e., TAZ level). This paper applies a count model that allows for spatial and temporal autocorrelation in historical crash data with observations gathered at the TAZ level. Specifically, we consider a Random Effect Negative Binomial model (RENB). RENB models do not require assumptions of homogeneity, autocorrelation, or statistical dispersion of the data (e.g., mean and variance). Instead, RENB models treat data as a longitudinal panel to account for heterogeneity and serial correlation.

## **2.3.Literature Review**

### *2.3.1. Measures of Safety*

Crash occurrence is the most consistently referenced measure of safety for roadway safety analysis and is interpreted as a frequency, e.g., the number of crashes divided by a

measure of exposure, e.g., traffic volume (specifically Annual Average Daily Traffic or AADT) passing over a segment of a roadway or through an intersection during a specified period. Crash rates are the simplest measure to assess the degree of safety of a roadway segment, intersection, or sites with similar characteristics and traffic volumes (Carter, D., et al., 2017). Caution on the use of crash rates must be taken due to the non-linear relationship between crash rates and volumes. Thus, it is recommended to employ count-data models to identify crash risk factors (Roshandeh, A. M., et al., 2016; Coruh, E., et al. 2015; Mannering, F. L., et al., 2016; Xu, P., et al., 2017).

### *2.3.2. Causal Factors Associated with Crash Occurrence*

Causal factors of crash incidence are commonly associated with roadway network attributes, e.g., lane width, median type, speed limit, and the number of lanes; thus, helping engineers and other traffic safety professionals design safer roads (Mitra S., 2009; Pulugurtha, S. S., et al., 2013; Yu, R., et al., 2015). Additionally, crash causal factors can be associated with drivers' socio-demographic characteristics (age, gender, household income levels) to determine risk factors and develop laws and policies (Pirdavani, A., et al., 2014; Sagar, S., et al., 2020). Weather conditions, e.g., rain, snowfall, and temperature, considered causal to a crash that may aid in the specification of lighting, pavements, and other infrastructure or vehicle designs (Tefft, B. C., 2016; Saha, S., et al., 2016; Wong, J. T., et al., 2008). These elements are the most common causal factors identified in the literature, which can be associated in broader categories as spatial variables (e.g., land-use, population, roadway characteristics) and temporal variables (e.g., weather parameters) (Wong, J. T., et al., 2008; Ahmed, M. M., et al., 2012; Pulugurtha, S. S., 2013).

### 2.3.3. *Methods to Identify Causal Factors for Crash Occurrence*

The most common methods for estimating crash-contributing factors include multiple linear regression (MLR) (Jovanis, P. P., et al., 1986; Fitrianti, H., et al., 2019), multinomial logistic regression (Arbabzadeh, N., et al., 2017), and Poisson regression (Arbabzadeh, N., et al. 2017; Ye, X., et al., 2018). These models estimate coefficients (parameters) for causal factors to identify and compare significant factors. Models differ in their assumptions regarding the structure of crash data, e.g., normal, random, discrete, and non-negative. Assumptions of observed heterogeneity and spatial correlation are often violated by real-world historical crash data (Quddus, M. A., 2008; Siddiqui, C., et al., 2012; Zeng, Qiang, et al., 2017). Li et al. (2013) developed a Geographically Weighted Poisson Regression model and identified traffic patterns, road network attributes, and socio-demographic characteristics as causal factors. Of these, Daily Vehicle-Miles Traveled (DVMT) had the strongest influence on the crash occurrence, reflecting the general relationship between crashes and exposure. While this method captures the observed heterogeneity that exists in the relationship between crash occurrence and explanatory variables over the geographical extent of the study area, the calibrated model is not spatially transferable since it does not account for spatial correlation in the dataset. Quddus et al. (2008) found that, in London, traffic flow and the resident population aged 60 or over were serially correlated and thus violated the assumption of Poisson/NB models for homogeneity over time.

Negative binomial (NB) count-models are often used for crash estimation at the TAZ level (Mitra S., 2009; Yakovlev, P. A., et al., 2010) for data with over-dispersion and autocorrelation. Pulugurtha (2013) developed a crash estimation model using TAZ level data for a single period for Charlotte, North Carolina. They uniquely included land-use characteristics as a factor along with demographic and socio-economic characteristics like population, number of

household units, employment, network elements, and traffic indicators (e.g., trip productions and attractions by zone). Results showed over-dispersion leading to rejection of the use of Poisson distribution models. Land-use characteristics such as mixed-use development, urban residential, single-family residential, multi-family residential, business, and office districts were strongly associated with an increase in estimating TAZ level crashes. Their main limitation was that the study period consisted of one year, and they were unable to note the impact of changes to the surrounding environment over time. Conversely, in this paper a longitudinal approach is employed to analyze changes in individual factor levels, to account for changes in TAZ characteristics over time and space.

By introducing model forms like spatial regression in place of Poisson or NB models, limiting assumptions of homogeneity can be addressed. Using spatial regression methods, Mitra (2009) used traffic volume (i.e., ADT) as exposure data to investigate the influence of traffic on the crash occurrence at signalized intersections. A major limitation of their approach was that only exposure was used to define the relationship between crash occurrence and location.

Considering crashes are random events influenced by many space-specific factors, it is critical to include multiple years of data (Mannering, F. L., et al., 2016; Venkataraman, N. S., et al., 2011; Venkataraman, N., et al., 2013). Mannering et al. (2017) concluded that estimation techniques providing insights into the effects of time-variant and -invariant elements are necessary for crash models. Therefore, this paper uses historical data (i.e., measurements of the same variables over time or longitudinal data) to consider temporal changes. The inclusion of longitudinal data in crash estimation can strengthen, weaken, or hide the relationship between crash factors and their variation in crash frequency models like Poisson and NB since longitudinal data is inherently serially correlated (Mohammadi, M. A., et al., 2014). The



objective of this paper is to outline an approach for using longitudinal data in Random-Effects Negative Binomial (RENB) models for crash estimation in a rural state. This approach allows for the identification of factors that influence crash occurrence while explicitly considering the observed heterogeneity of crash occurrence by location.

## **2.4. Methodology**

### *2.4.1. Spatial Scope*

TAZs are defined by geographical boundary and aggregated socio-demographic characteristics. TAZs are the smallest unit of geography used in travel demand forecasting models and are structured to have homogenous travel and land-use characteristics within a zone (FHWA, 2007).

### *2.4.2. Factor Identification*

Pre-processing and suggested sources for each factor is explained in this section and summarized in **Table 2.1**.

### *2.4.3. Dependent Variable (Crash Data)*

Each crash record should include the geo-location of the accident (latitude/longitude), year, and month. Crashes were aggregated into TAZs using Geographical Information System (GIS) tools. For this study, all crash types (e.g., severity, pedestrian-involved, single car, property damage only, heavy vehicle, etc.) were included. The dependent variable in this study,  $y_{itm}$ , was the total number of crashes in TAZ ( $i$ ), in month ( $m$ ) of year ( $t$ ).

#### 2.4.4. *Explanatory Variables*

##### 2.4.4.1. *Weather Data*

Weather conditions such as rain, snow, temperature, and precipitation can influence crash occurrence (Yu, R., et al., 2015; Yu, R., et al., 2013). Monthly weather data can be obtained from the National Oceanic and Atmospheric Administration (NOAA)'s National Centers for Environmental Information (NCEI) (NOAA, 2016). Since weather stations often do not collect data each day of the year due to maintenance periods, gaps in temporal coverage may be observed. Besides, not every TAZ is assigned to a single weather station. Thus, the following process is necessary to convert the “raw” weather data from NCEI to monthly averages for each TAZ.

For the weather station assignment to TAZ, in this paper, it was assumed that if there is at least one weather station within a TAZ, then the parameters for that weather station can be assigned to be representative of that TAZ. If more than one weather station were contained within a TAZ, then the average weather parameters were calculated and assigned to that TAZ. If there were no weather stations found within a TAZ, then the closest neighbor analysis was performed to determine which of the neighboring stations was the closest to the centroid of the TAZ, using as maximum threshold the cut-off distance proposed in Akter et al. (2020). Weather can be considered homogenous within a specified “cut-off” distance of 10-16 miles around the weather station (Datla, S., et al., 2008).

##### 2.4.4.2. *Roadway Data*

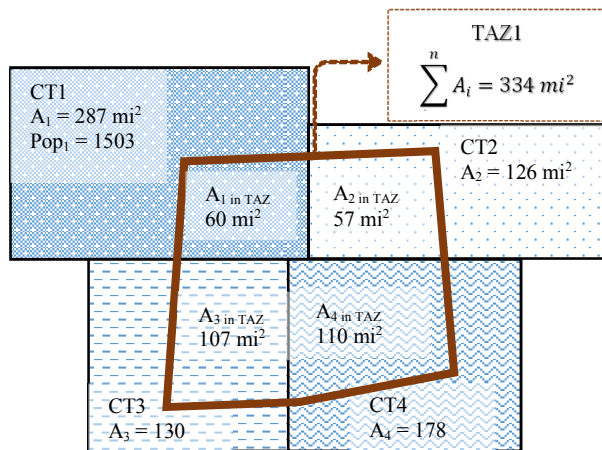
Roadway characteristics aggregated to the TAZ include: (i) the total road length by roadway functional class (e.g., interstate, other freeways and expressways, other principal arterials, minor arterials, major arterials, major collector, minor collector, and local road), (ii)

average vehicle-miles traveled (VMT), and (iii) average daily traffic (ADT). The road links contained in a TAZ were collected using GIS software (e.g., ‘sum lines length’) to calculate the total length of roadways by functional class within a TAZ in miles. Pulugurtha et al. (2013) assumed that road links which overlapped with TAZ boundaries should not be considered in their analysis because there was no approach to attribute the segment to a single TAZ. Similar overlapping issues were found in our analysis. Unlike Pulugurtha et al. (2013), using GIS software links overlapping TAZ boundary were identified and the total traffic volume was proportionally split according to the length within each TAZ to each TAZ spanned by the link.

#### *2.4.4.3. Built-Environment Data*

Built-environment data include TAZ designation as urban or rural, population, and employment density can be obtained from the American Community Survey 5-year estimate at the census tract level (U.S. Census Bureau, 2008). For Arkansas within the boundaries of a census tract, there are approximately one to five TAZs, and the majority of TAZ boundaries overlap with census tracts. To (dis)aggregate from the census tract to the TAZ level, it was assumed that socio-economic traits are evenly distributed across the entire census tract. When a census tract intersected with a TAZ, the percent coverage of each census tract within the TAZ was calculated (**Figure 2.1**). Then, the percentage coverage is used to associate census-derived variables to the TAZ. The resulting values were the weighted average of the built-environment variables aggregated by year.

Due to the lack of available land-use data for Arkansas, employment density was used as a proxy for land-use (Lu, J., et al., 2015). Land-use data can be captured by employment densities, which measure how efficient land is being used per unit of employment in a geographical area.



Example of percent coverage for Census Tract (CT1):

- Total Area: 287 mi<sup>2</sup>
- Area inside TAZ: 60 mi<sup>2</sup>
- Proportion:
 
$$P_{ij} = \frac{A_{i,j}}{A_i} * 100 = \frac{60}{287} * 100 = 20.9\%$$

Where,

$P_{ij}$  = Coverage of area of CT  $i$  in TAZ  $j$ , (percent)

$A_{i,j}$  = Area of CT  $i$  in TAZ  $j$ , (mi<sup>2</sup>)

$A_i$  = Total Area of CT  $i$  (mi<sup>2</sup>)

- Population assigned to the TAZ:

$$Pop_{i,j} = Pop_i * \frac{P_{ij}}{100} = 1503 * 0.209 = 314 \text{ people}$$

Figure 2.1 Example of Disaggregation from Census Tract to TAZ Level

**Table 2.1 Model Variables and Summary Statistics**

<b>Variables</b>	<b>Unit</b>	<b>Expected Relationship</b>	<b>Source</b>	<b>Time-variant?</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Min</b>	<b>Max</b>
<b>Dependent Variable</b>								
Number of Crashes per Month per TAZ	count	N/A	ASP <sup>1</sup>	Yes <sup>m</sup>	1.75	2.50	0.00	24.0
<b>Explanatory Variables</b>								
<i><b>Weather Effects</b></i>								
Average Precipitation	inches	+	NOAA <sup>2</sup>	Yes <sup>m</sup>	0.005	0.024	0.00	0.29
Binary 1: if there is a day with Snow depth > 1 in; 0: Otherwise	binary	+	NOAA	Yes <sup>m</sup>	0.097	0.296	0.00	1.00
Average Wind Speed	mps	+	NOAA	Yes <sup>m</sup>	0.047	0.128	0.00	7.04
Average Percent of Percent of Possible Sunshine	%	-	NOAA	Yes <sup>m</sup>	8.18	12.40	0.00	31.0
Average Temperature	Celsius	+	NOAA	Yes <sup>m</sup>	60.8	15.01	24.90	89.6
Minimum Temperature	Celsius	+	NOAA	Yes <sup>m</sup>	71.8	15.26	33.70	106
Maximum Temperature	Celsius	+	NOAA	Yes <sup>m</sup>	49.9	14.87	14.40	77.2
<i><b>Roadway Characteristics</b></i>								
Road Length of Interstate	mi	+	ARDOT <sup>3</sup>	No	1.49	4.378	0.00	41.4
Road Length of Freeways and Expressways	mi	+	ARDOT	No	0.36	2.471	0.00	53.4
Road Length of Primary Arterial	mi	+	ARDOT	No	2.28	5.383	0.00	51.2
Road Length of Minor Arterial	mi	+	ARDOT	No	4.49	6.787	0.00	52.3
Road Length of Major Collector	mi	+	ARDOT	No	10.7	19.99	0.00	174
Road Length of Minor Collector	mi	+	ARDOT	No	4.65	11.32	0.00	93.1
Road Length of Local Road	mi	+	ARDOT	No	46.9	99.69	0.00	1344
Ln (ADT), in thousands	count	+	ARDOT	Yes <sup>t</sup>	6.77	1.369	0.00	10.2
Ln (VMT), in hundred thousand	count	+	ARDOT	Yes <sup>t</sup>	10.0	1.746	3.61	15.0 3
<i><b>Built-Environment</b></i>								
Employment Density, in hundreds	count/ mi <sup>2</sup>	+	ACS <sup>4</sup>	Yes <sup>t</sup>	0.59	0.699	0.00	2.75
Total Population, in thousand	count	+	ACS	Yes <sup>t</sup>	1.50	3.640	0.001	48.5
Binary 1: if TAZ is Urban	binary	+	ARDOT	No	0.56	0.496	0.00	1.00

<sup>m</sup> time-variant by month; <sup>t</sup> time-variant by year; <sup>1</sup>ASP is the Arkansas State Police; <sup>2</sup>NOAA is the National Oceanic and Atmospheric Administration; <sup>3</sup>ARDOT is the Arkansas Department of Transportation; <sup>4</sup>ACS is the American Community Survey from the US Census.

## 2.5. Modeling Approach

This paper uses a Random-Effects Negative Binomial (RENB) regression model to assess the relationship between the number of accidents within a TAZ and selected explanatory factors. A key contribution of this paper is the use of longitudinal data spanning 15 years, which combines cross-sectional and temporal characteristics at the TAZ level to assess realistic behavioral models that cannot be identified at the site-level. Traditional count-based models, e.g., Poisson and NB, which assume that the number of crashes in a TAZ for period  $t$  is independent of other times, provide incorrect estimation in the presence of over-dispersion and serial correlation, respectively. If over-dispersion and serial correlation exist in the data, RENB models are recommended since group-specific effects (i.e., TAZ specific effects) are believed to be randomly distributed across locations. Depending on how the effect deviates from the mean, and across time, serial correlation can be found to be positive or negative. Due to the heterogeneity of the TAZ group-location constraint, it can be assumed that the number of crashes is related to location-specific effects. In this study, the RENB regression model considers  $n$  number of group-locations (e.g., TAZs) and  $tm$  periods (e.g.,  $t$  years with  $m$  months) such that the estimated number of crashes is associated with location-specific effects. RENB differs from the NB because NB does not explicitly capture location-specific groups over time for clustered (spatially dependent) crashes.

From the parent NB regression model, the RENB can be derived by introducing a random location-specific and time effect. The main benefit of using this approach is that the variance-to-mean ratio is not assumed equal or constant across the group-locations since they are random. The relationship between the estimated number of crashes in a TAZ and the covariance of an observation unit,  $i$ , in year  $t$  with month  $m$ , can be written as:

$$\hat{\lambda}_{itm} = \lambda_{itm} \delta_i \quad (1)$$

Where  $\delta_i$  represents random locations with specific effects. The non-negativity can be rewritten as:

$$\hat{\lambda}_{itm} = \lambda_{itm} \delta_i = \exp(X_{itm}\beta + \eta_i) \quad (2)$$

Where  $\beta$  is the coefficient vector to be estimated,  $\eta_i$  is the random effect across observations, and  $\exp(\eta_i)$  is gamma-distributed with a mean of one and variance  $\alpha$ , where  $\alpha$  is the over-dispersion parameter in the NB regression model. If  $\alpha$  is not statistically significant from zero, then the NB is reduced to the Poisson distribution.

The formulation for the RENB model for a crash occurrence at the TAZ level is as follows. Let  $y_{itm}$  be the number of crashes occurring in TAZ  $i$  for a given year  $t$  with month  $m$  that is NB distributed with parameters  $\lambda_{itm} \delta_i$  and  $\phi_i$ , where  $\lambda_{itm} \delta_i = \exp(X_{itm}\beta)$ . Hence,  $y_{itm}$  has mean  $\frac{\lambda_{itm} \delta_i}{\phi_i}$ , and variance  $(\frac{\lambda_{itm} \delta_i}{\phi_i})/Z$ , where  $Z = \frac{1}{(1+\delta_i/\phi_i)}$ . Additionally, to account for the variation of the location over time,  $Z$  is assumed to follow a beta-distribution with distributional parameters  $(a, b)$ . Using the derivation of Hausman et al. (1984), the probability density function of the RENB regression model for the  $i^{th}$  TAZ is:

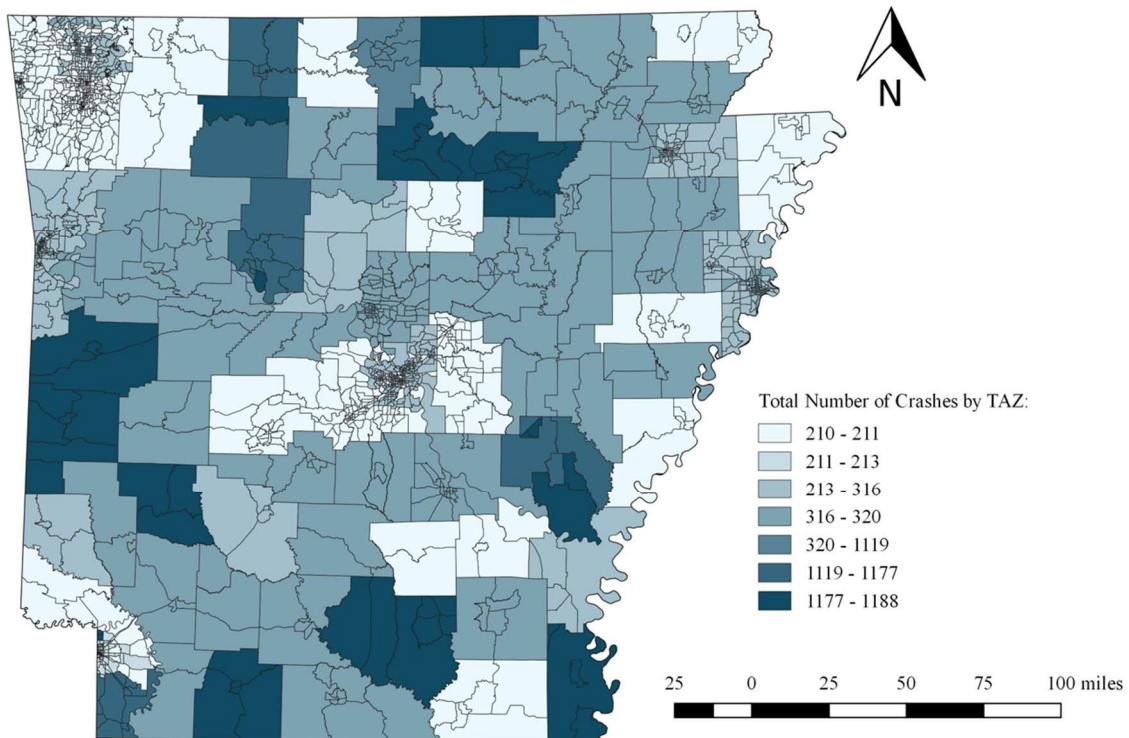
$$\begin{aligned} & \mathbf{P}(y_{i11}, \dots, y_{itm} | \mathbf{X}_{i11}, \dots, \mathbf{X}_{itm}) \quad (3) \\ &= \frac{\Gamma[\mathbf{a} + \mathbf{b}]. \Gamma[\mathbf{a} + \sum_T \lambda_{itm}]. \Gamma[\mathbf{b} + \sum_T y_{itm}]}{\Gamma[\mathbf{a}]. \Gamma[\mathbf{b}]. \Gamma[\mathbf{a} + \mathbf{b} + \sum_T \lambda_{itm} + \sum_T y_{itm}]} \prod_T \frac{\Gamma[\lambda_{it} + y_{itm}]}{\Gamma \lambda_{it} \Gamma[y_{itm} + 1]} \end{aligned}$$

## 2.6. Case Study: Factors Attributed to Crash Occurrence in Arkansas

The RENB model was applied to Arkansas to identify crash causal factors at the TAZ level. Arkansas is a relatively rural state with a population of 3,017,804 people (U.S. Census Bureau,

2020), 16,481 miles of state-maintained roadway, and 102,594 miles of public roads (Arkansas Department of Transportation. Arkansas, 2014). Arkansas ranks 12th in the U.S. by highway mileage.

A total of 1,817 TAZs are included in the study after removing 150 TAZs for which data was not available. The final dataset consists of 180 months, e.g., fifteen years, totaling 327,060 observations (**Table 2.1**). Crash data was obtained from the Arkansas State Police (ASP). In total, 611,318 crashes were reported between January 2000 and December 2014 (**Figure 2.2**). The dependent variable (e.g., number of crashes) ranges from zero to 1,188 crashes per TAZ.



**Figure 2.2 Spatial Distribution of Crashes by TAZ for Fifteen Years (2000-2014) in Arkansas**



## 2.7. Results and Discussion

### 2.7.1. Model Diagnostics

Models were estimated using Stata 16 (StataCorp, 2019.). The variance inflation factor (VIF) for the thirteen explanatory variables indicates that multicollinearity is not an issue as the largest VIF was equal to 2.27. The alpha ( $\alpha$ ) parameter in the NB model and the Likelihood-Ratio (LR) test of  $\alpha$  parameter in the Poisson model were significant which indicates there was overdispersion in the dependent variable and therefore the Poisson model is not appropriate (**Table 2.2**). Comparison of the NB and RENB models show that the RENB model outperformed the NB model in terms of the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and Log-Likelihood (LL). In addition, the beta-distribution parameters a and b were statistically significant in the RENB model proving the existence of autocorrelation between multiple observations within a TAZ. The likelihood test that compares the panel estimator (RENB model) with the pooled estimator (NB model) was also significant, illustrating the necessity of using the RENB model.

### 2.7.2. Parameter Estimates

The final model only shows significant variables of the RENB results since it outperforms the NB model (**Table 2.2**). Incidence Rate Ratio (IRR) values can be used to interpret the variables. If the IRR of a given variable is less than 1.0, then an increase in the value of the variable is associated with a significant safety improvement, as measured by the number of crashes. Conversely, if the IRR is greater than 1.0, an increase in the value of the variable is associated with a significant decline in safety. Otherwise, the variable has no effect on safety (Olmstead, T., 2001). Results showed that eleven variables have a significant positive impact,

while two variables have a significant negative impact on the total number of crashes in a TAZ (**Figure 2.3**). All the variables in the final model are highly significant in the RENB model ( $p \leq 0.01$ ).

#### 2.7.2.1. *Weather Effects*

Months with more precipitation and higher wind speed were associated with an increase in the number of crashes in a TAZ, consistent with the findings of previous studies (Tefft, B. C., 2016). From the computed IRR value, a one-unit increase in the average precipitation and one-unit increase in average wind speed was associated with increases of 134% (IRR value for average precipitation is 2.34, e.g.,  $(2.34 - 1.00) * 100 = 134\%$ ) and 16% in the total number of monthly crashes, while holding all other variables constant. This was expected since large amounts of rainfall lead to hydroplaning and strong winds limit the ability of drivers to control their vehicle.

The number of days with snow accumulation greater than 1-inch showed a negative relationship with the crash occurrence, e.g., IRR value of 0.85 indicating that a month with a snow day of greater than 1-inch was associated with a 15% reduction in total accidents per month, all other variables being equal. This counter-intuitive result might be true for Arkansas, which has only a few days of possible snow. The data reveals that on average there are four days of snow accumulation larger than 1-inch with a maximum of six days of snow in Arkansas. Many people avoid or postpone unnecessary travel and experienced drivers generally drive more slowly and carefully in those days. So crash counts are not necessarily higher in snowy weather when compared to dry weather as it is also supported by the results of previous studies (Eisenberg, D., et al., 2005; Brown B, et al., 2006; Fridstrom L, et al., 1995; Eisenberg D. et al., 2004).

The IRR value for the variable associated with the percentage of sunshine indicates that a 1% increase in the maximum amount of sunshine possible from sunrise to sunset with clear sky conditions was associated with a 2% reduction in total accidents per month. Average temperature was not found to be significant in the model, consistent with the findings of previous studies (Usman, T., et al., 2010).

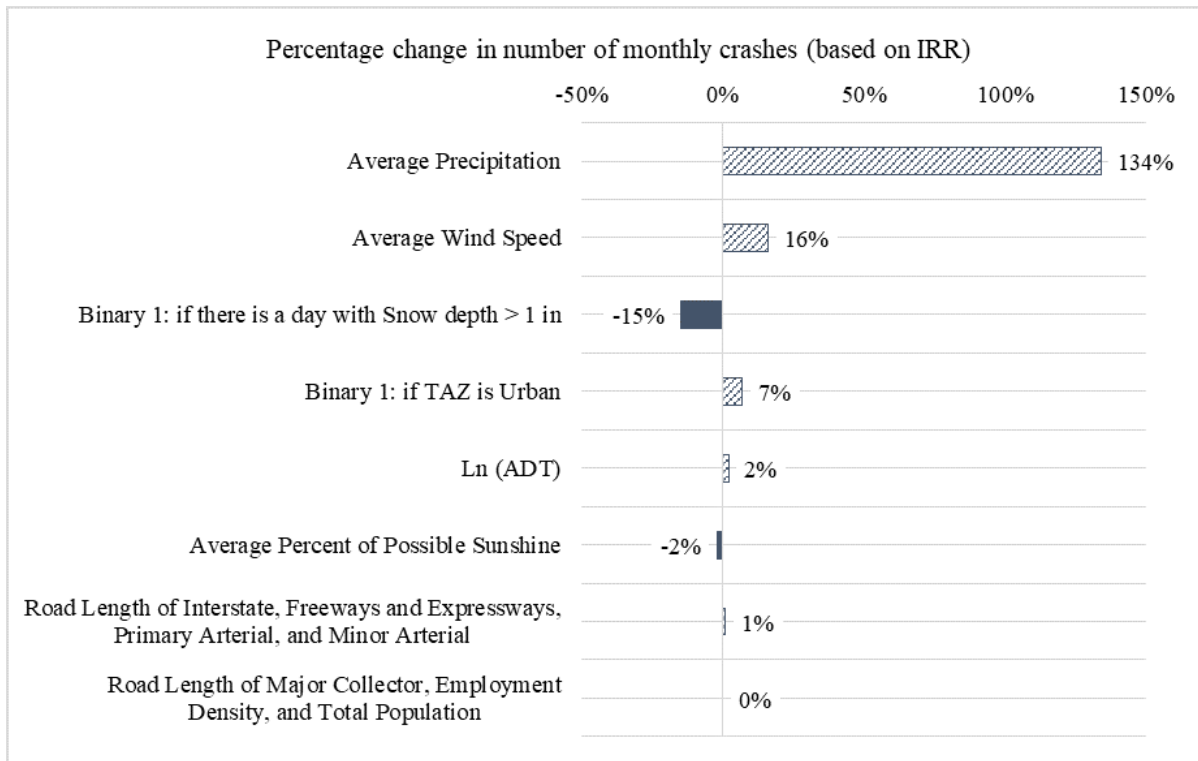
#### 2.7.2.2. Roadway Characteristics Effects

The statistically significant variables in the model for roadway characteristics were the total length of interstate, freeways, and expressways, primary arterial, minor arterial, major collector, and ADT. The results showed a positive relationship between the number of crashes and the total length of the roadway by functional class in a TAZ however, the magnitude of this impact is very low, around 1%. The highest effect among roadway variables was found for ADT, e.g., the IRR value indicates that a 1% increase in annual ADT was associated with a 2% increase in monthly accidents. The positive coefficient for all variables representing roadway characteristics was consistent with expectations since traffic exposure (e.g., volume) is associated with higher crash occurrence (Mitra S., 2009). The model results also found a positive relationship between VMT and crash occurrence. However, this variable caused multicollinearity when included in the model alongside ADT.

#### 2.7.2.3. Built-Environment Characteristics Effect

The total population and employment density were statistically significant and had positive signs. This indicates that TAZs with higher population and employment density was associated with a higher number of monthly crashes, however, the magnitude was low (IRR=1.00 for both variables). Population and employment density were associated with a higher risk of pedestrian collisions (Quistberg, D. A., et al., 2015).

The binary variable for the TAZ designation as urban was positive and statistically significant, indicating that urban TAZs were linked to a higher number of crashes. A TAZ with urban characteristics was associated with 7% more crashes than its rural counterparts. This can be attributed to urban area travel patterns. In urban areas, non-motorized modes (walking, biking) can be used to access activities and jobs, possibly increasing exposure of vulnerable populations. The diversified activities and services offered in urban areas may attract people from external/surrounding areas who may be unfamiliar with driving conditions and navigation for denser urban networks. Moreover, there tend to be more intersections and road segments with strong street compactness and mixed land-use leading to more exposure to accidents (Dai, D., et al., 2010).



**Figure 2.3 Percentage Change in Number of Monthly Crashes (Based on IRR)**

**Table 2.2 Model Results (Dependent Variable: Number of crashes per month per TAZ)**

Variables	Coefficient		
	RE Poisson	NB	RENB (IRR)
<b><i>Weather Effects</i></b>			
Average Precipitation	1.201***	1.979***	0.850 (2.34) ***
Average Wind Speed	0.106**	2.988***	0.152 (1.16) ***
Binary 1: if there is a day with Snow depth > 1 in	-0.163***	-0.183***	-0.166 (0.85) ***
Average Percent of Possible Sunshine	-0.019***	-0.041***	-0.020 (0.98) ***
<b><i>Roadway Characteristics</i></b>			
Road Length of Interstate	0.003	0.001**	0.007 (1.01) ***
Road Length of Freeways and Expressways	-0.011***	-0.013***	0.008 (1.01) ***
Road Length of Primary Arterial	0.013**	0.011***	0.006 (1.01) ***
Road Length of Minor Arterial	0.01	0.007***	0.007 (1.01) ***
Road Length of Major Collector	0.005**	0.004***	0.002 (1.00) ***
Ln (ADT)	0.022	-0.004***	0.021 (1.02) ***
<b><i>Built-Environment</i></b>			
Employment Density	0.003	-0.064***	0.046 (1.00) ***
Total Population	0.001	0.006***	0.003 (1.00) ***
Binary 1: if TAZ is Urban	0.024	0.060***	0.066 (1.07) ***
<b><i>Constant</i></b>			
	0.479*	0.577***	-0.255***
<b><i>Model Diagnostic Statistics</i></b>			
Wald Chi2 (DF <sup>1</sup> =13)	431,546***	22,768***	12,447***
Ln (Alpha)		0.353***	
LR test of alpha=0 Chi-squared (DF = 1)	1.1E05***		
LR test vs. Pooled (Chi-squared)			2.5 E04***
Ln a			2.667***
Ln b			3.308***
AIC	1,311,614	1,140,686	1,121,188
BIC	1,311,775	1,140,846	1,121,359
Log-Likelihood (LL)	-655,792	-570,328	-560,578
<i>N</i> (Number of observations)		327,060	
<i>i</i> (Number of TAZs)		1,817	
<i>t</i> (Number of years)		15	
<i>m</i> (Number of months)		180	

Note: RE Poisson: Random Effect Poisson Model; DF = Degrees of Freedom. \* Significance at 10%. \*\* Significance at 5%. \*\*\* Significance at 1%.

### 2.7.3. Sensitivity Analysis

A key assumption in the model framework was the designation of weather conditions to a TAZ. When two or more weather stations were in a TAZ, their parameters were averaged. When there were no weather stations in a TAZ, the closest within a specified threshold (65 miles for Arkansas, see Akter et al. 2020) was used. For the TAZs in this study, the maximum distance from a weather station to a TAZ was 22 miles, thus the threshold was not invoked. However, the

weather conditions for a TAZ are assumed to be more representative for a TAZ if the weather station is within the TAZ. Therefore, a sensitivity analysis was conducted on the method for relating weather conditions to TAZs. Three scenarios were defined for the specified weather homogeneity threshold: (i) maximum distance (21 miles), (ii) half the maximum distance (11 miles), and (iii) the mean distance (3 miles).

At 3-, 11-, and 21-mile thresholds, the number of TAZs were 1,220, 1,769, and 1,817, respectively. The three scenarios were assessed based on the number of significant explanatory variables. Average temperature was only significant for the RENB model at the 3-mile threshold such that statistical significance disappeared as the threshold increased. This can be attributed to inaccuracy in temperature associated with a TAZ when longer threshold distances are used. Other changes in statistical significance were found for minor collector road type, local roads, and VMT, which were not significant at all threshold distances. Although the model with the lowest, 3-mile, threshold show better goodness-of-fit (e.g., lower AIC), this model reduced the number of TAZs by 597. Thus, there is a notable tradeoff in fit and sample size, which brings to light questions of overfitting and limiting spatial transferability.

## **2.8. Conclusions**

This study was uniquely able to identify causal factors that are associated with the number of crashes originating at the TAZ level in a relatively rural state. For crash analyzes, count-models like Poisson and NB models may be inappropriate for estimating causal factors as they do not account for dispersion or consider location-specific and serial correlation. To overcome these limiting assumptions, the RENB model was introduced and applied. The RENB model was applied to a dataset of fifteen years of data, aggregated by month. Weather, roadway, and built-

environment factors were gathered and merged from NOAA, state databases, and the U.S. Census.

The significant causal factors found to contribute to increases in observed crashes include, in order of IRR-estimated magnitude: (i) average precipitation (a one-unit increase in average precipitation results in a 134% increase in total monthly crashes for a TAZ), (ii) average wind speed (16%), (iii) urban designation (7%), (iv) traffic volume (2%), and (v) total roadway mileage (1% for each functional class). These findings are indicative of the need to implement real-time traffic management systems, such as changeable message signs broadcasting forecasted adverse weather conditions, to alert drivers to lessen the probabilities of crash occurrence. Snow depth and days of sunshine were found to decrease the number of accidents by 15% and 2%, respectively. Employment and the total population had no impact on crash occurrence. The direction of the effect (positive or negative) of these estimates was in line with prior studies, although the magnitudes differ since the RENB accounts for inherent over-dispersion and serial correlation. Prior studies suggest that the most consistently significant and influential factors are precipitation, traffic exposure (e.g., ADT), roadway geometric characteristics, and safety culture characteristics. Goodness-of-fit comparisons referencing AIC, BIC, and Log-Likelihood showed that RENB provides the best fit among Poisson and NB formulations. Model diagnostics confirm the presence of over-dispersion and serial correlation in the monthly crash occurrence data indicating the necessity of RENB model estimation.

Extensions of the RENB model developed for this paper include disaggregation of crash types (severity and type) and further temporal synchronization of weather, roadway, and built-environment variables. Distinction of crashes by type would allow further identification of causal factors that may be crash specific. While in this paper employment density was used as a proxy

for land uses, as land-use data was not available, future work should consider the inclusion of land-use mix to capture built-environment influences on crash occurrence and type.

Another limitation is that the roadway network data was time-invariant, although the most updated highway network map was used. If roadway data was available for multiple periods it could be synchronously matched to weather data. In relation to data, several disaggregation could improve insights derived from the model. First, employment data could be broken into more categories. Different employment types might differently influence land-use and thus accident occurrence. Likewise, accident severity and type could be disaggregated. With the increasing availability of detailed digital GIS land-use data, trip productions, and attractions from forecasted travel demand models, such extensions may become more feasible for urban and metropolitan territories.

By estimating crash causal factors at the TAZ level, several policies and planning decisions regarding safety performance can be generated. Considering that federal legislation in the U.S. requires performance-based planning, it is necessary to analyze safety at spatial levels of resolution that match those generated for mobility, accessibility, and other performance measures. Thus, the results of this model can improve how state transportation agencies prioritize safety-related projects.



## **2.9. Acknowledgments**

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## **2.10. Author Contributions**

The authors confirm contribution to the paper as follows: study conception and design: S. Mitra, K. Diaz-Corro.; data collection: K. Diaz-Corro and L. Coronel; analysis and interpretation of results: K. Diaz Corro, S., Mitra, and S. Hernandez; draft manuscript preparation: K. Diaz-Corro, S. Hernandez, and S. Mitra. All authors reviewed the results and approved the final version of the manuscript.

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## **Conclusion**

The focus of this thesis is on providing tools to transportation planners to help identify transportation project impacts. The framework presented in this thesis can be used to evaluate public perceptions of the economic impacts of transportation projects and identify factors affecting crash occurrence. Specific attention was placed on the impacts of highway widening and bypass projects in small and mid-sized communities in rural areas. The methods presented fill methodological gaps identified in the literature related to repeatable methods to conduct retrospective project impact analysis. Retrospective project impact analysis is recommended by AASHTO as part of project evaluation. The goal is to better understand project impacts to mitigate negative impacts and harness positive impacts. Attention was given to public perceptions of impacts, as these are important for engaging the local community in the transportation planning and project decision making process.

To evaluate public perceptions of project impacts, this work developed a survey protocol consisting of generating a sample frame from public hearing documents, generating questions based on quantitative evidence of impacts, and analyzing survey responses through content analysis methods. This thesis also developed a method to estimate crash causal factors using econometric modeling, specifically using regression techniques. By estimating crash causal factors at the TAZ level, several policies and planning decisions regarding safety performance can be generated. Considering that federal legislation in the U.S. requires performance-based planning, it is necessary to analyze safety at spatial levels of resolution that match those generated for mobility, accessibility, and other performance measures. Thus, the results of this model can improve how state transportation agencies prioritize transportation-related projects taking into consideration the public perceptions and the safety effect.

The survey framework was applied to nine cities in Arkansas that had received transportation treatments (bypass and widening projects) aimed generally at reducing traffic congestion along the towns' main streets. Through the content analysis, community member supports each project and concerns were identified.

Evidence supporting projects included reducing travel time along the main route through the city, improving speed and reliability of trucks, inducing shorter travel distances, and producing to safer traffic conditions. Key concerns were the lack of infrastructure (water, electric, sewer) along the bypass route to promote economic development (attract new businesses), noise pollution, and increased severity of accidents at the new interchanges connecting the bypass to the main route. Overall, respondents in bypassed cities noted shifts in traffic volume from the main road towards the bypass with a positive depiction of relief of traffic on the main road. Respondents were concerned that bypass projects reduced business activity on the main road but there was not a strong feeling that the bypass or widening projects were the source of business declines observed. A comparison of economic impact measures across all nine case studies suggests all projects have some perceived impact on business growth, residential development, and vehicular traffic in the study area. However, bypass projects tend to have a greater perceived impact on business growth and residential development; meanwhile, widening projects have a perceived impact across all these measures since traffic utilizing the new infrastructure is perceived to increase when the existing road gets widen.

Extensions of the survey framework include additional snowball sampling to expand the sample frame beyond the original public hearing attendees. The current framework proposed using public hearing documents to generate a sample frame. This however can lead to response bias. Further, using this approach can be difficult for older projects (5 or more years) as many



participants may move or die which causes problems finding updated addresses. Future work will look to incorporate local Chambers of Commerce and other community groups to distribute survey invitations and expand the sample frame.

While the survey generated insights into the perception of economic and safety impacts, econometric modeling was used to quantify factors that lead to safety impacts. A Random Error Negative Binomial (RENB) model was developed to identify causal factors of crash occurrence at the Traffic Analysis Zone (TAZ) level. Transportation planners can apply the survey framework to evaluate public perceptions of economic and safety impacts, and then use the RENB model to identify safety countermeasures at the TAZ level where transportation infrastructure project is located. The RENB model was applied to a dataset of fifteen years of data, aggregated by month, for the TAZs in Arkansas. The significant causal factors found to contribute to increases in observed crashes include, in order of magnitude (e.g., IRR-estimated magnitude): (i) average precipitation (one-unit increase in average precipitation results in a 134% increase in total monthly crashes for a TAZ), (ii) average wind speed (16%), (iii) urban designation (7%), (iv) traffic volume (2%), and (v) total roadway mileage (1% for each functional class). These findings are indicative of the need to implement real-time traffic management systems, such as changeable message signs broadcasting forecasted adverse weather conditions (rain and wind), to alert drivers to lessen the probabilities of crash occurrence.

Extensions of the RENB model developed for this paper include disaggregation of crash types (severity and type) and further temporal synchronization of weather, roadway, and built-environment variables. A distinction of crashes by type would allow further identification of causal factors that may be crash specific. While employment density was used as a proxy for

land uses, as land-use data was not available, future work should consider the inclusion of land-use mix to capture built-environment influences on crash occurrence and type. Another limitation is that the roadway network data used for the RENB was time-invariant, although the most updated highway network map was used. If roadway data was available for multiple years it could be synchronously matched to weather and crash data.

The work in this thesis will advance transportation planning efforts in terms of post project impact analyses. This thesis introduced a framework and methodology for gauging public perceptions of project impacts post-project and conducting safety evaluations at the zonal level. The broader impact of the work is to better inform communities about potential changes they may experience because of transportation project investment in their town. In this way, communities can be more equipped to discuss project alternatives during project planning meetings and public hearings. This will help to ensure that public voices continue to be a central part of the project planning process.

## Appendix

### Appendix A: Summary of Possible Impact on the Study Areas

**Table A.1 Summary of Possible Impact on the Study Areas**

<b>Impact Category</b>	<b>Impact Sub-Category</b>	<b>Description</b>
<b>Land-Use</b>	Land-Use	Describes the land-use type along the project route.
	Relocation	Mentions any structure scheduled for relocation because of the project.
	Prime Farmland	Describes the topology of the area of the highway corridor and the main farmland activity.
	Public Land	Contains the lands which function primarily in the highway corridor.
<b>Social</b>	Social/Economic	Describes the potential business attraction due to the construction of the project and how this affects the overall economy of the town and the social response to these impacts.
	Social Environment	Consists of evaluations for existing social condition and environmental consequences and the environmental Justice Act is analyzed.
<b>Economic</b>	Economic	Provides a detailed description of the economic conditions and trends within an area including changes in the labor force and employment.
<b>Environmental</b>	Environmental Justice	Lists any environmental justice issues associated with the construction of the project.
	Wetlands	Includes a preliminary survey of wetlands and stream crossing along with the proposed alternatives of the project.
	Mitigation	Describes all regulatory floodway invasion of privacy coordinated with FEMA as well as the impacts of floodplains.
	Water Quality	Describes any water quality impacts in the project area.
	Public Water Supply	Provides a description of the wellhead protection areas and potential water supply. This also includes any permanent impacts to private drinking water sources due to the construction of the projects.
	Floodplains	Describes drainage structures and impounds to the floodplain such as longitudinal encroachments, drainage structures, channel alteration, etc.
	Endangered and Threatened species	List any endangered or threatened species located in the project area.
	Hazardous Waste	This is a preliminary hazardous waste evaluation of the proposed project area. This evaluation identifies if during construction hazardous waste sites are identifies or accidentally uncovered.

**Table A.2 (Cont.)**

<b>Impact Category</b>	<b>Impact Sub-Category</b>	<b>Description</b>
<b>Environmental</b>	Wild and Scenic Rivers	Includes if there is a proximity to the components of the Wild and Scenic Rivers System or streams listed on the National Rivers Inventory.
	Hazardous Waste Sites	Contains all hazardous materials sites within the proposed project area plus a buffer around the project corridors.
<b>Construction/ Historic Sites</b>	Construction	Contains the special provisions of the Standard Specifications for Road and Bridge Construction as issued by AHTD (now ARDOT), provided by the contractors.
	Archeological/Historic	Includes an archeological survey of the project corridor and identify sites with historical tenant houses.
<b>External Factors</b>	Noise	Provides results on the analysis of noise levels along the project area.
	Air Quality	Contains the analysis that indicates the air quality around the project area. Analysis of carbon monoxide concentrations and pollutants are often provided in this section.
	Hazardous Materials and Underground Storage tanks	Identifies the presence of any asbestos-containing materials, plans to accomplish the safe removal of these materials before demolition.
	Visual Impacts	Describes any visual change attributable to the reposed project. For example, views of the proposed highway from adjacent areas and views from the proposed highway of the surrounding landscape, dependent upon land use.
<b>Road Users</b>	Pedestrian and Bicyclist considerations	Describes the primary use of the project area and if there is a presence of pedestrian or bike paths along the highway corridor.
	Cultural Resources	Contains a literature review for recorded prehistoric and historic archaeological sites and architectural sites in the vicinity of the project area.

## Appendix B: Survey Protocol and Questionnaire

### Internal Review Board (IRB) Approval Documentation



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**To:** Sarah Vavrik Hernandez  
BELL 4159

**From:** Douglas James Adams, Chair  
IRB Committee

**Date:** 02/18/2020

**Action:** **Expedited Approval**

**Action Date:** 02/18/2020

**Protocol #:** 1905197074

**Study Title:** Developing an Evidenced-Based Framework for Bypass and Widening Projects and the Effects on Communities

**Expiration Date:** 01/23/2021

**Last Approval Date:**

The above-referenced protocol has been approved following expedited review by the IRB Committee that oversees research with human subjects.

If the research involves collaboration with another institution then the research cannot commence until the Committee receives written notification of approval from the collaborating institution's IRB.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date.

Protocols are approved for a maximum period of one year. You may not continue any research activity beyond the expiration date without Committee approval. Please submit continuation requests early enough to allow sufficient time for review. Failure to receive approval for continuation before the expiration date will result in the automatic suspension of the approval of this protocol. Information collected following suspension is unapproved research and cannot be reported or published as research data. If you do not wish continued approval, please notify the Committee of the study closure.

**Adverse Events:** Any serious or unexpected adverse event must be reported to the IRB Committee within 48 hours. All other adverse events should be reported within 10 working days.

**Amendments:** If you wish to change any aspect of this study, such as the procedures, the consent forms, study personnel, or number of participants, please submit an amendment to the IRB. All changes must be approved by the IRB Committee before they can be initiated.

You must maintain a research file for at least 3 years after completion of the study. This file should include all correspondence with the IRB Committee, original signed consent forms, and study data.

cc: Mervin Jebaraj, Investigator  
Karla Diaz Corro, Investigator  
Muhammad Saifur Rahman, Investigator

## Letter of Invitation (Structured Phone Interviews)



**[City] [Project Type] on [Project Location]**

**[date]**

Dear [Name of Participant]:

You are invited to participate in a research study to measure the economic, social, and environmental effects of highway bypass and widening projects on Arkansas communities. We are conducting structured telephone interviews to better understand public perceptions about the impact of **[Project Type]** of **[Project Location]**. Because you participated in past public involvement meetings related to this project, you are invited to participate in this research study.

We will work with you to find a convenient time and date for the phone interview. The interview will take approximately around 30 minutes. The discussion will consist of scripted questions read by the project research team followed by your responses. The data collected will provide useful information regarding the impacts of the **[Project Type]** of **[Project Location]** on community groups, businesses, and the local economy.

**If you are willing to be interviewed, please contact Karla Diaz-Corro at [kjdiazco@uark.edu](mailto:kjdiazco@uark.edu) or 479-575-8430, so that we can schedule a time and day.**

If you require additional information, have questions, or would like a summary of the study results, please contact Dr. Sarah Hernandez at the number or email listed below. There is no compensation for responding nor is there any known risk. We will not collect your personal information during the focus groups. If you are not satisfied with the manner in which this study is being conducted, you may report (anonymously if you so choose) any complaints to the University of Arkansas Internal Review Board (IRB) Coordinator Ro Windwalker at 109 MLKG, Fayetteville, AR, 72701 or 479-575-2208.

Sincerely,

*Karla Diaz-Corro*  
Graduate Research Assistant  
Department of Civil Engineering  
University of Arkansas  
479-575-8430  
[kjdiazco@uark.edu](mailto:kjdiazco@uark.edu)

*Sarah Hernandez, PhD*  
Assistant Professor  
Department of Civil Engineering  
University of Arkansas  
479-575-4182  
[sarahvh@uark.edu](mailto:sarahvh@uark.edu)

**Figure B- 1 Sample Letter of Invitation Mailed to the Community Leaders**



## Community Survey [City] [Project Type] Impact

Survey  
#001

### INTRODUCTION AND CONSENT

[Read the consent form script]

*Introduction: In [Year], a proposed [Project Type] was considered to alleviate [Project Motivations]. However, due to [Decline reasons, local concerns, disapproval, lack of feasible improvement, etc] the project was declined. The following questions are intended to capture the perceived changes within the city of [Project Location] as a result of deciding not to go forward with the proposed project. Prior to this interview we gathered data on project impacts from property records, census data, and other public data sources. Now we wish to compare your observations and experiences to our data.*

*We will go through a set of around 25 questions. The topic for each set of questions will be introduced by [name of interviewer] and then a set of questions will be asked. After reading each question, we will ask for your input. We will record your responses and may ask for clarification to your statements. We plan to allow 30 minutes for this interview.*

### VEHICULAR TRAFFIC

*Introduction: One of the factors contributing to the need for the [Bypass/Widening] project was to ease traffic congestion along [Project Location]. The next set of questions relate to your perception of changes in traffic congestion or volume since the project decline in [Year].*

1. How do you think **vehicular traffic** along [Street Name] has changed over the last [Number of years since the decline]?
2. How do you think **vehicular traffic** has changed in the area surrounding [City] over the last [Number of years since the decline]?
3. How do you think **vehicular traffic** has changed due to any other factors other than the decline of the [Project Type] on [Project Location] over the last [Number of years since the decline]?

### CRASH OCCURRENCE

*Introduction: Crash occurrence is one measure of traffic safety often used to compare the impacts of a new project. Historical data over the last [Number of years since the decline] show a [reduction/increase/no change] in the number of crashes occurred along [Street Name]. The next set of questions relate to your perception and experience with changes in crash occurrence that may be a result of the project.*

4. How do you think **crash occurrence** along [Street Name] has changed over the last [Number of years since the decline]?
5. How do you think **crash occurrence** has changed in the area surrounding [City] over the last [Number of years since the decline]?
6. How do you think **crash occurrence** has changed due to any other factors other than the decline of the [Project Type] on [Project Location] over the last [Number of years since the decline]?

### PROPERTY VALUE

*Introduction: The next set of questions related to perceived or observed changes in property values over the last [Number of years since the decline]. Here we consider property values to be the amount of money someone is willing to pay for a property and how much the seller of the property is willing to accept. Based on historical data, we see that property values have [increased/decreased/stayed the same] from over the last [Number of years since the decline].*

7. How do you think **property values** have changed in [City] over the last [Number of years since the decline]?
8. How do you think **property values** have changed in the area surrounding [City] over the last [Number of years since the decline]?
9. 6. How do you think **property values** have changed due to any other factors other than the decline of the [Project Type] on [Project Location] over the last [Number of years since the decline]?

### BUSINESS

*Introduction: The next questions refer to changes in businesses along and near the proposed project site. Here, a business is considered to be any and all commercial ventures of any industry, type, or size.*

10. How do you think **existing businesses** have changed in [City] over the last [Number of years since the decline]?
11. How do you think **existing businesses** have changed in the area surrounding [City] over the last [Number of years since the decline]?
12. How do you think **existing businesses** have changed due to any other factors other than the decline of the [Project Type] on [Project Location] over the last [Number of years since the decline]?
13. How do you think **new businesses** have opened in [City] over the last [Number of years since the decline]?
14. How do you think **new businesses** have opened in the area surrounding [City] over the last [Number of years since the decline]?
15. How do you think **new businesses** have opened due to any other factors other than the decline of the [Project Type] on [Project Location] over the last [Number of years since the decline]?
16. How do you think the mix of **business types** has changed in [City] over the last [Number of years since the decline]?
17. How do you think the mix of **business types** has changed in the area surrounding [City] over the last [Number of years since the decline]?
18. How do you think the mix of **business types** has changed due to any other factors other than the decline of the [Project Type] on [Project Location] over the last [Number of years since the decline]?



19. How do you think the number of **shoppers** visiting local businesses has changed in [City] over the last [Number of years since the decline]?
20. How do you think the number of **shoppers** has changed in the area surrounding [City] over the last [Number of years since the decline]?
21. How do you think the number of **shoppers** has changed due to any other factors other than the decline of the [Project Type] on [Project Location] over the last [Number of years since the decline]?

#### TOURISM

*Introduction: Promotion of tourism can be a motivating factor for transportation projects. Potential observable changes in tourism can be attributed to new hotels and business growth, for example. The term tourist refers to someone who travels for pleasure rather than for business. The following questions relate to impacts on tourism over the last [Number of Years since the decline].*

22. How do you think **tourism** has changed in [City] over the last [Number of years since the decline]?
23. How do you think **tourism** has changed in the area surrounding [City] over the last [Number of years since the decline]?
24. How do you think **tourism** has changed due to any other factors other than the decline of the [Project Type] on [Project Location] over the last [Number of years since the decline]?

#### ECONOMIC DEVELOPMENT PROGRAMS (Planners or chamber of commerce representative only)

*Introduction: The next set of questions relate to perceptions and observations of economic development over the last [Number of Years since the decline]. Economic development refers to the process of expanding the economic activity in an area to provide more jobs and income for the residents. Economic development programs, led by city leaders, state agencies, or local business groups, may lead to increased productivity and improved competitive position of the city. Examples of economic development programs include, new distribution facilities, incentives to manufacturers to stay at an existing location, or expansion of current businesses. Based on your knowledge about any type of business assistance and attraction programs currently offered by the city, please answer the following questions:*

25. How do you think **economic development programs** have changed in [City] over the last [Number of years since the decline]?
26. How do you think **economic development programs** have changed in the area surrounding [City] over the last [Number of years since the decline]?
27. How do you think **economic development programs** have changed due to any other factors other than the decline of the [Project Type] on [Project Location] over the last [Number of years since the decline]?



# Community Survey [City] [Project Type] Impact

Survey  
#001

## GENERAL QUESTIONS

- 7. Do you have additional insights that would explain the data divergence found on *[Topic]* between the years *[Range of Years]* in *[Project Location]*?
- 8. What general opinion do you have about the decision made in *[Year of decline]* about the construction of *[Project Type]* on *[Project Location]*?
- 9. Is there anyone else with whom we should speak?

*Please provide contact information:*

Name: \_\_\_\_\_

Phone Number: \_\_\_\_\_

Reason(s) for suggesting this person for an interview:

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

----- *End of Survey* -----

**Figure B- 2 Community Survey (No Implementation Projects)**



# Business Survey Form [City] [Project Type] Impact

Survey  
001

## BUSINESS PROFILE INFORMATION

1. Date: \_\_\_\_ / \_\_\_\_ / \_\_\_\_
2. Name of Company: \_\_\_\_\_ Telephone: \_\_\_\_\_
- Address: \_\_\_\_\_
- City/State/Zip: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_
- Contact Name(s): \_\_\_\_\_

## INTRODUCTION AND CONSENT

[Read the consent form script]

*Introduction: The purpose of this survey is to gather information about perceived and observed impacts of the [Project] in [City] on businesses. The project we are referring to is the [name and description of project]. The project construction began in [start date] and was completed in [end date]. Prior to this interview we gathered data on project impacts from property records, census data, and other public data sources. Now we wish to compare your observations and experiences to our data.*

*We will go through a set of around 25 questions. The topic for each set of questions will be introduced by [name of interviewer] and then a set of questions will be asked. After reading each question, we will ask for your input. We will record your responses and may ask for clarification to your statements. We plan to allow 30 minutes for this interview.*

## SURVEY QUESTIONS

3. Please select a category that best represents the principal products/services your business offers: *(check one)*
- |  |  |  |
|--|--|--|
| <input type="checkbox"/> restaurant or bar | <input type="checkbox"/> gas station               | <input type="checkbox"/> hotel / motel       |
| <input type="checkbox"/> retail store      | <input type="checkbox"/> trucking / transportation | <input type="checkbox"/> wholesale/warehouse |
| <input type="checkbox"/> business services | <input type="checkbox"/> personal services         | <input type="checkbox"/> banking / finance   |
| <input type="checkbox"/> manufacturing     | <input type="checkbox"/> other (specify) _____     |  |
4. Which of the following categories best describes the primary market for your company's product? *(check one)*
- |   |  |  |
|---|--|--|
| <input type="checkbox"/> pass-by traffic  | <input type="checkbox"/> local residents | <input type="checkbox"/> county/region |
| <input type="checkbox"/> within 500 miles | <input type="checkbox"/> national        | <input type="checkbox"/> international |
5. How do customers get to your business or otherwise obtain your products or services?
- |                                      |  |  |
|--------------------------------------|--|--|
| <input type="checkbox"/> Driving     | <input type="checkbox"/> Bus passenger         | <input type="checkbox"/> Other (specify) _____ |
| <input type="checkbox"/> Air or Taxi | <input type="checkbox"/> Mail, Tel or Internet |  |
6. Has the size of your **customer base** has changed by the implementation of the [Project Type] on [Project Location]?
7. Has **retaining your existing customers** been impacted by the implementation of the [Project Type] on [Project Location]?



## Business Survey Form [City] [Project Type] Impact

Survey  
001

8. Does any portion of **shipments** pertaining to your business travel on the *[Project Type]* on *[Project Location]*?
9. In terms of the cost of supplies, delivery time, and suppliers, has the ability to obtain **materials and supplies** been affected by the implementation of the *[Project Type]* on *[Project Location]*?
10. Roughly how many people do you employ?
11. Do your employees **commute** to work using the *[Project Type]* on *[Project Location]*?
12. Has **retaining employees** been affected by the implementation of the *[Project Type]* on *[Project Location]*?
13. Has **recruiting new employees** been affected by the implementation of the *[Project Type]* on *[Project Location]*?
14. Were you satisfied with the existing roadway, traffic, and access conditions in the area **before** the implementation of the *[Project Type]* on *[Project Location]*?
15. Are you satisfied with the existing roadway, traffic, and access conditions in the area **after** the implementation of the *[Project Type]* on *[Project Location]*?
16. Has the **size** of your business operation changed as a result of the *[Project Type]* on *[Project Location]*?
17. Has the **profitability** of your business changed by the implementation of the *[Project Type]* on *[Project Location]*?
18. Has the **sales volume** of your business changed by the implementation of the *[Project Type]* on *[Project Location]*?
19. How long has your company been at its current location (in years)? \_\_\_\_\_
20. Is this your original location?  Yes (*skip to #22*)  No
21. Has the decision to operate in this area been influenced by the implementation of the *[Project Type]* on *[Project Location]*?
22. In terms of advantages and disadvantages, do you consider the *[Project Type]* on *[Project Location]* as a place to do business?
23. Has the number of companies in your line of business changed after the implementation of the *[Project Type]* on *[Project Location]*?
24. What types of companies do you think will be more attracted to the area by the implementation of the *[Project Type]* on *[Project Location]*?
25. Do you have additional insights that would explain the data divergence found on *[Topic]* between the years *[Range of Years]* in *[Project Location]*?



**Business Survey Form**  
**[City] [Project Type] Impact**

*Survey*  
*001*

26. Is there anyone else with whom we should speak?

*Please provide contact information:*

Name: \_\_\_\_\_

Phone Number: \_\_\_\_\_

Reason(s) of suggesting this person for interview on this topic:

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

----- *End of Survey* -----

**Figure B- 3 Private Businesses (Bypass and Widening Projects)**



# Business Survey Form [City] [Project Type] Impact

Survey  
001

## BUSINESS PROFILE INFORMATION

1. Date: \_\_\_\_/\_\_\_\_/\_\_\_\_
2. Name of Company: \_\_\_\_\_ Telephone: \_\_\_\_\_
- Address: \_\_\_\_\_
- City/State/Zip: \_\_\_\_\_/\_\_\_\_\_/\_\_\_\_\_
- Contact Name(s): \_\_\_\_\_

## INTRODUCTION AND CONSENT

[Read the consent form script]

*Introduction: In [Year], a proposed [Project Type] was considered to alleviate [Project Motivations]. However, due to [Decline reasons, local concerns, disapproval, lack of feasible improvement, etc] the project was declined. The following questions are intended to capture the perceived changes to businesses in [Project Location] as a result of deciding not to go forward with the proposed project. Prior to this interview we gathered data on project impacts from property records, census data, and other public data sources. Now we wish to compare your observations and experiences to our data.*

*We will go through a set of around 25 questions. The topic for each set of questions will be introduced by [name of interviewer] and then a set of questions will be asked. After reading each question, we will ask for your input. We will record your responses and may ask for clarification to your statements. We plan to allow 30 minutes for this interview.*

## SURVEY QUESTIONS

3. Please select a category that best represents the principal products/services your business offers: *(check one)*
- |  |  |  |
|--|--|--|
| <input type="checkbox"/> restaurant or bar | <input type="checkbox"/> gas station               | <input type="checkbox"/> hotel / motel       |
| <input type="checkbox"/> retail store      | <input type="checkbox"/> trucking / transportation | <input type="checkbox"/> wholesale/warehouse |
| <input type="checkbox"/> business services | <input type="checkbox"/> personal services         | <input type="checkbox"/> banking / finance   |
| <input type="checkbox"/> manufacturing     | <input type="checkbox"/> other (specify) _____     |  |
4. Which of the following categories best describes the primary market for your company's product? *(check one)*
- |   |  |  |
|---|--|--|
| <input type="checkbox"/> pass-by traffic  | <input type="checkbox"/> local residents | <input type="checkbox"/> county/region |
| <input type="checkbox"/> within 500 miles | <input type="checkbox"/> national        | <input type="checkbox"/> international |
5. How do customers get to your business or otherwise obtain your products or services?
- |                                      |  |  |
|--------------------------------------|--|--|
| <input type="checkbox"/> Driving     | <input type="checkbox"/> Bus passenger         | <input type="checkbox"/> Other (specify) _____ |
| <input type="checkbox"/> Air or Taxi | <input type="checkbox"/> Mail, Tel or Internet |  |
6. Has the size of your **customer base** has changed over the past *[Number of years since the decline]*?



## Business Survey Form [City] [Project Type] Impact

Survey  
001

7. Has **retaining your existing customers** been impacted over the past *[Number of years since the decline]*?
8. Does any portion of **shipments** pertaining to your business travel on the *[Project Type Proposed]* on *[Project Location]*?
9. In terms of the cost of supplies, delivery time, and suppliers, has the ability to obtain **materials and supplies** been affected over the past *[Number of years since the decline]*?
10. Roughly how many people do you employ?
11. Do your employees **commute** to work using the *[Street Name]* on *[Project Location]*?
12. Has **retaining employees** been affected over the past *[Number of years since the decline]*?
13. Has **recruiting new employees** been affected over the past *[Number of years since the decline]*?
14. Were you satisfied with the existing roadway, traffic, and access conditions in the area **before** the proposal of the *[Project Type Proposed]* on *[Project Location]*?
15. Are you satisfied with the existing roadway, traffic, and access conditions in the area **after** the decline of the *[Project Type Proposed]* on *[Project Location]*?
16. Has the **size** of your business operation changed over the past *[Number of years since the decline]*?
17. Has the **profitability** of your business changed over the past *[Number of years since the decline]*?
18. Has the **sales volume** of your business changed over the past *[Number of years since the decline]*?
19. How long has your company been at its current location (in years)? \_\_\_\_\_
20. Is this your original location? Yes (*skip to #22*) No
21. What were the factors that influenced the decision to operate in this area?
22. In terms of advantages and disadvantages, do you consider the *[Project Location]* as a place to do business?
23. Has the number of companies in your line of business changed over the past *[Number of years since the decline]*?
24. What types of companies do you think will be more attracted to the area if there was an implementation of the *[Project Type]* on *[Project Location]*?
25. Do you have additional insights that would explain the data divergence found on *[Topic]* between the years *[Range of Years]* in *[Project Location]*?





**Business Survey Form**  
**[City] [Project Type] Impact**

*Survey*  
*001*

26. Is there anyone else with whom we should speak?

*Please provide contact information:*

Name: \_\_\_\_\_

Phone Number: \_\_\_\_\_

Reason(s) of suggesting this person for interview on this topic:

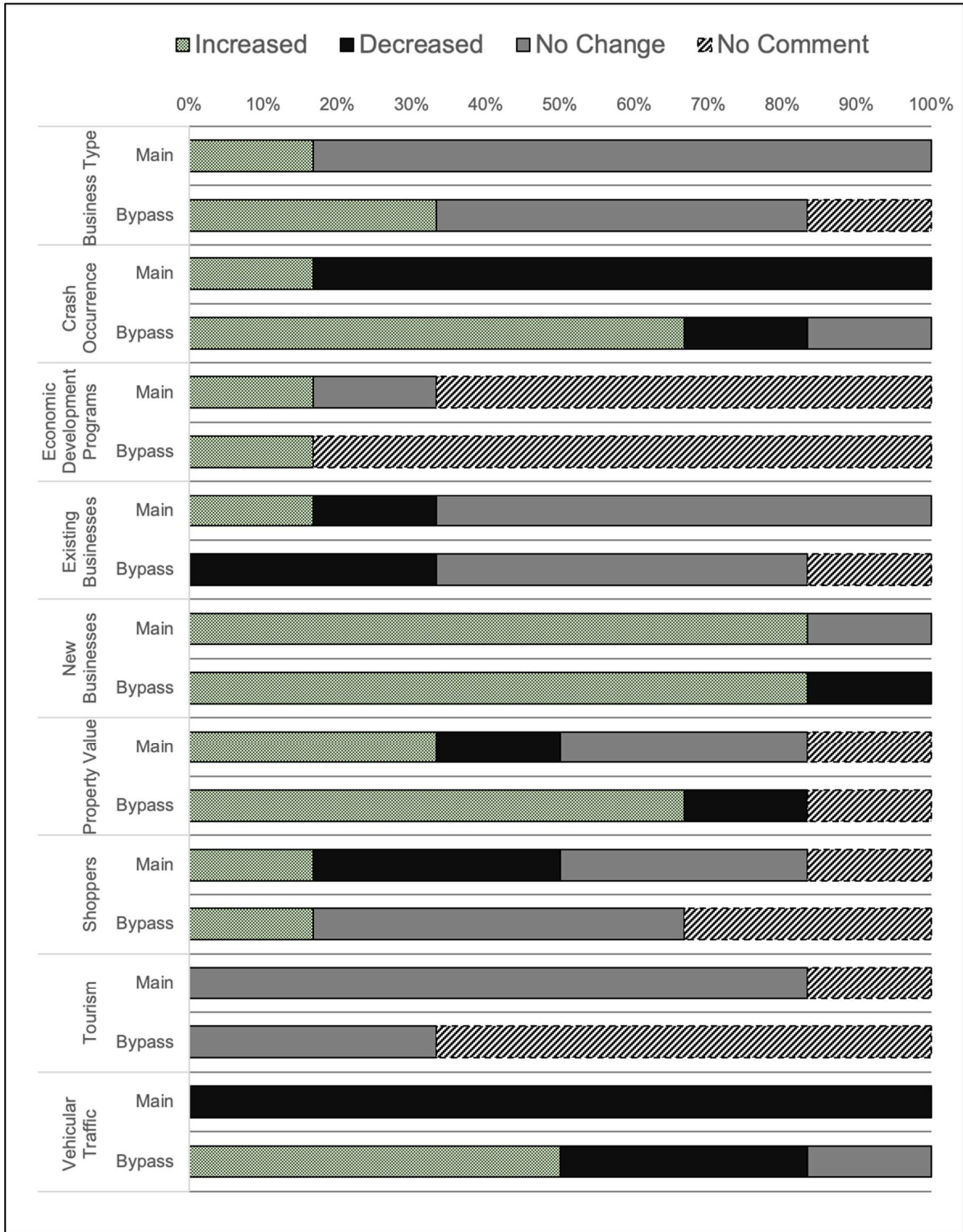
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

----- *End of Survey* -----

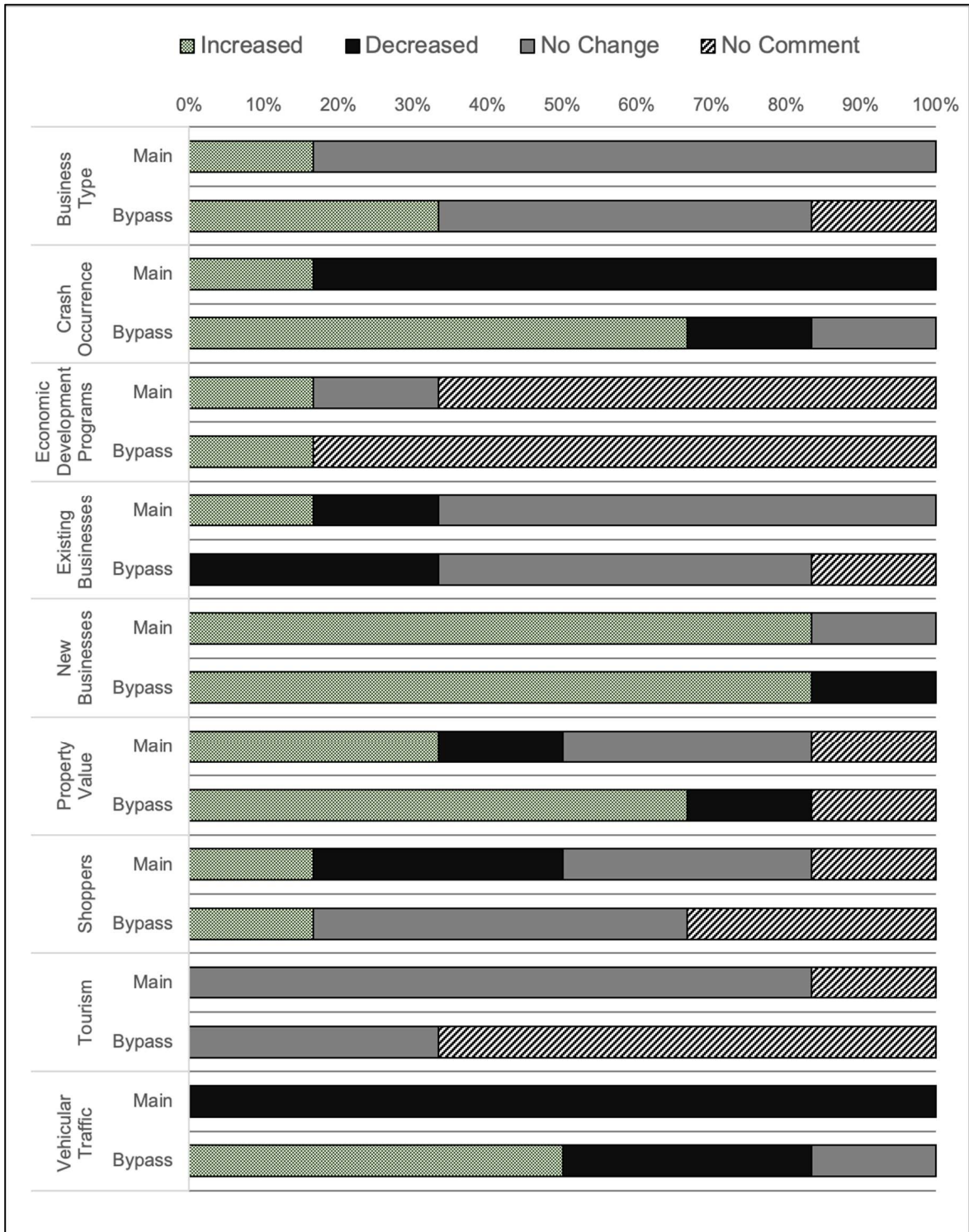
**Figure B- 4 Private Businesses (No Implementation Projects)**



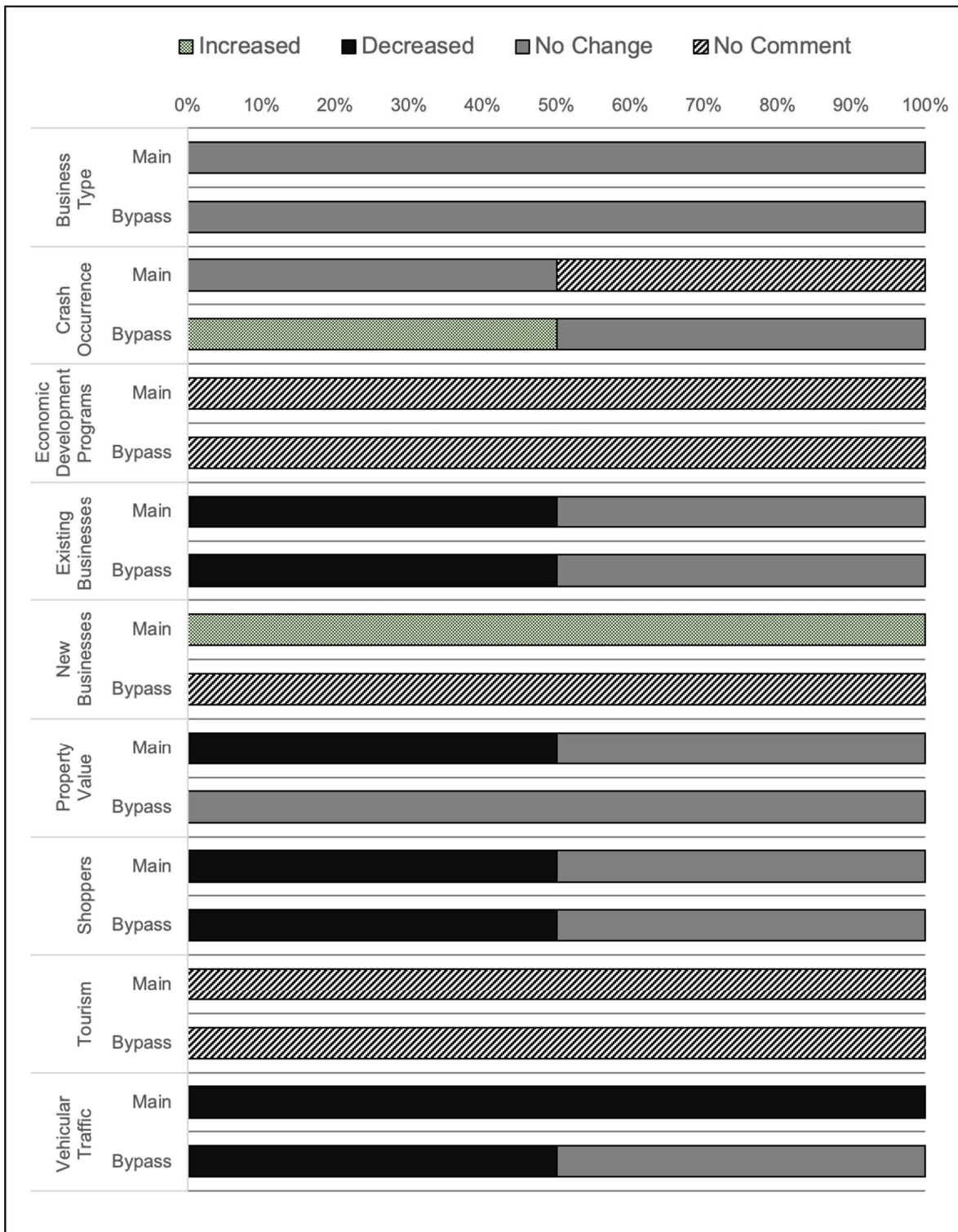
## Appendix C: Survey Results



**Figure C- 1 Community Member Response Summary for the US 167 Bypass in Sheridan**



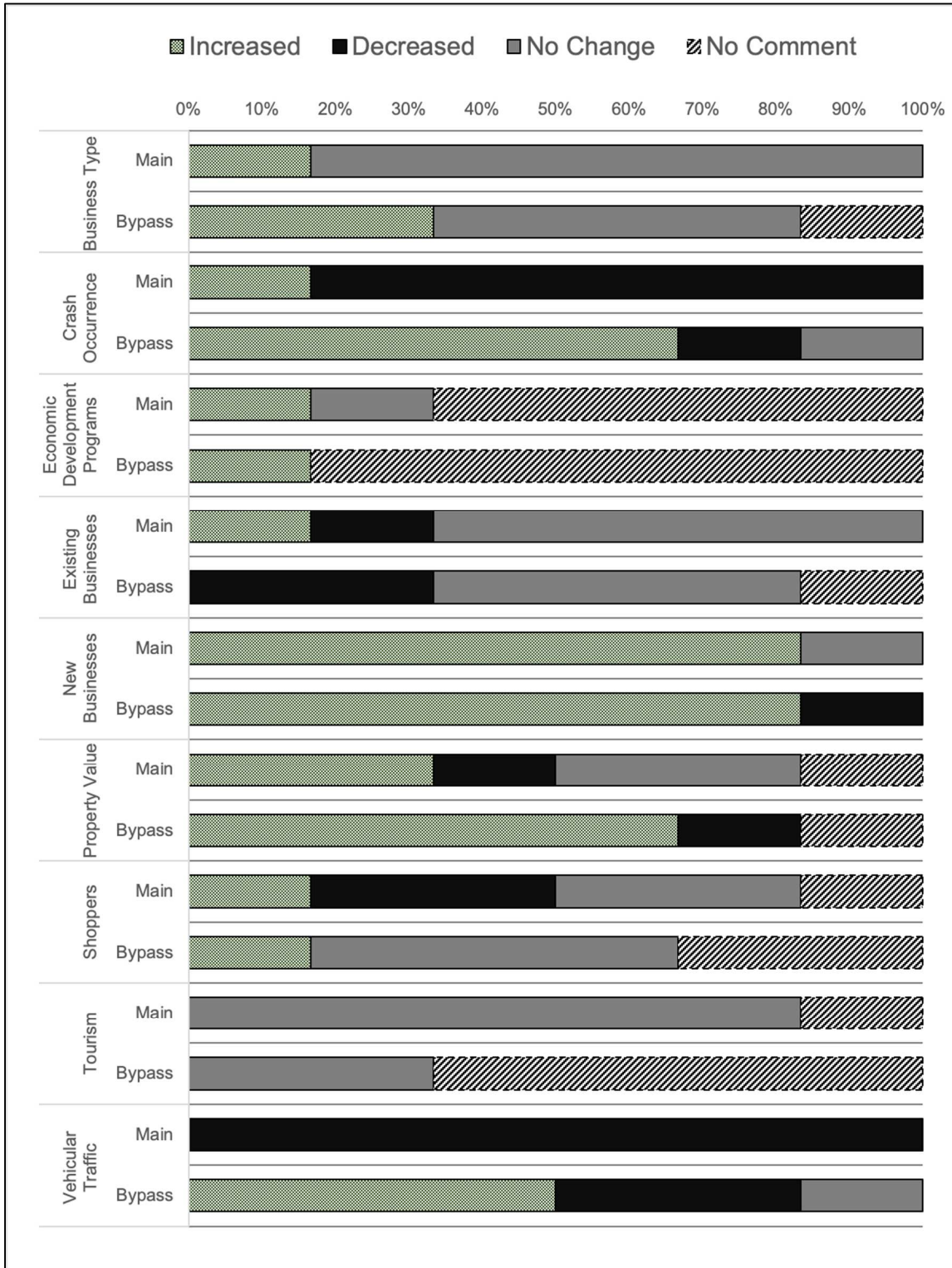
**Figure C- 2 Community Member Response Summary for the Highway 64 Bypass in Vilonia**



**Figure C- 3 Community Member Response Summary for the Highway 412 Bypass in Flippin**



## Widening Projects



**Figure C- 4 Community Member Response Summary for the Highway 65 Widening in Gould**

## No Treatment Applied

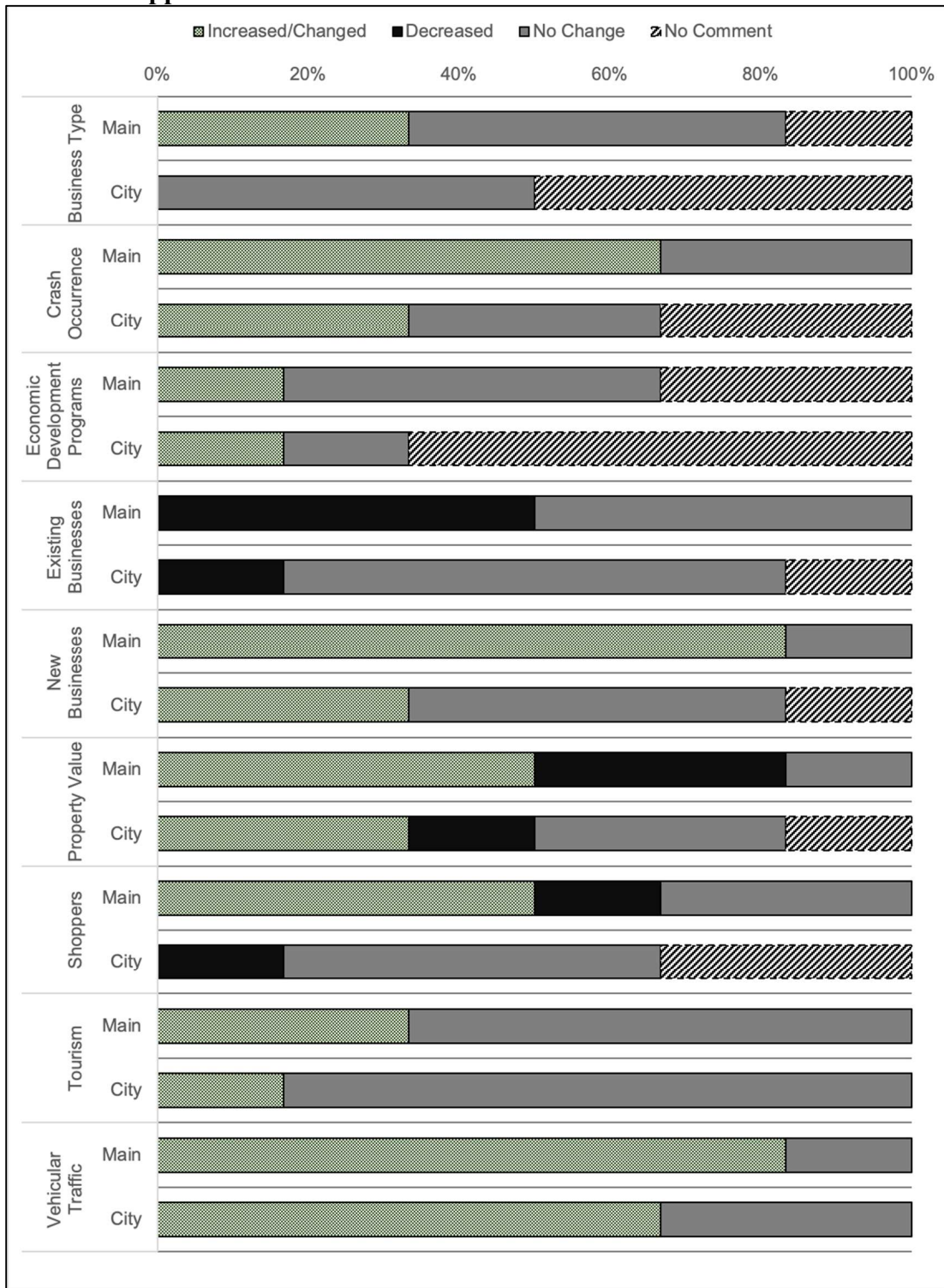
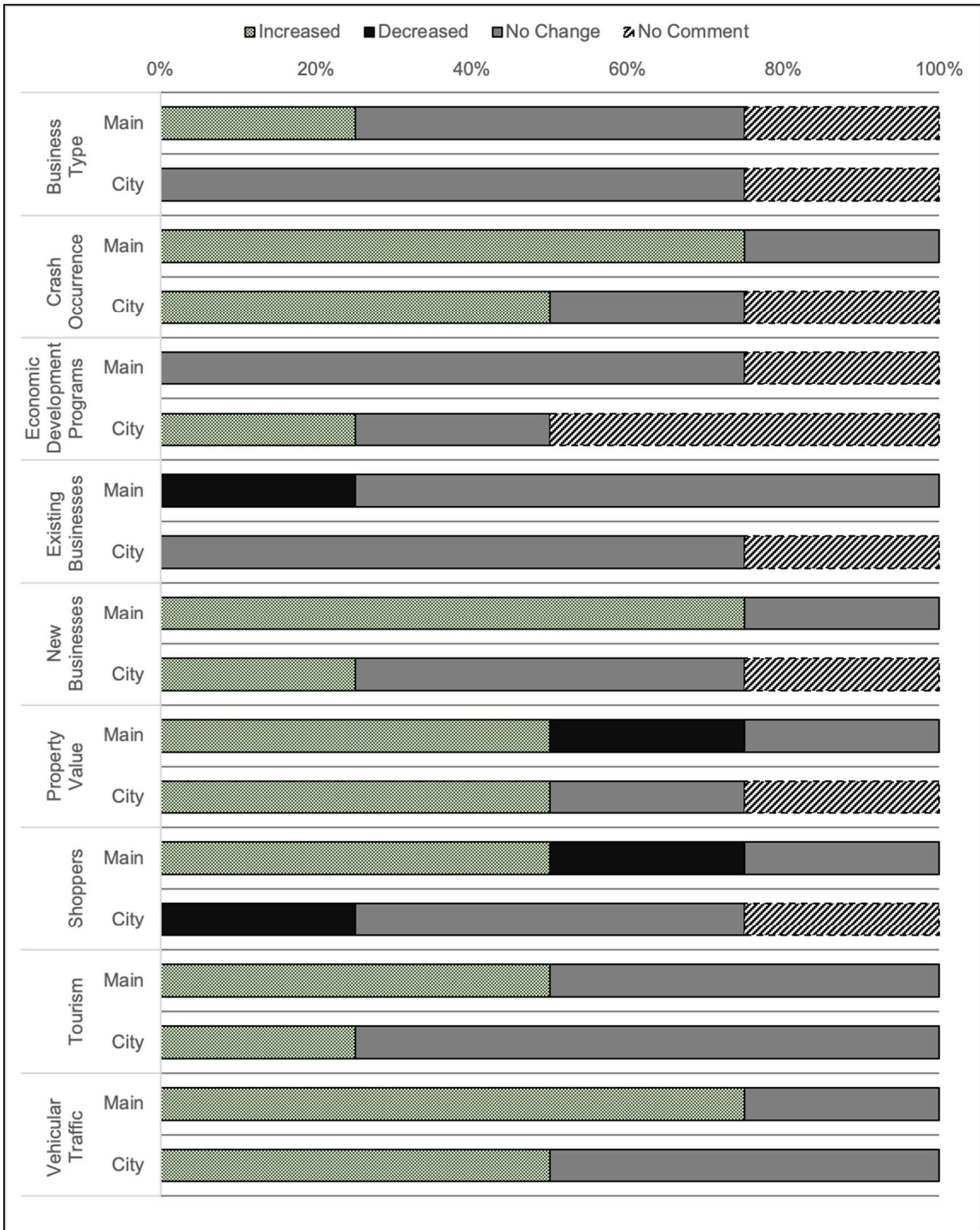


Figure C-5 Community Member Response Summary for Dover and Green Forest



**Figure C- 6 Community Member Response Summary for the Proposed Highway 7 Treatment in Dover**