A Methodology Using Geographic Information Systems to Evaluate Socioeconomic Data Concerning Impacts of Highway Bypasses in Oklahoma

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This research focuses on developing a methodology for selecting and aggregating socioeconomic data that will be useful in assessing the impacts of highway bypasses on towns in Oklahoma. Understanding the economic impacts of building highway bypasses around small towns is an important component of making economically rational, as well as socially equitable, decisions. Small cities and towns that rely on two-lane highways as the main artery for commerce and business can be particularly devastated by a bypass because much of the through traffic will likely divert to the newer, presumably faster bypass route. Currently, the Oklahoma Department of Transportation (ODOT) employs several methods when studying the feasibility of constructing highway bypasses, but has no established methodology for assessing the economic impacts of bypasses. Thus, the ODOT makes bypass decisions based chiefly on traffic and congestion, safety, and environmental issues. The research presented here outlines developing a comprehensive modeling framework that will allow the ODOT to assess quantitatively the potential economic impacts bypasses may cause. The end goal is a user-friendly computer interface that will allow ODOT personnel to estimate impacts of bypass proposals throughout the state of Oklahoma. ***© 2000 Oklahoma Academy of Science***

INTRODUCTION

This report outlines the methodology and data collection strategies that are useful in assessing the economic impacts of constructing highway bypasses. We developed a consistent methodology that merges an analysis of historical trends, geo-referenced socioeconomic data, and Geographic Information Systems (GIS) technology to simplify and largely automate the task of evaluating future bypass alternatives. The desire of the Oklahoma Department of Transportation (ODOT) to possess such a methodology led to the funding of this research project because that agency is currently considering several bypass alternatives in Oklahoma towns along US Highway 70. With a defendable methodology and with reliable data, the ODOT hopes to provide solid estimates of the positive and negative aspects of bypass construction for numerous small towns in Oklahoma. This methodology should help reduce the friction between the ODOT and the public when bypass alternatives are proposed and developed by allowing the ODOT staff and other interested parties to make more informed decisions regarding projects of this type.

The ODOT currently evaluates bypass alternatives via five primary factors: total cost, ability to serve traffic, number of residential and commercial displacements, effect on the local businesses, and environmental considerations along the route (*1*). The ODOT's methodology is to assign each bypass alternative a score of 1 to 5 for each of the five factors, with 1 being the most preferable and 5 being the least. For any given town, the bypass alternative with the lowest score is tentatively chosen. At least two alternatives are evaluated for each town, with one alternative always being an upgrade of the existing route through the town (*1*).

The ODOT already has detailed and standardized procedures for analyzing four of the five factors; the effect on local business is the least analyzed factor. The ODOT's current method of addressing economic impacts apparently consists of receiving feedback at public meetings in which bypass alternatives are presented to affected communities and working closely with city leaders to qualitatively assess bypass alternatives. The absence of a systematic and quantitative approach to economic impacts analysis led the ODOT to request project proposals to fill this gap, resulting in the research presented here.

Although detailed economic analyses of bypass impacts in Oklahoma are scarce, the larger body of transportation literature contains a long history of highway impact studies. A brief review is given next as a precursor to a discussion of the data and methodological issues to be overcome in the case of Oklahoma.

Economic Impact Literature: Analyzing the economic benefits and costs of highway construction is a well-established area of research within the larger field of transportation studies. At the highest level of analysis, abundant recent examples document the economic impacts of highway construction, including the role of transportation corridors as catalysts for economic development (*2*,*3*), land use impacts of highways (*4*), and how employment levels are affected by constructing new highway corridors (*5*).

These types of studies are useful because they outline the various ways that transportation networks impact the area near a highway. Improved efficiency of movement for users, as well as overall improvements in the regional economy, are two main areas in which the economic impacts of highways are typically assessed. User benefits include reduced travel time, reduced operating costs, and increased safety, whereas regional benefits include expanding business, attracting new business, and increasing tourism (*6*).

Most impact studies tend to focus on state- or county-level economic benefits, comparing the economic growth resulting from new highway construction to growth levels in areas without new construction (or to the study area's economic growth before highway construction occurred). However, highway bypasses involve both user and economic benefits because the impetus for bypassing a community probably involves issues of traffic volume, speed, and safety. Once a bypass route is proposed, the economic issues come into play. This research centers on the economic pros and cons of highway bypasses, given that issues of user benefits have already been factored into the decision to consider alternate routes through small communities.

Bypass Studies: Bypass studies are also well-represented in the literature, though none precisely match the needs of the research proposed here. We drew on prior bypass studies to provide a basis for creating a methodology for the ODOT to use in pending and future bypass decisions. The most common methodologies are before-and-after analyses of previously bypassed towns and comparing bypassed towns to non-bypassed control towns (*7*), a procedure this research will follow for its second, analytical stage.

To develop an overall picture of bypass impacts, Horwood et al. (*8*) collected and reviewed 45 of the 70 bypass studies known to have been performed through the early 1960s in the United States. They aggregated variables and results, and derived general trends of the economic impacts from those studies. Thus, rather than performing an original bypass study themselves, they instead analyzed the aggregate results of other bypass studies. This document thus serves as an excellent summary of the state of bypass studies through 1965 and in fact has been neither duplicated nor supplanted by later research. An important conclusion reached in this study was that the size of bypassed towns was possibly the most crucial variable in the bypass analyses. A population of 5,000 appeared to be a fairly critical cut-off; towns larger than this generally experienced few or no negative impacts from bypasses (*8*). Hence, a single statistical model for all towns to be studied will likely be flawed and a hierarchical model of economic impacts analysis, in which different weighting factors or even different variables come into play depending on the size of the bypassed town, should be used.

However, size alone will not determine all the impacts of a bypass. Other factors such as relative location to nearby, larger towns, the length of the bypass and its distance from the downtown core, and the mix of businesses should all influence the net impact of a bypass. Horwood et al. (*8*) noted that while a large array of diverse variables had been used among the 45 studies they reviewed, most could be categorized as either non-highway-oriented or highway-oriented. In particular, highway-oriented retail functions along the bypassed route experienced net income declines. The three primary types of highway-oriented retail functions identified were service stations, restaurants, and hotels. Restaurants were often the hardest hit by bypasses, although hotels likewise could be negatively impacted. However, the small towns under study in Southeastern Oklahoma lack hotels for the most part. Alternatively, non-highway-oriented retail functions generally benefitted from bypasses because of the reduced congestion and pollution in the bypassed cities. Often, even the service stations and restaurants proved able to adapt in many cases, reorienting their services and merchandise to a non-highway-oriented clientele (*8*).

Guidelines for Studying Bypasses: Recent studies provide a fairly consistent set of procedures and guidelines for conducting bypass analyses and larger scale analyses of the overall impacts of transportation improvements. Following Perera's (*9*) example, we classified the economic impacts of bypasses along US 70 into several main areas, including business and industry, tax revenues, and community- and region-level impacts. Perera further divided impacts into temporary (construction related) and permanent (impacts after the completion of the bypass). This research, in keeping with the goal of the ODOT project, will focus on the permanent impacts of bypasses. Within this framework, several possible areas of economic growth, such as expansion of existing businesses; attraction of new businesses; and redistribution of traffic from one portion of the town to another, an action which may depress development in the bypassed portion of the town (*9*), can be measured and evaluated.

Impacts on property values constitute a separate area of analysis because this area involves not only perceived value of homes and businesses but also tax collections (*4*). Because property taxes constitute a main source of revenue for small communities and rural counties, we must pay attention to this aspect when studying the impacts of a bypass. Bypasses generally require the purchase of mostly private land, reducing the tax revenues from that property. Additionally, a new highway route may increase the desirability and accessibility of the area near the bypass, boosting property values and perhaps offsetting the loss of taxes from the land occupied by the bypass. However, in some situations the environmental and aesthetic aspects of the bypass may depress property values (*9*). Ordinarily, local tax rolls would be useful, especially for existing bypasses, in determining the relationship between bypasses, land use changes, assessed land values, and tax revenues.

Finally, a common element of many studies is a qualitative analysis of how business and community leaders feel about the bypass. A recent example is an analysis of six Texas towns (*10*) that involved reviewing each city's history and economy, tracking changes in how highway-oriented businesses were distributed in the community, and interviewing local business and governmental leaders. Perhaps most surprising were the findings that bypasses were generally not perceived as devastating, that the removal of high volumes of traffic from the downtown area was seen as an improvement, and that downtown business owners typically found ways to restructure their businesses to account for the change in clientele (*10*).

Other bypass studies have likewise demonstrated that, because of the diversity that exists in economic conditions in different places, economic impacts are not consistently positive or negative. Thus, no clear cause and effect relationship exists between the highway construction and the resulting economic changes. As a result, no single methodology alone can adequately address the issue of the economic impacts of bypasses, and the framework presented here merges several techniques, an approach quite common in the literature (*10*,*11*).

METHODS

Data Collection and Analysis: The needs of the ODOT and data availability issues in Oklahoma require some modification from the bypass studies reviewed above. Specifically, the end product needs to be reliant on standardized, regularly collected data from sources such as state and federal agencies. Although detailed, on-site analyses (including the qualitative approaches discussed earlier) are ideal methods for assessing all the impacts on a single town, the ODOT requires a methodology that is generic enough to be used for a multitude of small and medium-sized towns that might be bypassed in the near future. This restriction does not preclude the possibility that the ODOT may use the quantitative results in conjunction with its own qualitative analysis to ultimately make bypass decisions, but that aspect is beyond the scope of this project as outlined to us by the ODOT. As a result, we have streamlined data-gathering to allow the ODOT to incorporate future censuses (from CD-ROMs) and data that are regularly collected by state agencies. This approach will permit the ODOT to maintain internally the database and analysis package into the future. This need has required an intense investigation of all reasonable data sources, as described below.

Standard business variables, which make up the primary source of data for determining retail and economic changes resulting from bypasses, include total retail sales, gas station sales, restaurant sales, and service receipts (*10*). These variables thus cover both highway-oriented and non-highway-oriented retail activities. However, in Oklahoma the most comparable data available are sales tax collections gathered by the Oklahoma Tax Commission (OTC). These data are available for 490 incorporated cities as well as for all 77 counties. Counties, however, cover too large a geographic area to be useful in analyzing the impacts of a one or three kilometer stretch of new highway. City-level data, at least for larger towns, were further subdivided by standard industrial classification (SIC)[1] code , and a variety of economic activities that might demonstrate sensitivity to traffic flow were selected. Besides the activities mentioned above, data on clothing stores, drug stores, florists, and video tape rental establishments were gathered to determine if these activities are impacted by bypasses.

Another important data set includes the number of commercial firms, number of manufacturing firms, persons employed (total and by category), wages, and income (*11*). These variables are available from the Economic Census[2] conducted by the US Bureau of the Census, but unfortunately include only the larger urban places in Oklahoma. Some previously bypassed towns are reported in these censuses, but virtually none of the very small places that the ODOT wishes to study are represented. As a result, bypass impacts on larger towns in Oklahoma can be modeled more fully than the smaller towns for which this data could only be collected through intensive, on-site research.

Property tax data would also require exhaustive research at the 77 county courthouses in Oklahoma. Again, this data would strengthen the analysis possible in this project, but the time needed to collect and electronically code it precluded its use in this project, given the desire of the ODOT and us to reduce such intensive data collection and entry. Finally, these data would have to be address-matched and then aggregated to a suitable geographic area (defined below) for use, further limiting their accuracy and usefulness.

Other variables capture the locational context of a bypassed town but are not themselves *directly* affected by the highway construction. Notable among these are socioeconomic conditions, average income per capita in the city before and after construction, and population of the town (*10*). These data are available digitally from the US Bureau of the Census and allow for the finest geographic level of detail in this project, census block groups.

Census block groups are among the smallest geographic units used in compiling the decennial US Census. The decennial census has always reported population by state and county and, in the latter half of the 20th century, added the concepts of the census tract, the block group (or enumeration district), and the census block to its spatial breakdown of the these larger geographic units. The census tract is defined as a small, homogeneous area with an average population of 4,000 persons. The census block, normally used only in urbanized areas, is an actual physical block or other spatial unit within the census tract, with an average population of approximately 100 persons. The census block group combines several blocks to comprise approximately 1,000 persons, on average, and normally represents a residential subdivision or other reasonable geographic entity. Although the actual populations of these spatial units can vary widely, the general rules for average populations for these units tend to be maintained.

Like other predominantly rural states, Oklahoma population census data at the block group level were not reported until 1990, except for Tulsa and Oklahoma Counties. This situation provides little historical data on which to base analyses of socioeconomic changes resulting from bypasses. As a result, we will use these data to inform the ODOT of the existing socioeconomic conditions along the various routes, primarily as a means of determining the potential impacts of bypass construction in terms of numbers of residents, income levels, and employment in various occupations.

Geographic or highway-related explanatory variables include the number of state and US highways in the city, average daily traffic (ADT) volumes on incoming highways (which were supplied by the ODOT), types of new routes, distance between the old and new routes, length of the old and new routes, and distance to a larger city (*11*). The latter variable is crucial, because small towns within approximately 12 kilometers of a larger town seem to be particularly hard hit by new bypasses, as this facilitates the travel of people past the newly bypassed town toward the larger city (*8*). The last three variables listed above require a method of determining distances and topological relationships between places and bring into play the other crucial component of the project, GIS.

Utility of Geographic Information Systems in Transportation Research: The research methodology developed in this project extends beyond of the scope of past work by incorporating quantitative analysis and GIS into a single, comprehensive framework. This approach will allow bypass analysts (initially us, but ultimately the ODOT personnel) to designate potential bypass routes directly on a map displayed on the computer screen. Then, the merger of GIS and the quantitative methodology will produce estimates of employment, business, retail, and tax revenue impacts. Alternative routes can be easily derived and compared to find the most equitable (or least damaging) solution, including the possibility of not constructing a new bypass but instead widening and improving the existing route. This aspect of the project sets it apart from previous studies of highway impacts analyses.

GIS provides an excellent technical basis for conducting bypass studies. Because of its user-friendly graphical interface and ability to produce maps, GIS provides the ideal platform within which data can be selected and aggregated for economic impacts assessments. Within a GIS, data for nodes (intersections), links (highways), and polygons (cities and/or block groups) can be easily chosen, modified (such as proposing a new bypass), and displayed (*12*). This approach will be particularly useful to ODOT in meeting its goal of obtaining a rigorous methodology to weigh benefits and costs associated with potential bypasses and for producing statistics and maps to support such analyses.

When the analyses of the impacts of past bypasses are complete, determining the impacts of such bypasses on any highway within Oklahoma will be a relatively rapid process, compared to such analyses made without GIS. As a part of this project a pilot database for US Highway 70 throughout southeastern Oklahoma is being constructed as outlined above. With the use of this database as a model, a similar data set could be constructed for the entire state, on which the methodologies proposed in this research could be applied. This model will allow the ODOT planners to make more informed decisions regarding such projects and also allow the constituencies living in impacted communities to be better informed regarding the potential impact of future projects.

The reliance on regularly published, secondary data sources will allow the ODOT planners and engineers to maintain the GIS database to continue using these tools and methodologies. However, this update process should be relatively simple and automated, and will help keep such ODOT employees well informed as to the activities and needs of communities throughout Oklahoma. By properly developing and maintaining the GIS database and using the developed model, planners will be able to identify a proposed new bypass route graphically on a map, identify the bypassed highway section, and quickly calculate estimates of affected businesses and other economic activities within a specified distance of these routes. This identification, combined with the impact models developed by using past bypass experiences in Oklahoma, should provide the ODOT with a reasonable estimate of changes that could be expected for the proposed bypass route and replaced highway section.

RESULTS and DISCUSSION

The approach to analyzing the impacts of highway bypasses on small towns and cities developed for this project involves using ArcView GIS to determine the impacted zones within the urban area. ArcView is a desktop GIS that allows the trained user to develop spatial and aspatial queries of socioeconomic data sets, to aggregate spatially referenced data, and to display visually the results of these operations, all tasks useful for this project.

The methodology for determining the impacted area of a bypassed city involves several steps. First, the path for either an older, already-bypassed route or a proposed new route is selected. Using the predefined functions developed for this project, the user "traces" over the old or proposed route with the cursor, and ArcView creates an impact buffer around the selected street or proposed highway at a distance defined by the user. In the second stage of buffering, ArcView selects all impacted streets and side street segments intersected by the initial buffer and creates a second buffer around all these segments.

During the third and final phase of the buffering and selection process, ArcView chooses all block groups that intersect the buffer from the second stage. After completing this process for both the old and new routes, ArcView passes the tabular data relating to the selected block groups for the outlined routes to an analytical model for impacts analysis or for direct computation of summary measures along the routes. By identifying impacted zones in this manner, the user can select and analyze the potentially impacted areas and the data relating to these areas more accurately.

Durant, Oklahoma, was used to demonstrate the power of GIS in highway bypass application. Durant is in southeastern Oklahoma and is one of six towns along US 70 for which the ODOT is considering a bypass (Fig. 1). Durant had been bypassed in 1975 along north-south oriented US 69/75; an east-west bypass of US 70 is being considered. Using the buffering process described earlier, the 1975 bypass route was traced with a 0.2 km buffer that highlighted the areas most directly impacted by that bypass (darkest area on Fig. 2). In this case, the block groups to the west of downtown Durant were selected (lightest area on Fig. 3), while those comprising downtown remained unselected. This tracing and buffering process may be used to delineate a proposed bypass in any location in or around the town.

In addition to selecting socioeconomic data along the old and new bypass route (bottom portion of Fig. 3), GIS allows other characteristics of the city to be selected for analysis. City-level sales tax data for impacted retail functions were selected for Durant (Table 1). Also, traffic count data have been digitally entered into a database,

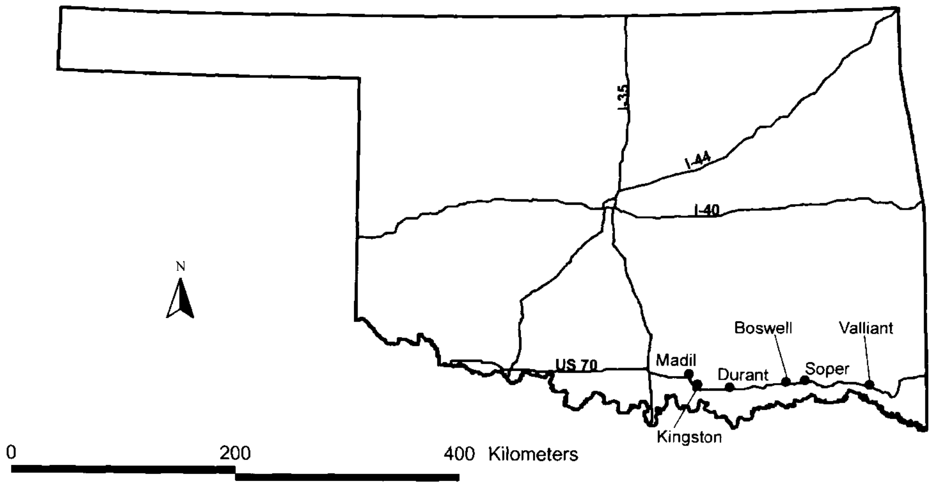

Figure 1. Proposed bypass locations along US 70 in southeastern Oklahoma.

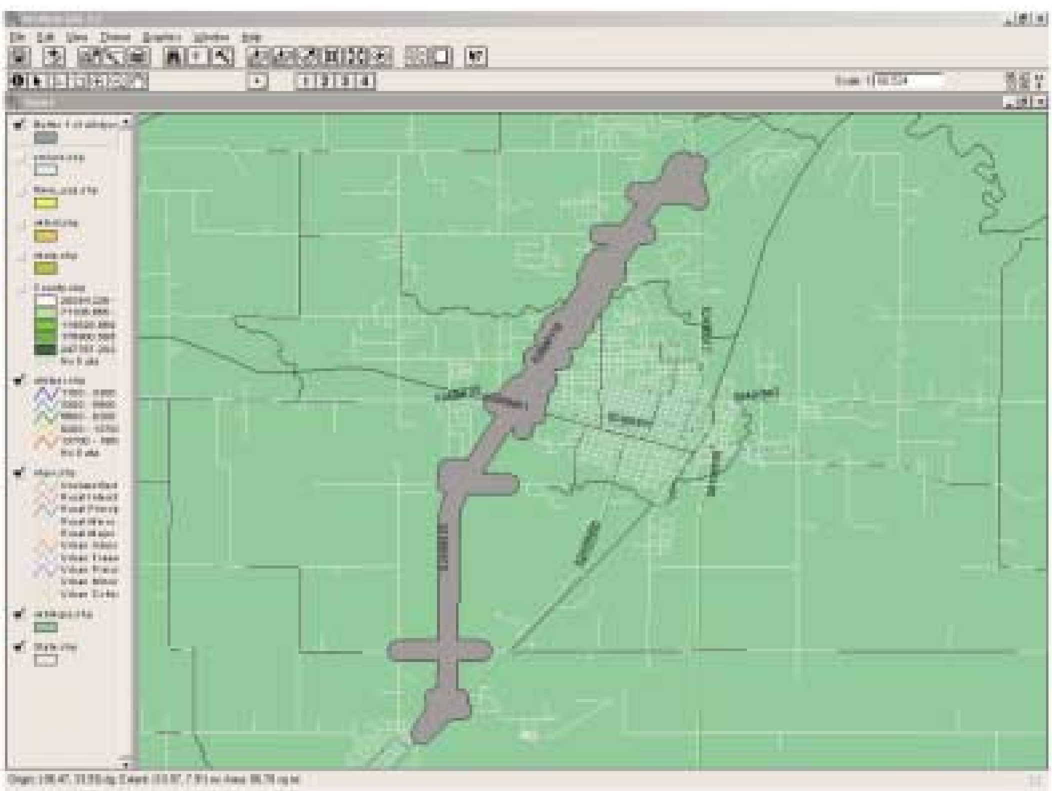

Figure 2. Workscreen showing two-tenths km buffer along existing bypass route in Durant, Oklahoma.

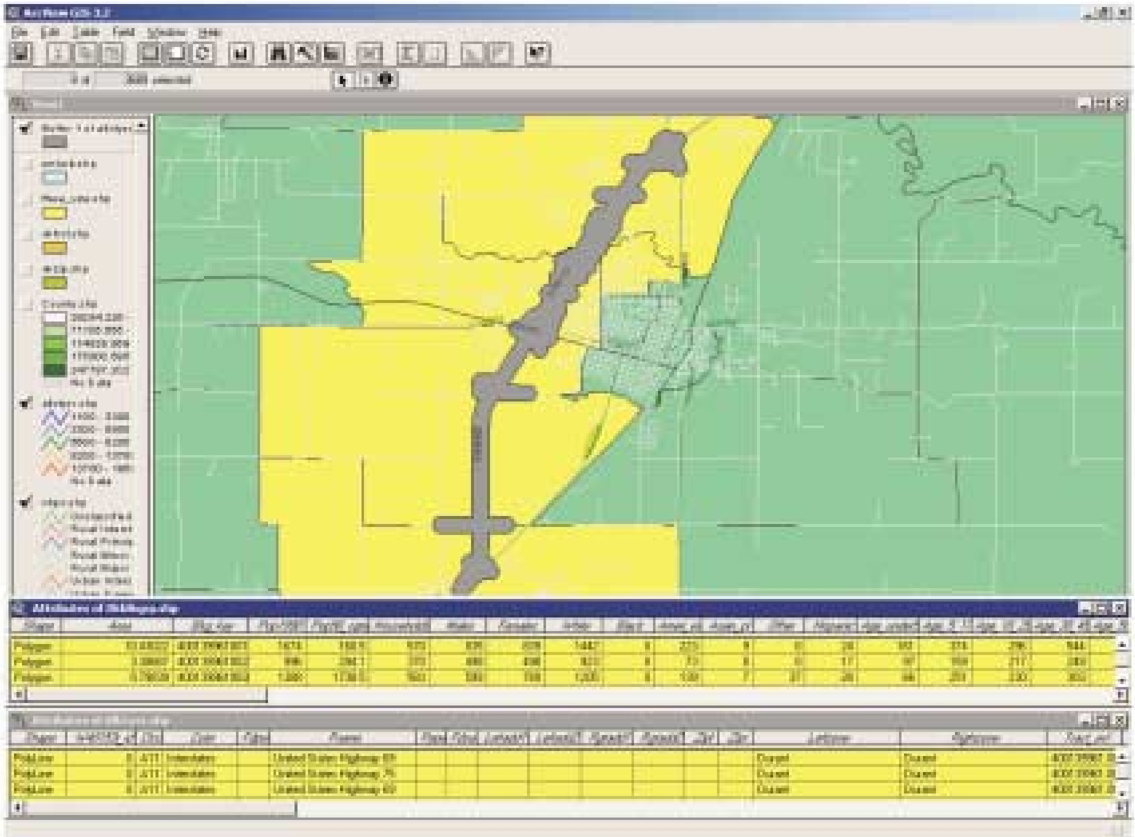

Figure 3. Workscreen showing selected block groups in buffer zone in Durant, Oklahoma.

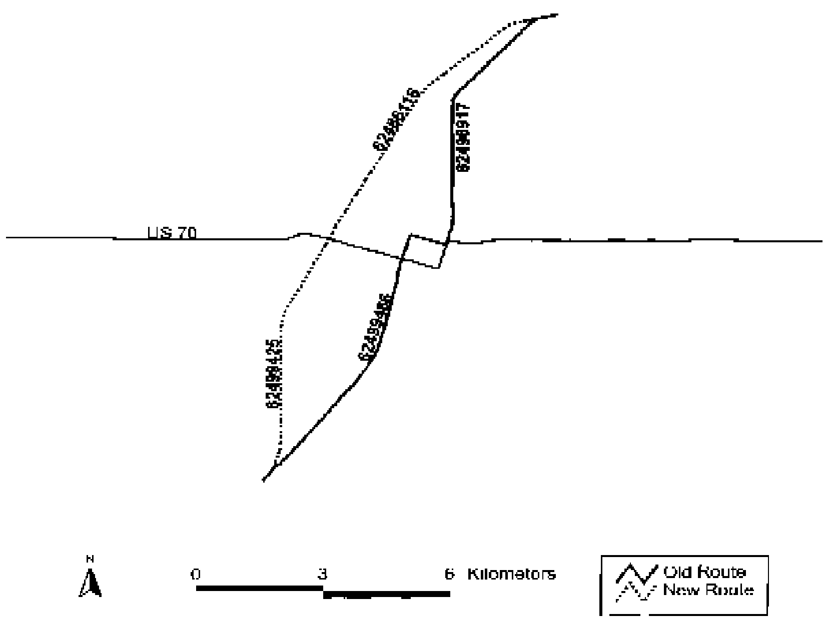

Figure 4. Traffic count meter locations in Durant, Oklahoma

TABLE 1. 1986 city tax collections by SIC code, in 1998 dollars.

City	T86_53	T86_54	T86_55	T86_56	T86_57	T86_58	T86_59
Elk City	291522	318063	63222	52332	32801	106686	132426
Durant	**220150**	**407613**	**82756**	**33244**	**35702**	**100789**	**103938**
El Reno	202530	344484	65973	24217	18458	122906	132388
Ardmore	569981	701308	159576	118289	87381	279304	359710
Talequah	189649	275421	29598	28990	14580	92503	55211
Hugo	132534	170661	28951	9966	10472	44244	50313
Clinton	123894	248439	41757	26115	34022	69652	119210

Note: T86 refers to the year 1986; the two digit numbers that follow are 2-digit SIC codes:
53 = General merchandise stores
54 = Food stores
55 = Automotive dealers and gasoline service stations
56 = Apparel and accessory stores
57 = Furniture, home furnishings, and equipment stores
58 = Eating and drinking places
59 = Miscellaneous retail
Source: Oklahoma Tax Commission

TABLE 2. Traffic counts along old and new routes in Durant, Oklahoma, as a result of the 1975 bypassing of US 69/75.

TLID	TC1971	TC1972	TC1973	TC1974	**TC1975**	TC1976	TC1977	TC1979	TC1981
62499466	6700	7200	7600	7900	**5000**	4500	5000	4800	5100
62496917	9000	9100	9800	9400	**4200**	3800	3500	3500	3800
62499425	4200	4200	4600	4800	**6700**	7500	7900	8500	8800
62486116					**5200**	5600	6800	8000	8500

Notes:TLID is the traffic link ID# for specific sections of highways in the US (see Fig. 4).
TC19** is the traffic count total for the given year.
Traffic counts for TLID 62486116 began in 1975 when that section of the bypass opened.
Source: Oklahoma Department of Transportation

and traffic-link identification (TLID) codes denote specific links along the highway for which traffic counts were measured. In the case of Durant, both the original route of US 69/75 and the bypass route have two monitoring locations (Fig. 4). The traffic counts for these four locations can be easily obtained for analysis of past bypass traffic impacts (Table 2). In the case of Durant, a clear drop-off of traffic occurred along the old route with a concomitant increase of traffic along the new route. Analysis of such traffic changes in previously bypassed towns will be a crucial component of determining the range of economic changes caused by bypasses.

CONCLUSIONS

This paper presented a methodology that will aid in the analysis of the economic impacts of highway bypasses on small towns, with specific reference to Oklahoma and US 70. The methodology presented here is unique in that GIS is used to both visually represent a proposed bypassed directly on a computerized map, as well as to select appropriate socioeconomic data associated with that city for analysis. Although GIS has been used in transportation analysis primarily as a routing and network analysis tool, virtually no previous attempts have made full use of both the topological and database functions that define a GIS. With the completion of these functions for bypass delineation and automatic selection of geo-referenced data, it is now possible to export properly selected data to new or existing statistical models that assess the economic impacts of highway bypasses.

Such statistical analysis represents a logical next step, and in fact comprises the other half of our research for the ODOT. Thus, the work presented here can be considered a work in progress to the extent that the ODOT's desire for overall analysis capabilities through the merger of GIS and statistical analysis has only been half met. However, we believe that the GIS component described in this paper is a crucial first step in bringing all the various variables and analyses together, and that documenting the GIS methodology represents a self-contained module that could prove valuable to researchers performing bypass studies with different goals and working for different agencies. Our work continues with the completion of the statistical analyses, their integration into the GIS methodology, and the ultimate reporting of results to the ODOT, which we intend to describe in future work.

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NOTES

1. Beginning with the 1997 Economic Census, the US Bureau of the Census has

changed its organization of data from the long-used SIC codes to the North American industrial classification system (NAICS) codes. Although the data gathered for historical modeling were originally reported in SIC codes, the final product converts these codes to NAICS so that the ODOT personnel in the future will not have to make this conversion.

2. The US Bureau of the Census conducts the Economic Census in years ending in 2 and 7 (i.e. the last census was 1997 and the next will occur in 2002). These censuses include separate series on various aspects of the economy, including mining, construction, manufacturing, utilities, wholesale trade, retail trade, and transportation and warehousing, to name a few.

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