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RESEARCH

NON-USER IMPACTS OF DIFFERENT HIGHWAY DESIGNS AS MEASURED BY LAND USE AND LAND VALUE CHANGES

in cooperation with the
Department of Transportation
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ECONOMICS OF HIGHWAY DESIGN ALTERNATIVES

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16. Abstract

Many studies are found in the literature pertaining to highway impacts on non-users. This report contains a review of the types of highway impacts, highway impact assessment elements, techniques available to measure land use and land value impacts, and findings of previous studies which indicate the magnitude of land use and land value changes resulting from various types of highway improvement. The land use and/or land value impact measurement techniques are of three major types: (1) land use - land value measurement models, (2) land use - traffic models, and (3) land use - urban development models. Those of the first group have been used much more frequently than those of the other two groups. The finding of land use and land value studies are briefly described in narrative, tabular, or graphic form, according to the following "key" characteristics of highway improvements and affected areas: (1) location of impact area, (2) type of highway improvement, (3) stage of development of impact area, and (4) dominant land use of impact area. The bulk of highway impact research has been directed toward measuring land use and land value impacts of new limited access highways located in suburban and rural areas. The literature contains no procedure that is designed for the highway analyst to use impact data from previous studies in predicting land use and land value impacts of proposed highway improvements. Therefore, the report suggests two procedures which can be used for this purpose. Both procedures fit the prescribed criteria for selecting an impact prediction procedure. The comparability of data from previous studies is the deciding factor as to which prediction technique should be used.

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NON-USER IMPACTS OF DIFFERENT HIGHWAY DESIGNS AS MEASURED BY LAND USE AND LAND VALUE CHANGES

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ABSTRACT

Many studies are found in the literature pertaining to highway impacts on non-users. This report contains a review of the types of highway impact, highway impact assessment elements, techniques available to measure land use and land value impacts, and findings of previous studies which indicate the magnitude of land use and land value changes resulting from various types of highway improvement. The land use and/or land value impact measurement techniques are of three major types: (1) land use - land value measurement models, (2) land use - traffic models, and (3) land use - urban development models. Those of the first group have been used much more frequently than those of the other two groups. The findings of land use and land value studies are briefly described in narrative, tabular, or graphic form, according to the following characteristics of highway improvements and affected areas: (1) location of impact area, (2) type of highway improvement, (3) stage of development of impact area, and (4) dominant land use of impact area. The bulk of highway impact research has been directed toward measuring land use and land value impacts of new, limited access highways located in suburban and rural areas. The literature contains no procedure that is designed for the highway analyst to use impact data from previous studies in predicting land use and land value impacts of proposed highway improvements. Therefore, the report suggests two procedures which can be used for this purpose. Both procedures fit the prescribed criteria for selecting an impact prediction procedure. The comparability of data from previous studies is the deciding factor as to which prediction technique should be used.

SUMMARY OF FINDINGS

The findings of the study of non-user impacts of different highway designs are based on an extensive review of the literature and are summarized below under the appropriate section headings of the report.

Assessment of Highways Impacts

The second section of this report describes how highways influence the environment and affect land development and land use, and reviews the essential elements required to assess these impacts.

As man-made elements, highways become a part of the man-made environment and impact other elements of the environment. Environmental impacts that impose physical changes in an area cause adjustments in the quality and kind of human activity that occurs on the affected properties. In assessing highway impacts on the environment, critical elements -- such as type, location, timing, cause, magnitude, incidence, and significance of impact must be considered. Highway impacts are one of three types: (1) social, (2) economic, or (3) environmental. These impacts can affect people and properties in four locations: (1) right of way, (2) corridor, (3) community, and (4) region. Also, these impacts can be in urban, suburban, or rural locations. Such impacts are expected to occur before, during, and after construction of the facility. The "after" period impacts should be classified into short-term, intermediate-term, and long-term types. Highway impacts can be caused by various highway design, maintenance, traffic volume and demand, and accessibility characteristics. The magnitude, incidence, and significance of the impacts attributed to many of these characteristics have not been determined. This report does present data from previous studies to assist the analyst in making such determinations.

Besides the above highway characteristics, other major determinants of the extent of land development and land use in a particular area are as follows: (1) accessibility to other areas, (2) growth potential of area, (3) stage of development, (4) dominant land use, (5) type of land use controls, and (6) level of land values.

Impact Measurement Techniques

The literature contains several reports which summarize techniques for measuring specific social, economic, and environmental impacts of highway improvements. A review of such techniques is not repeated in this report.

The literature reports several techniques used for estimating highway impacts on land use and land value. These techniques can be classified into three basic groups: (1) land use-land value measurement models, (2) land use-traffic analysis models, and (3) land use-urban development models.

The first group of models measures both land use and land value impacts and includes the following types:

- study area-control area comparison,
- study area-parallel band comparison,
- study area-lateral band comparison,
- regression analysis, and
- case study analysis.

This group of measurement techniques uses the "before" and "after" approach, which compares land use and/or land value data for two points in time for each area. The study-control area comparison is the most common technique used to measure land value impacts. It is the only technique of the group which uses a separate control area. Therefore, it should be the most accurate in measuring general and/or overall highway influence on land use and land value. The band techniques use the most distant band as a control. Multiple regression and case study analyses attempt to quantify many variables which influence land uses and land values. The difficulty with the regression technique is the fact that the most important variable, "the highway improvement," cannot be quantified as a continuous variable. This variable can only be represented in the regression equation as a "discrete" or "dummy" variable. The case study technique is not used extensively because highway research is usually aimed at estimating highway influence on aggregated parcels of land rather than on individual parcels.

The second group of models attempts to quantify the relationship between land uses and traffic volumes for various types of highways. The two models that have been developed are: (1) traffic measurement-land use forecasting model, and (2) land use-traffic volume forecasting model. The first attempts to forecast land use data based on traffic volumes on a highway, and the second attempts to forecast traffic volume and congestion data based on land uses along a highway. The first model has been tested to some extent, but the second has not. The great amount of data required to derive reliable coefficients for the second model may prove to be too costly.

The third group of models attempts to predict land uses resulting from various transportation systems and land development policies. These models are designed to either describe or simulate the process of urban development and growth. The two models which are operational are descriptive in nature. The urban transportation models reviewed are very comprehensive, require extensive data collection, and are designed to forecast land and transportation development of a large region or urban area. In their present form, these models are not applicable to forecasting small area land use impacts resulting from specific highway improvements.

Findings of Highway Impact Studies

In the fourth section of this report, the findings of land use and land value highway impact studies are briefly described and are presented in tabular form. The tables of findings are designed to summarize the reported land use and land value changes that are attributed to highway improvement projects. A comprehensive review of the available highway impact literature is contained in this section.

In reviewing the literature, it was found that the impact studies could be summarized according to the most important characteristics of highway improvements and those areas affected by the improvement. The four "key" characteristics used to summarize the studies are as follows:

- location of impact area;
- type of highway improvement;
- impact area stage of development; and
- dominant land use in the area.

The studies are grouped into three major categories based on the location of the area in which the analysis of the highway improvement takes place; i.e. rural, suburban, and urban locations. Then, the studies within each of the locational categories are subdivided according to the impact area's stage of development and dominant land use type and the general highway description (full or limited access).

The bulk of rural highway impact research has been directed toward analyzing the impact of constructing new interstate highways on land use and land values in undeveloped agricultural areas. Generally speaking, the studies found that land uses and land values change very little along the improvement. Most of the impact of highway change is experienced at interchange areas and by land abutting the facility. Highway-oriented land developments, such as service stations, restaurants, and motels, are the major types of developments that locate at rural interchanges.

Along full access rural road improvements, agricultural land values and building values were found to increase as the level of road service improved, i.e. dirt road to hard-surfaced highway. Several rural road service-land value surveys report similar findings.

The most obvious and profound land use and land value changes resulting from highway improvements are reported to occur in suburban locations. As a result, a large percentage of highway impact research has been devoted to analyzing the interrelationships between land development and highway development. Limited access facilities, such as freeways, have received most of the attention in the literature.

Suburban highway impact areas usually experience large increases in land values and land development due to the improved accessibility brought to the area by the highway improvement and due to the large supply of unimproved land. Normally, residential development is found to be the first type of land use change followed by supportive commercial and institutional development. Within the impact area, commercial and industrial developments locate on abutting properties and near interchanges, while nonabutting properties normally experience residential development.

In general, the amount of land use and land value change in urban areas is dependent upon the stage of development of land adjacent the highway improvement. In impact areas containing very little or no unimproved (vacant or idle) land, previous studies report insignificant amounts of land use and land value change. These types of areas are termed as developed urban areas. On the other hand, studies analyzing the effects of highway improvements in developing areas containing ample supplies of unimproved land found significant amounts of land use and land value change.

Highway improvements in developed or developing urban areas usually cause a dramatic increase in abutting unimproved property values, a significant increase in abutting commercial property values, and a modest decrease in residential property values. Land use changes occur more slowly in urban areas than in suburban areas because of the uncertain feelings of property owners relative to the overall effect of highway improvements.

Suggested Impact Prediction Procedures

In the last section of the report, procedures are suggested for use by the highway analyst to predict land use and land value impacts resulting from proposed highway improvements. The criteria that should be considered before selecting any impact prediction procedure are as follows:

- availability of comparable data from previous studies,
- accuracy of the procedure's predictions, and
- costs and personnel requirements to implement the predictive procedure.

The first of the three criteria seems to be the most critical in selecting a suitable procedure.

Determining the comparability of data from previous studies is a very important task and requires the following types of data: (1) description of highway improvement, (2) description of alternate and intersecting routes, and (3) description of project impact area and nearest urban area.

Two procedures are suggested for use by the highway analyst to predict land use and land value impacts that might result from a proposed highway improvement. The first procedure is called the Comparable Data Prediction Procedure (CDPP), and the second one is called the Inferred Data Prediction Procedure (IDPP). The first procedure uses data from previous studies that are more suitable than that used by the second procedure. To use the CDPP, the following "before" construction period characteristics must be the same for the previously studied highway improvement as for the proposed highway improvement:

- type of highway improvement (design and route location),
- dominant abutting land use, and
- stage of land development in area.

Until other more accurate and less costly prediction procedures are perfected, the above procedures are recommended for implementation by the highway analyst.

Conclusions

The literature is almost void of land use and land value impact data involving the improvement of existing highways of the "full access" type. In most of the previous studies, the land use impacts are not measured as vigorously as are land value impacts. The literature contains no procedure that is designed for the highway analyst to use impact data from previous studies in predicting the impacts of proposed highway improvements.

IMPLEMENTATION STATEMENT

The highway analyst who is responsible for predicting the extent of non-user impacts which may result from a proposed highway improvement will find the contents of this report most useful. It contains the results of an intense and extensive review of non-user impact studies to identify impact measurement techniques and to determine the amount of land use and land value impacts attributed to specific types of highway improvements. The analyst can easily identify previous studies which can furnish him the most accurate and comparable data for use in predicting the land use and/or land value impacts of a proposed highway improvement. By identifying and evaluating the alternative techniques used to measure land use and land value impacts generated from previous highway improvements, the highway analyst will have a better idea which technique is the most accurate in measuring such highway impacts. The report also describes two procedures which show the analyst how to use the results of previous impact studies to predict land use and/or land value impacts. It helps the analyst to decide which of the two procedures to use. This report reveals the data gaps in the highway impact literature which need to be filled with additional research efforts. In this regard, the highway analyst can use the contents of this report in evaluating the techniques that researchers plan to use in conducting the needed highway impact studies.

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INTRODUCTION

A recently completed study sponsored by Texas' State Department of Highways and Public Transportation (SDHPT) indicates that the level of highway funding at that time was insufficient for maintaining a desirable highway improvement program [1]. Lacking additional income, many scheduled improvements have been scaled down or, in some cases, deleted. This action is resulting in a loss of public benefits. The magnitude and scope of the loss are dependent upon which projects are deleted (do-nothing alternative) and the degree to which the surviving projects are scaled down. Also, the losses vary according to location (urban versus rural), types of land use affected, the volume of traffic generated, degree of accessibility, and growth potential of the community. The losses apply to both users and non-users of highways in different degrees, depending on the preceding factors.

Faced with both a large number of requests for highway improvement projects from local political jurisdictions and insufficient funding with which to respond to those requests, the SDHPT is having to make increasingly difficult decisions regarding project need, project selection, and project design. In response to this situation, the SDHPT shifted the emphasis from the building of new highways to increasing the capacity of existing highways. Increasing existing highway capacity can be accomplished in the following ways:

(1) increasing the number of lanes;

(2) improving intersection signalization;

(3) building grade separations at major interchanges;

(4) limiting access (closing intersection, curb openings, or ramps);

(5) eliminating on-street parking; and

(6) providing separate lanes for turning movements.

In order to minimize the loss of public benefits, accurate project impact evaluation procedures must be used. Such procedure will enable the SDHPT to assess the consequences of decisions made to fund or not to fund each potential highway project. The writing of required federal impact statements can also be facilitated through these evaluation procedures.

Although general analytical procedures have been developed to assist in project and design evaluation, there is a need to modify these procedures. For instance, benefit-cost analysis is often employed by decision-makers to assess the advisability of committing resources to a particular project improvement. However, benefit-cost analysis is seldom a comprehensive economic analysis because it usually includes only the benefits and costs that can be stated in dollar terms. In most cases, the benefits are limited to those attributable to highway users such as reductions in travel time costs, vehicle running costs, and accident costs. Due to the difficulty of placing dollar values on indirect effects attributable to non-users, the benefits or loss in benefits of these effects are not considered in arriving at a benefit-cost ratio for a given highway project. However, the impact of highway projects on non-users is an aspect of the decision-making process which has begun to receive more attention in transportation literature. As the SDHPT increases its efforts to expand existing highway capacities, non-user impacts take on added significance. Various non-user impacts can be measured in terms of changes in the use and value of abutting or nearby land. Current land uses and land values represent adjustments to the presence and design features of existing highways. By making subsequent design feature changes, it may be reasonable to anticipate that land uses and land values will undergo an adjustment process.

Purpose and Objective of Study

The purpose of this study is to identify and explain the analytical procedures used to measure highway impacts and to collect and present data from previous studies which indicate the magnitude of the impacts, particularly land use changes, caused by specific types of highway improvements.

The objectives of the study relevant to this report are as follows:

(1) Conduct a literature review of procedures and data developed for measuring user and non-user effects of alternative highway designs.

(2) Select and apply appropriate procedures for determining and evaluating user and non-user benefits, especially those affecting non-users, attributable to specific highway designs.

(3) Determine the land use changes which are attributable solely to changes in new and existing highway facilities.

This report contains results of only the non-user portion of the study. The user portion is presented in a separate report. By agreement with the sponsors, most of the research effort is directed toward the non-user aspects of the study, especially the land use effects.

Method of Study

There are two bodies of non-user information that are of interest to this study: (1) the available literature regarding the impact of highway improvements on land use and land value; and (2) existing impact assessment techniques that are applicable to or adaptable to assessment of land use and land value impacts resulting from highway improvements. In the past, research has been focused primarily on problems and opportunities related to new highway construction and little research has been given to the problems and opportunities related to improvement of existing highways. Therefore, it is reaonsable to expect that the bulk of the literature and most impact assessment techniques will not directly address the subject of this report.

The method of study calls for an extensive survey of the literature to identify and describe the relevant research findings from previous studies. Impact assessment techniques developed for land use and land value impacts must be described and analyzed. Social, economic, and environmental impacts must be examined individually to isolate and evaluate their relationship to land use and land value changes. The land use and land value adjustment process, as related to specific highway improvements, must be described.

Finally, if insufficient data are available on impacts resulting from the improvement of existing highways, assessment techniques designed to measure impacts from new highway construction must be adapted to the needs of this study.

Definition of Terms

Various terms used in this report are defined in the following manner.

User - is a person traveling on the highway.

Non-user - is one of two types of persons: (a) a user when he is not traveling on the highway; and (b) a person who never travels on the highway. A person may be, and often is, both a user and a non-user according to the above criteria.

Highway improvement - is any road construction activity on a new or existing highway. Throughout this report, it is essentially an improvement to the transportation system.

Impact area - is defined as the geographic area experiencing measurable land use and land value changes. This geographic area normally runs parallel to the highway and varies somewhat in width from a few hundred feet to two miles on either side of the improved facility, depending on the depth of abutting properties, the distance to other parallel roads, and the socio-economic and physical characteristics of the area. Previous studies furnish some guidelines on the width of the impact areas. This information is presented in the section of the report which summarizes the techniques used in previous studies.

Study area - is the impact area defined in previous studies which is influenced by the highway improvement.

Control area - is a geographic area similar in all respects to the study area except that the control area is far enough removed from the highway improvement project so as to have been unaffected by it.

Parallel band - is a continuous strip of study area land running parallel to the highway improvement. The band may or may not be abutting the highway improvement.

Lateral band - is a strip of study area land running discontinuously along the highway improvement. It may or may not be located at an intersection ot interchange.

Abutting property - is a tract of study area land immediately adjacent to a highway improvement and is under one ownership and not separated by another road.

Remainder property - is the remaining portion of a tract severed by a right-of-way taking of a highway improvement. A remainder property is usually abutting the highway project.

Non-abutting property - is a tract of study area land not adjacent to the highway improvement but is still located in the study area.

General benefit - is a benefit received by non-users and is accrued indirectly from a highway improvement, such as the benefit accrued to non-abutting properties in the study area.

Special benefit - is a benefit received by non-users and is accrued directly from a highway improvement, such as the benefit accrued to abutting properties in the study area.

Control of access - is the condition where the right of access to land abutting a highway improvement is fully or partially controlled by public authority [2].

Full control of access - means that preference is given to "through" traffic by providing access conditions with only selected public roads and by prohibiting crossings at grade or direct private driveway connections. Highways of this type are called "limited access" facilities.

Partial access - means that preference is given to "through" traffic to a degree that in addition to access connections with selected roads, there may be some crossings at grade and some private driveway connections.

Uncontrolled access - means that no limit is placed on the number of points of engress or egress, except through the exercise of control over the placement and the geometrics of connections as necessary for the safety of the traveling public. Highways of this type are called "full access" facilities.

Frontage or service road - is a road contiguous to and generally paralelling a highway and so designed as to intercept, collect, and distribute traffic desiring to cross, enter, or leave the highway and which may furnish access to property that otherwise would be isolated as a result of the controlled access feature.

Intersection - is a system of interconnecting roadways where vehicles using such roads may come into conflict.

Grade separation - is a structure used to separate vertically two or more intersecting roadways, thus permitting traffic on all roads to cross traffic on all other roads without interference.

Interchange - is a system of inter-connecting roadways, in conjunction with one or more grade separations, providing for the interchange of traffic between two or more roadways on different grade levels.

Closed interchange - is one that provides access to abutting properties by indirect routing only.

Partial interchange - is one that allows traffic to enter and exit in only one direction (usually a right-turn).

Full interchange - is one that allows traffic to enter and exit in both directions (right or left-hand turn).

Clover leaf interchange- isa full interchange which allows traffic turning right or left to proceed on inter-connection ramps that have no stop signs or traffic signals.

Diamond interchange - is a full interchange which has stop signs or traffic signals on the intersecting turning ramps.

Undivided road - is one which has no directional separator, either natural or structural, separating traffic moving in opposite directions.

Divided road - is one which separates the traffic traveling in opposite directions with a directional separator, such as a natural, structural, or striped barrier.

Protected left-turn lane - is an auxiliary lane used for left-turns only.

Continuous left-turn lane - is one that is protected from all other traffic movements from intersection to intersection, i.e. a flush median.

Discontinuous left-turn lane - is situated within the median and normally located at intersections.

Protected right-turn lane - is an auxiliary lane, usually discontinuous, located at intersections.

Median - is a depressed, raised or striped barrier separating traffic traveling in opposite directions.

Depressed highway - is one with the "through" lanes situated below grade.

Elevated highway - is one with the "through" lanes situated above grade by means of earthen or concrete structures.

At-grade highway - is one which is neither depressed or elevated.

Urban area - is one which is located within the "city limits" of a town or city which has a population of at least 10,000.

Suburban area - is one located on the fringe of a town or city which has a population of at least 10,000 and is within two miles of a built-up area.

Rural area - is one located outside the "city limits" of any city or town and is at least two miles from a built-up area.

Growing area - is one which the population density is increasing and new buildings have been recently constructed on much of the previously unimproved land.

Stable area - is one which the population density is changing very little, virtually no building activity is occurring, and the buildings are being kept in a good state of repair.

Declining area - is one in which the population density is decreasing, no building activity is occurring, and the buildings are clearly in a state of disrepair (some are unoccupied).

Undeveloped area - is one which has experienced little are no development of unimproved land into higher uses.

Developing area - is one which is experiencing some development of unimproved land into higher users.

Developed area - is one which has experienced development to the extent that over 95 percent of the unimproved land has succeeded to higher uses.

Unimproved land - is all land not improved with a building and not used for a park or school.

Residential land - is all land improved with a single-family or multi-family building.

Commercial land - is all land improved with a building used to house a retail or service business.

Commercial traffic-serving land - is all land improved with a building used to house a service station, restaurant, or motel business.

Commercial non-traffic serving land - is all other land improved with a building used to house other types of retail and service business (i.e. grocery and clothing stores).

Industrial land - is all land used for the manufacture and distribution of a product to be marketed through retail outlets. This category includes warehouses and storage facilities.

Institutional land - is all land used for schools, parks, governmental facilities, and non-profit operations.

Degree of influence - is a term used to describe the amount of land use and land value change in the study area that can be attributed to the highway improvement.

Absolute change - is the actual change in land use (number of acres) and land value (dollars per acre) measured between project time periods in continuous or discrete terms.

Relative change - is the percentage change in land use of land value based on the amount of absolute change in the respective unit of measure over the base value.

Current or actual dollars - are dollars not adjusted for inflation.

Adjusted or real dollars - are dollars that have been adjusted for inflation.

Before construction period - is a time period selected as a base for measuring land use and land values in the study area prior to any specific planning for the highway improvement is done and prior to the public sector being made reasonably assured of its construction (i.e. public funding). There is a lack of consistency in the literature about how the "before" period is identified, but usually is 3 to 5 years in length.

During construction period - is the period required for detailed planning and construction of a highway improvement in an impact study area. The "during" period normally extends from the time of the contract letting for construction to the opening of the facility to traffic.

After construction period - is a period which begins after the construction is completed and extends to some point in time afterwards, but usually extends to the time the impact study was initiated.

ASSESSMENT OF HIGHWAY IMPACTS

This section of the report consists of a description of how highways impact the environment and affect land development and land use. The elements of the environmental effects and the elements of the highway impact assessment process are described briefly. Particular emphasis is given to analyzing the factors which control the relationships between highways and land development and land use.

Impact on Environment

Of the various types of impacts, the major context in which impacts occur is in the environment. Elements affected by environmental impacts can be classified into: (1) primary elements and (2) secondary elements. Primary elements include air, atmosphere , soil, water, and the man-made environment.

The result of disturbing the primary elements (air, atmosphere, water, soil, and man-made environments) which affect secondary impacts (plants, animals, humans, and man-made objects) is seen in terms of altered human activity. Environmental impacts that impose physical changes in an area cause adjustments in the quality and kind of human activity on the land (land use). Adjustments in the quality and kinds of land use influence land values.

Highways are man-made objects and become a part of the man-made environment. Thus, highways are both primary and secondary elements, impacting other primary and secondary elements that make up the environment.

In assessing highway impacts on the environment, several critical elements must be considered. These are: (1) type of impact, (2) location of impact, (3) timing of impact, (4) cause of impact, and (5) magnitude, incidence, and significance of impact. Each of these is discussed separately.

Type of Impact

Highway impacts are traditionally classified into one of three categories: (1) social, (2) economic, and (3) environmental. Lane, et al., [4] name several specific types of impacts for each of these general impact categories (Table 1). Actually, each of the specific impacts can be subdivided into several more specific impacts (consequences). Winfrey and Zellner [5] listed 71 social, economic, and environmental consequence variables grouped into 15 general categories (Table 2).

A detailed listing of the non-user consequences is helpful to the analyst who must identify, interpret, and predict the impacts resulting from specific highway improvements. The analyst can group these consequences as he thinks best for evaluation purposes.

Location of Impact

Lane, et al., indicate that there is a relationship between their 13 social, economic, and environmental impacts and one or more geographic locations, such as, regional, corridor, and local/individual locations (Table 1). The black dots indicate that a relationship is thought to exist between a locational characteristic and an impact.

Winfrey and Zellner also indicate that there is a relationship between various impacts and geographical location (Table 2). They list four locations: (1) right of way, (2) corridor, (3) community or system, and (4) region of nation. A relationship is indicated by an "x" in the cell, and a blank implies that no relationship exists.

Even more specific locations should be considered in the process of studying highway impacts, especially with respect to corridor and local/individual locations. Among these are impacts such as (1) those parallel to the highway, (2) those at key nodes (interchanges) located laterally

Table 1. Impact Categories by Geographic Location [4]

Impact Categories	Geographic Location		
	Regional	Corridor	Local/ Individual
Social Impacts			
Community Cohesion		●	●
Accessibility of Facilities/ Services	●	●	●
Displacement of People		●	●
Economic Impacts			
Employment, Income and Business Activity	●	●	●
Residential Activity	●	●	●
Effects on Property Taxes	●	●	●
Regional and Community Plans and Growth	●	●	●
Resources	●		●
Environmental Impacts			
Environmental Design, Aesthetics and Historic Values		●	●
Terrestrial Ecosystems		●	●
Aquatic Econsystems		●	●
Air Quality	●	●	●
Noise		●	●

Source: Lane, Jonathan S., Grenzeback, Lance R., Martin, Thomas J., Lockwood, Stephen C., Impact Assessment Guidelines the Role of the No-Build Alternative in the Evaluation of Transportation Projects. National Cooperative Highway Research Program Report 8-11, October, 1976, p. 21.

Table 2. Social and Economic Consequences of Highway Improvements by Area, Type, Location, and Timing [5]

SOCIAL AND ECONOMIC CONSEQUENCE VARIABLES	AREA		TYPE		LOCATION				TIMING			
	URBAN	RURAL	ECONOMIC	SOCIAL	RIGHT-OF-WAY	CORRIDOR	COMMUNITY OR SYSTEM	REGION OR NATION	BEFORE CONSTRUCTION	DURING CONSTRUCTION	AFTER CONSTRUCTION -SHORT TERM-	AFTER CONSTRUCTION -LONG TERM-
1. Aesthetics												
A. The View from the Road	X	X		X	X	X					X	X
B. The View of the Road	X	X	X	X	X	X					X	X
C. Highway-mode-Induced Aesthetic Effects	X	X	X	X	X	X	X				X	X
2. Agriculture												
A. Access to Improved Road		X	X	X		X	X				X	X
B. Economic Units (Size of Farm Unit)		X	X		X	X				X	X	X
C. Productivity		X	X			X	X	X			X	X
D. Dislocation		X	X	X	X	X			X	X	X	X
3. Commercial												
Commercial sales receipts and incomes:												
A. Change Due to Dislocation and Relocation	X		X		X	X			X	X	X	
B. Change Due to Barrier	X		X		X	X				X	X	
C. Change Due to Population Change	X		X			X					X	X
D. Change Due to Income Group Change	X		X			X				X	X	X
E. Change Due to Traffic Volume Change (Bypass Effect)	X		X				X				X	X
F. Change Due to Accessibility Change (Trade Area)	X		X			X					X	X
G. Change Due to Community Price Change (Resulting from Transportation)	X		X				X	X			X	X
H. Rental Property Receipts	X		X		X	X			X			
I. Employment	X		X			X	X			X	X	X
J. Land Use	X		X		X	X	X			X	X	X
K. Land Value	X		X		X	X	X			X	X	X
L. Effect on Public Transportation	X		X	X		X	X				X	X
M. Parking	X		X		X	X	X			X	X	X
4. Community Government												
A. Community Services and Facilities	X		X		X	X				X	X	
B. Park, Recreation and Open Space	X		X	X	X					X	X	X
C. Non-Highway Government Revenue and Expenditure Changes	X		X		X				X			
D. Public Policy and Laws	X	X	X	X	X	X	X	X	X	X	X	X
E. Community Goals	X	X	X	X	X	X	X	X	X	X	X	X
5. Construction												
A. Community Social and Economic Effects During Construction	X		X	X	X	X	X			X		
B. Immediate Effects on Highway Construction Industry	X		X				X	X		X		
C. Long Run Effects on Non-highway Construction Industry	X		X				X	X			X	X
6. Employment												
A. Employment Change Due to New Land Use Development	X	X	X			X	X			X	X	X
B. Employment Change Due to Dislocation and Relocation	X	X	X		X	X	X		X	X		
7. Environment												
A. Noise	X	X	X	X		X				X	X	X
B. Air Pollution	X		X	X		X	X	X			X	X
C. Vibration	X		X			X				X	X	X
D. Drainage Patterns	X	X	X		X	X				X	X	X

Table 2 (Continued)

SOCIAL AND ECONOMIC CONSEQUENCE VARIABLES	AREA		TYPE		LOCATION				TIMING			
	URBAN	RURAL	ECONOMIC	SOCIAL	RIGHT-OF-WAY	CORRIDOR	COMMUNITY OR SYSTEM	REGION OR NATION	BEFORE CONSTRUCTION	DURING CONSTRUCTION	AFTER CONSTRUCTION -SHORT TERM-	AFTER CONSTRUCTION -LONG TERM-
8. Industrial												
A. Industrial Development	X		X			X	X	X			X	X
B. Industrial Dislocation	X		X		X				X	X		
C. Industrial Relocation	X		X			X	X			X	X	
D. Industrial Land Use	X		X			X	X				X	X
E. Industrial Land Value	X		X			X	X				X	X
9. Institutions												
A. Institutional Dislocation and Relocation	X		X	X	X					X	X	X
B. Institutional Accessibility and Patronage Change	X		X	X		X				X	X	X
10. Population												
A. Population Growth	X	X		X		X	X					
B. Population Density	X			X		X	X					
C. Population Geographic Shifts	X	X		X			X	X				
D. Population Distribution	X			X			X					
11. Public Utilities												
A. Utility Joint-Use of Right-Of-Way	X	X	X		X					X	X	X
B. Utility Dislocations and Relocations	X	X	X		X	X			X	X		
C. Utility Patterns and Costs	X		X				X				X	X
12. Residential Neighborhoods												
A. Rents, Costs and Prices of Replacement Housing	X		X			X	X		X	X	X	
B. Residential Relocation Costs	X		X		X				X			
C. Social and Economic Relationships of Dislocatees	X		X	X	X	X			X	X		
D. Quality of Neighborhood Life	X			X	X	X			X			
E. Property Values in Right-Of-Way Before Taking	X		X		X				X			
F. Neighborhood and Community Stability	X		X	X	X	X					X	X
G. Neighborhood and Community Linkage Patterns	X		X	X		X					X	
H. Residential Land Development	X		X			X	X				X	X
I. Residential Property Values	X		X			X	X				X	X
J. Neighborhood and Community Patterns	X			X		X	X				X	X
K. Social Life and Social Patterns	X			X		X	X				X	X
13. Road User												
A. Accident and Safety	X	X	X	X	X	X	X	X			X	X
B. Running Costs--Distance Related	X		X		X	X	X			X	X	X
C. Running Costs--Land-Use Intensity and Population Density Related	X		X		X	X	X				X	X
14. Spatial and Geographical Changes												
A. Local	X	X	X	X	X	X	X		X	X	X	X
B. Metropolitan	X	X	X	X			X				X	X
C. Regional	X	X	X	X				X			X	X
15. Urban Form and Development												
A. Land-Use Inventory	X		X				X			X	X	X
B. Land Values; General	X		X			X	X				X	X
C. Central Business District	X		X	X	X	X	X	X		X	X	X
D. Urban Form and Development Patterns	X		X	X		X	X	X			X	X
E. Real Property and Land Taken for Right-of-Way; Use and Value	X		X				X			X	X	

Source: Winfrey, Robley and Zellner, Carl, Summary and Evaluation of Economic Consequences of Highway Improvement, National Cooperative Highway Research Program Report 122, 1971, pp. 116 and 117.

along the highway, (3) those in urban areas, (4) those in suburban areas, and (5) those in rural areas. Certainly, distance from the highway should be considered in these breakdowns in order to determine how far away highway impacts extend. Thus, influence bands should be utilized.

Timing of Impact

The timing of impact is very important to the impact assessment process. Winfrey and Zellner relate their list of consequence variables to the time in which highway impacts are expected to occur, that is, before, during, and after construction of the facility (Table 2). The "after" period is further divided into short-term and long-term periods. Actually, it is desirable to have an intermediate time period placed between these periods in order to more accurately measure the timing of the after period impacts.

Winfrey and Zellner indicate which time period relates to each of their consequence variables listed in Table 2 by placing an "x" in the appropriate cell. A blank cell indicates that no impact is expected to occur during that time period.

Cause of Impact

There are many highway characteristics which are related to the impact variables listed in Table 2. Lane, et al., name five transportation attributes which are related to one or more of their impact variables (Table 3). These attributes are very broad in scope, in that they do not identify specific facility, maintenance, traffic, and other characteristics. They indicate that a general relationship is thought to exist between a particular transportation attribute and an impact variable by putting a black dot in the appropriate cell in Table 3.

Table 3. Highway Impacts, by Transportation Attributes [4]

Impact Categories	Transportation Attributes: Direct				Indirect
	Physical Facility Characteristics	Maintenance Characteristics	Traffic Characteristics	Travel Demand Characteristics	Accessibility Characteristics
<u>Social Impacts</u>					
Community Cohesion	●		●		●
Accessibility of Facilities/ Services	●		●	●	●
Displacement of People	●				
<u>Economic Impacts</u>					
Employment, Income and Business Activity	●		●		●
Residential Activity					●
Effects on Property Taxes	●				●
Regional and Community Plans and Growth	●			●	●
Resources	●	●		●	
<u>Environmental Impacts</u>					
Environmental Design, Aesthetics and Historical Values	●				
Terrestrial Ecosystems	●	●	●		
Aquatic Ecosystems	●	●	●		
Air Quality	●		●		
Noise	●		●		

Source: Lane, Jonathan S., Grenzeback, Lance R., Martin, Thomas J., Lockwood, Stephen C., <u>Impact Assessment Guidelines the Role of the No-Build Alternative in the Evaluation of Transportation Projects</u>. National Cooperative Highway Research Program Report 8-11, October, 1976, p. 33.

Winfrey and Zellner list 24 highway characteristics that are more specific as to type of design and traffic control that might be encountered (Table 4). The authors indicate the approximate magnitude of an expected consequence resulting from a highway characteristic. However, Winfrey and Zellner give no indication as to whether they expect a favorable or unfavorable consequence. They do indicate with two dashes (--) the pairings in which they think that no relationship exists. Also, an "x" indicates the non-applicable pairings.

Even the list of highway characteristics prepared by Winfrey and Zellner is incomplete or is not specific enough. The new or more detailed characteristics which should be added to the list in Table 4 are as follows:

Highway Design Characteristics

- Service or frontage roads
- Number of main lanes
- Types of interchanges
- Spacing of interchanges
- Grade separations

Traffic Control Characteristics

- Raised or depressed medians
- Median openings between intersections
- Turning lanes at intersections
- Continuous left-turn lanes
- Parking lanes
- Driveway spacing
- Indirect access to abutting properties

Table 4. Degree of Effect of Engineering Factors on Specific Social and Economic Consequences [5]

H - Heavy
M - Medium
S - Slight
-- - None
X - Not applicable

Social and Economic Consequential Factor	1. Coordination with other transportation facilities	2. Coordination with land use plans, projections, and zoning	3. Degree of support of community objectives and goals	4. Length of time involved from conception to award of construction contract	5. Corridor location	6. Centerline location	7. Landscape of right-of-way	8. Degree of control of access	9. Basic geometric design	10. Steepness of gradient	11. Elevation of grade line relative to adjacent land	12. Horizontal curves	13. Intersections and interchanges	14. Traffic safety factors	15. Geometric shape	16. Physical size	17. Aesthetics of constructional materials	18. Period or duration	19. Equipment necessary	20. Handling of traffic during construction	21. Driveway openings	22. Highway lighting	23. One-way and reversible traffic flow	24. Speed changes
Highway Design Element and Degree It Affects The Consequences	GROUP I. Planning, Predesign, and Preconstruction Activities				GROUP II. Rights-of-way and Route Location			GROUP III. Highway Design							GROUP IV. Structural Design and Materials			GROUP V. Construction Operations			GROUP VI. Traffic Control and Traffic Service			
1. Aesthetics																								
a. The view from the road	--	S	M	--	M	H	H	H	H	S	H	M	M	--	H	H	M	H	--	H	--	--	--	--
b. The view of the road	--	M	M	--	M	H	H	H	H	S	M	M	M	--	H	H	M	H	--	H	--	--	--	--
c. Highway-mode induced aesthetic effects	--	M	M	--	M	M	M	H	H	S	M	M	H	S	H	H	M	H	--	H	--	--	--	--
2. Agriculture																								
a. Access to improved road	--	M	M	--	--	M	--	H	S	S	H	--	H	--	--	--	--	H	--	H	H	--	M	--
b. Economic units (size of farm unit)	--	S	--	--	S	M	--	H	S	S	M	S	S	--	--	--	--	--	--	--	M	--	--	--
c. Productivity	--	M	--	--	--	--	M	--	--	--	--	--	--	--	--	--	--	--	--	M	--	--	--	--
d. Dislocation	--	--	--	--	S	H	--	S	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3. Commercial																								
a. Commercial sales receipts and incomes	--	M	M	M	H	H	S	M	M	S	M	--	H	S	S	M	--	M	S	H	H	S	M	S
(a) Change due to dislocation and relocation	--	--	M	M	S	H	--	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(b) Change due to barrier	--	M	M	--	S	H	--	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(c) Change due to population change	--	M	M	M	S	S	S	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(d) Change due to income group change	--	M	M	M	S	S	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(e) Change due to traffic volume change (bypass effect)	--	M	M	--	M	M	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(f) Change due to accessibility change (trade area)	--	M	M	--	M	M	H	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(g) Change due to community price change (resulting from transportation)	--	--	--	--	S	M	--	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
b. Rental property receipts	--	M	--	M	S	H	S	S	S	M	H	--	S	--	--	--	--	H	M	H	S	S	S	--
c. Employment	--	M	M	S	S	H	--	M	S	--	--	--	S	--	--	--	--	M	M	M	S	S	S	--
d. Land use	--	H	M	S	S	H	M	M	S	S	H	S	M	--	--	--	--	S	S	S	M	S	S	--
e. Land value	--	H	M	S	S	H	M	M	S	S	M	S	M	--	--	--	--	S	S	S	M	S	S	--
f. Effects on public transportation	H	M	M	S	M	H	--	M	H	--	--	--	M	--	--	--	--	H	M	H	--	--	S	--
g. Parking	M	M	M	--	M	H	--	H	H	--	--	--	S	S	--	--	--	H	S	H	--	--	M	--
4. Government																								
a. Community services and facilities	M	M	M	S	M	H	S	S	H	--	--	--	M	--	--	--	--	M	--	M	--	S	S	--
b. Park, recreation, and open space	--	H	M	--	M	H	H	S	M	--	--	--	M	--	--	--	--	--	--	H	--	S	--	--
c. Non-highway government revenues and expenditure changes	M	S	S	S	S	H	--	M	--	--	--	--	M	--	--	--	--	S	--	M	--	--	--	--
d. Public policy and laws	S	S	M	--	--	--	M	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
e. Community goals	H	H	H	--	M	M	H	S	--	--	--	--	S	--	--	--	--	--	--	--	--	--	--	--
5. Construction																								
a. Community social and economic effects during construction	--	--	--	--	S	H	--	S	M	--	M	--	M	--	--	--	--	H	S	H	--	--	--	--
b. Immediate effects on highway construction industry	--	--	--	--	--	--	--	X	X	X	X	X	X	X	X	X	X	M	X	X	X	X	X	X
c. Long run effects on non-highway construction industry	--	--	--	--	--	--	--	M	S	--	--	--	M	--	--	--	--	--	--	--	--	--	--	--
6. Employment																								
a. Employment change due to new land use development	--	S	S	--	S	M	S	--	M	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
b. Employment change due to dislocation and relocation	--	S	S	--	S	H	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7. Environment																								
a. Noise	--	--	M	--	S	H	H	--	S	M	--	--	S	--	--	--	--	M	H	H	--	--	--	M
b. Air pollution	--	--	M	--	--	S	S	--	S	M	-	--	S	--	--	--	--	H	M	H	--	--	--	M
c. Vibration	--	--	M	--	--	M	S	--	-		-	--	S	--	--	--	--	--	H	M	--	--	--	--
d. Drainage patterns	--	--	M	--	S	H	M	S	S	M	M	--	S	--	S	S	--	--	--	--	--	--	--	--

Table 4 (Continued)

Social and Economic Consequential Factor

H - Heavy
M - Medium
S - Slight
-- - None
X - Not applicable

Highway Design Element and Degree It Affects The Consequences

Social and Economic Consequential Factor	GROUP I. Planning, Predesign, and Preconstruction Activities				GROUP II. Rights-of-way and Route Location			GROUP III. Highway Design							GROUP IV. Structural Design and Materials			GROUP V. Construction Operations			GROUP VI. Traffic Control and Traffic Service			
	1. Coordination with other transportation facilities	2. Coordination with land use plans, projections, and zoning	3. Degree of support of community objectives and goals	4. Length of time involved from conception to award of construction contract	5. Corridor location	6. Centerline location	7. Landscape of right-of-way	8. Degree of control of access	9. Basic geometric design	10. Steepness of gradient	11. Elevation of grade line relative to adjacent land	12. Horizontal curves	13. Intersections and interchanges	14. Traffic safety factors	15. Geometric shape	16. Physical size	17. Aesthetics of constructional materials	18. Period or duration	19. Equipment necessary	20. Handling of traffic during construction	21. Driveway openings	22. Highway lighting	23. One-way and reversible traffic flow	24. Speed changes
8. Industrial																								
a. Industrial development	--	M	M	S	S	M	--	M	S	S	M	--	M	--	--	--	--	--	--	--	M	S	S	--
b. Industrial dislocation	--	--	--	--	S	H	--	--	S	--	--	--	M	--	--	--	--	--	--	--	--	--	--	--
c. Industrial relocation	--	M	M	S	M	H	--	M	S	S	M	--	M	--	--	--	--	--	--	--	M	S	--	--
d. Industrial land use	--	M	M	S	M	H	S	M	S	S	M	--	M	--	--	--	--	--	--	--	M	M	S	--
e. Industrial land value	--	M	M	S	M	H	S	M	S	S	M	--	M	--	--	--	--	--	--	--	M	M	S	--
9. Institutions																								
a. Institutional dislocation and relocation	--	M	M	S	S	H	--	S	--	S	S	--	S	--	S	S	--	--	--	--	M	M	S	--
b. Institutional accessibility and patronage change	--	M	M	S	S	H	--	S	--	--	--	--	S	--	S	S	--	--	--	--	M	M	S	--
10. Population																								
a. Population growth	S	M	M	S	S	H	S	S	S	S	S	--	M	--	--	--	--	--	--	--	--	--	--	--
b. Population density	M	M	M	S	S	H	--	M	S	S	S	--	H	--	--	--	--	--	--	--	--	--	--	--
c. Population geographic shifts	M	M	M	S	S	H	S	S	S	S	S	--	S	--	--	--	--	--	--	--	--	--	--	--
d. Population distribution	M	M	M	S	M	H	--	H	M	--	M	--	H	S	--	S	S	S	--	S	--	--	S	--
11. Public utilities																								
a. Utility joint-use of right-of-way	M	--	--	--	S	M	S	M	M	S	S	--	S	M	M	K	--	--	--	--	S	S	--	--
b. Utility dislocations and relocations	S	--	--	--	S	H	--	H	M	S	S	--	--	--	M	M	--	--	--	--	--	--	--	--
c. Utility patterns and costs	S	--	--	--	S	M	S	M	M	S	S	--	S	--	M	M	--	H	--	M	S	--	--	--
12. Residential neighborhoods																								
a. Rents, costs, and prices of replacement housing	--	--	--	S	M	M	S	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
b. Residential relocation costs	--	--	--	S	M	M	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
c. Social and economic relationships of dislocatees	--	--	S	S	S	H	S	S	--	--	--	--	S	--	--	--	--	--	--	--	--	--	--	--
d. Quality of neighborhood life	S	S	M	M	S	M	H	S	S	S	S	--	M	--	--	S	S	--	--	--	--	S	--	--
e. Property values in right-of-way before taking	--	--	--	M	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
f. Neighborhood and community stability	M	M	M	M	M	H	M	S	R	--	--	--	M	--	--	--	S	--	--	--	--	S	--	--
g. Neighborhood and community linkage patterns	M	M	M	M	M	H	M	H	M	S	S	--	M	--	M	M	S	M	--	M	--	--	S	--
h. Residential land development	S	M	M	S	M	H	H	S	S	S	M	--	M	--	S	S	--	--	--	--	S	--	--	--
i. Residential property values	S	M	M	S	M	H	H	S	S	S	M	--	M	--	S	S	S	--	--	--	S	--	--	--
j. Neighborhood and community patterns	H	M	M	S	M	H	M	M	S	S	S	--	M	--	--	S	S	S	--	S	--	S	S	--
k. Social life and social patterns	S	M	M	S	M	H	S	M	S	S	M	--	M	--	--	S	S	S	--	S	--	S	S	--
13. Road-user																								
a. Accident and safety	--	--	--	--	--	S	S	H	M	S	S	S	M	H	M	M	--	S	--	S	M	M	M	M
b. Running costs -- distance related	--	--	--	--	M	H	--	H	--	--	--	--	H	M	M	M	--	M	--	M	M	--	S	S
c. Running costs -- land and population density and intensity related	--	--	--	--	M	M	M	M	--	--	--	--	M	--	S	S	--	--	--	--	--	--	--	--
14. Spatial and geographic changes																								
a. Local	M	M	M	S	M	H	H	H	--	--	S	--	M	--	--	--	--	S	--	S	--	--	--	--
b. Metropolitan	M	M	M	--	M	S	M	M	--	--	S	--	S	--	--	--	--	--	--	--	--	--	--	--
c. Regional	S	M	S	--	M	S	S	S	--	--	S	--	S	--	--	--	--	--	--	--	--	--	--	--
15. Urban form and development																								
a. Land use inventory	S	S	M	--	M	M	M	S	S	--	--	--	M	--	S	S	--	--	--	--	--	--	--	--
b. Land values; general	--	--	M	S	M	M	M	S	S	S	S	--	M	--	S	S	--	--	--	--	--	--	--	--
c. Central business district	H	M	M	--	M	H	--	S	S	--	--	--	S	--	--	--	--	--	--	--	--	--	--	--
d. Urban form and development patterns	H	M	H	--	H	H	M	M	S	S	S	--	M	--	--	--	--	--	--	--	--	--	--	--
e. Real property and land taken for right-of-way; Use and Value	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Source: Winfrey, Robley and Zellner, Carl, Summary and Evaluation of Economic Consequences of Highway Improvements, National Cooperative Highway Research Program Report 122, 1971, pp. 70 and 71.

Timing and Location Characteristics

Time lapse after construction

New highway location

Proximity to Central Business District (CBD)

There are probably others that should be added to this list, but these seem to be the major missing design characteristics that should be studied. The literature contains only limited data on the economic consequences of many of the highway characteristics listed above and in Table 3 and 4. These data are reviewed in a later section of this report.

Magnitude, Incidence, and Significance of Impact

The magnitude, incidence, and significance of highway impacts need to be established, if at all possible, to furnish the proper information for rational decision-making concerning highway expenditures [4]. The incidence of impact (identification of the affected persons or things) may not have to be established except in a few cases. In most cases, it is sufficient to measure the impacts on groups of persons or properties.

In some cases, it is very difficult to measure the magnitude of impact in suitable physical units, much less in dollars. Consequently, it is difficult to determine the significance or meaningfulness of the change or impact.

Impact on Land Development and Land Use

As can be seen in the previous tables, many of the impacts or consequence variables that are affected by various highway characteristics pertain to different types of land development and land use. Many of the others, such as land values, rents, population, employment, and income are highly related to types of land development and land use. In other words, many social, economic, and environmental factors affect land development and land use. In turn, many of these same factors are affected by one or more transportation (highway) characteristics. For this reason, it is important to concentrate attention on land development and land use variables which can represent or reflect many impacts. In fact, it is difficult to distinguish highway improvement impacts from other urban impacts unless the proper measurement techniques are used [6]. This is not to say that measurement of the individual impacts is not necessary or desirable, but the more separate impacts that are considered by the decision-maker, the greater the chance of double counting and the more complex the evaluation procedure becomes.

There are several important determinants of land development and land use of particular areas which are discussed separately in the following text.

Accessibility to Area

The one highway characteristic that stands out as being an important determinant of land development and land use is simply the accessibility to and from an area. Some highways are designed to provide little or no access to an area, while others are designed to give full access to all abutting properties. Turnpikes, freeways, expressways, and all interstate highways are of the first type and called limited access facilities. The remaining kinds of highways are of the second type and referred to as full access facilities. The lane capacity, number and types of intersections or interchanges, ramps, and driveway openings, all help determine the degree of accessibility provided an area by a particular highway. Service roads, turning lanes, medians, and grade levels also can affect an area's accessibility.

Since the design of a highway largely determines the degree of accessibility given to an area or to the abutting land, it is important for the highway to be classified according to type of design in order to study its impact on land development and land use. Also, the construction of a new highway in an area should have a much greater impact on land development and land use than improving an existing highway which has already affected land development and land use. Therefore, both old and new highway improvements should be studied for land development and land use effects.

Travel time is another measure of accessibility. The authors of The Growth Shapers [6] say that access is good if the rush hour travel time to the central business district is less than about 30 minutes or if there is other substantial employment within 20 minutes travel time. They say that access is poor if the central business district is one hour or more distant or if there is little employment within approximately 30 minutes travel time. Of course, these travel times will vary depending on the size of a community.

Growth Potential of Area

The growth potential of an area depends on how accessible the area is via a highway or alternate routes to areas that provide employment, shopping, and other services. On the other hand, the extent of land development and land use impact caused by a highway not only depends on the amount of accessibility provided the area but also on the growth potential of the area itself. The growth potential of an area can be explained in terms of the supply and demand for land. The supply of land is determined generally by the amount of vacant land which is developable within the area [6]. Also, the amount of land in low-density use near the highway can be the potential supply of land for high density use, especially if little vacant land is available.

The demand for land is measured by how many people would be willing to occupy new development in the area and how much they would be willing to pay for new homes or business locations constructed in the area. If the demand for land is high, the potential exists for fast development and major shifts in land use.

Existing and projected traffic volumes on highways and roads serving an area are also indicators of the demand for land, especially for high density uses (apartment houses, shopping centers, and other commercial uses) adjacent to the highway. Good access is essential for high density development to occur. The attractiveness of an area also helps determine the demand for land, especially for residential usage.

The supply and demand for land must be used together to forecast the extent of land use change and the rate and pattern in which the change may occur. Table 5 shows nine possible combinations of land supply and demand conditions which affect the amount of land development and land use change [6]. Of these nine supply and demand combinations, there are four conditions, indicated by the unmarked squares, under which land development can be expected to occur. The five marked squares represent conditions under which land development will be inhibited due to low demand or supply of land.

Generally speaking, as the distance from the central business district (CBD) of an urban area or city increases, the density of land use descreases and the amount of vacant or developable land increases. Therefore, distance from the CBD is an important variable that can be used in a model to forecast

Table 5. Two-Way Table Showing Relationship of Demand for Land and Supply of Land [6]

Demand	Supply of Land: High	Moderate	Low
High			X
Moderate			X
Low	X	X	X

Source: Adapted from Urban Systems Research and Engineering, Inc., The Growth Shapers: The Land Use Impacts of Intrastructure Investments, Council of Environmental Quality, Washington, D.C., May, 1976.

the potential for land development and land use changes. Although the population and traffic growth in the immediate area served by a highway under study is of primary importance, the potential growth of the area depends to some extent on the overall growth rate of the whole city. If the primary growth of the city is occurring in the direction of and near the study area in question, the growth potential of that area can be assessed more effectively.

Stage of Development and Type of Land Use

All areas impacted by new highway improvements, including those to be made on existing highways, can be classified into one of three stages of development:

1. undeveloped;
2. developing; and
3. developed.

These stages are defined according to the amount of land development in the study area, as shown in Table 6.

Table 6. Stage of Development and Dominant Abutting Land Uses Categories Defined by Amount of Area Developed and Type and Amount of Land Use Change in Highway Impact Area

Stage of Development and Dominant Land Use	Percent of Area Developed	Land Use Change	
		Type	Percent
Undeveloped Stage			
Unimproved	0 to 5%	to residential	0 to 5%
Unimproved	0 to 5%	to commercial	0 to 5%
Developing Stage	5 to 95%		
Unimproved	5 to 95%	to residential	5 to 90%
Unimproved	5 to 95%	to commercial	5 to 90%
Residential	50 to 95%	to residential	5 to 45%
Commercial	50 to 95%	to commercial	5 to 45%
Developed Stage	95 to 100%		
Residential	95 to 100%	to other residential	0 to 5%
Residential	95 to 100%	to commercial	0 to 5%
Commercial	95 to 100%	to other commercial	0 to 5%
Residential	95 to 100%	to other residential	5 to 25%
Commercial	95 to 100%	to other commercial or light residential	5 to 25%
Residential	95 to 100%	to other residential	25 to 50%
Residential	95 to 100%	to commercial	25 to 50%
Commercial	95 to 100%	to other commerical or light industrial	25 to 50%

Classifying highway impact areas into the above stages of development is helpful in studying land use changes attributable to particular types of highway improvements. Of course, the classification must be made in the "before" period, that is, just before the new improvement has had any impact on land use.

In order to more accurately determine land use changes attributable to a particular type of highway improvement, the impact areas should also be classified according to the dominant land use of the property abutting the facility. Table 6 shows the suggested land use categories for each stage of development and defines them according to the percent of area developed and percentage of land use change in the study area before the construction of a highway improvement. Even other subclassifications within each land use category might be meaningful, such as single-family and multi-family residential or new and old residential, for example.

The above land development and use classification scheme are not only useful as a means determining land use changes attributable to a specific type of highway improvement but also in determining the magnitudes of other impacts, such as land value changes.

Land Use Controls

Land use controls may or may not prevent land use changes from occurring due to a specific highway improvement. Zoning ordinances, building permit requirements, and subdivision restrictions are land use control procedures. Zoning and building permits land use controls are determined and enforced by local city governments, but subdivision restrictions are usually determined by the developer of the subdivision (usually approved by the city).

It would be wise to examine present and previous zoning maps of cities involved in any study to determine the effect of zoning on land use changes in highway impact areas under study.

Land Values

The supply of and demand for land in an area are translated into dollars when willing buyers and sellers agree to exchange certain tracts at specific prices. Land sales prices are the best indicators of land values. Land values, as measured by land prices, are affected by the aggregative economic, social, and environmental conditions prevailing in an area (specific locations) at the time of sale.

Highway improvement projects may provide enough stimulus for a change in abutting land uses to take place and current and potential uses affect land values. Unimproved properties, which have a greater potential to be converted to a higher use than improved or developed properties, normally experience a larger increase in value than improved properties along the right-of-way. Therefore, the relationship between land use and land value is strong and inseparable [7]. Usually, the potential for "higher uses" will increase property value. Higher and higher land uses indicate higher and higher land values.

Land succeeding to higher uses has the potential to yield a higher income stream than land in lower uses. For example, a tract improved with a commercial business is more likely to yield a higher income stream than a tract improved with a single family residence. Therefore, the former should command a higher price in the market place.

In conclusion, land values, like land uses, are affected by the same factors. Both are affected greatly by an area's accessibility characteristics, growth potential, stage of development, existing land uses, and land use controls.

TECHNIQUES AVAILABLE FOR ESTIMATING HIGHWAY IMPACTS ON LAND USE AND LAND VALUE

As indicated earlier, many of the social, environmental, and economic impacts of highways are eventually reflected in the land values and land uses of affected properties. Therefore, it is important to employ research techniques which accurately measure land value and land use changes resulting from highway improvements. Although the primary concern of this section is to review the available land value and land use measurement techniques, the importance of techniques which attempt to measure specific social, environmental, and economic impacts is not minimized. In fact, certain techniques are reviewed which quantify the relationships between land value and land use changes and specific social, environmental, and economic impacts.

There have been several recently completed studies that analyzed the various impacts of highways. For example, Guseman, et al., [9] have summarized the various predictors and techniques for estimating the different social impact of highways. They indicated that the degree of social impact resulting from any large scale public works project (i.e. highway improvement) is primarily dependent on three factors:

1. land use attributes;
2. human ecological factors relating to characteristics of area residents; and
3. social-psychological attributes of residents.

The authors stated that the label applied to a particular use of land primarily describes a characteristic set of human activities or functions which occurs in an area. Therefore, if a highway improvement changes the environment in an area, it will bring about social changes, many of which are reflected in land use and land value changes. Cantilli, et al., in a report entitled

"Toward Environmental Benefit/Cost: Measurement Methodology - Final Report," [3] described several procedures for measuring specific environmental impacts. In a recently completed study by Bigelow-Crain and Associates entitled, "State and Regional Transportation Impact Identification and Measurement," [8] techniques for measuring social, environmental, and economic impacts were reviewed and evaluated. Bigelow-Crain Associates indicated that some land use analyses are used as a surrogate for socio-economic effects such as employment, which, in turn, is often used as a surrogate for gross product. This example illustrates how easy it is to double count the highway effects through duplicating analyses. Skorpa, et al., [10] in a report entitled "Transportation Impact Research: A Review of Previous Studies and a Recommended Methodology for the Study of Rural Communities," summarized previously used techniques to measure highway impacts. Therefore, the reports cited above may be consulted for additional techniques which measure specific social, environmental, and economic impacts of highway improvement projects.

The land use and land value measurement techniques, or methodologies, summarized and described in this report may be divided into three basic groups:

1. land use - land value measurement models;
2. land use - traffic analysis models; and
3. land use - urban development models.

The first group strives to measure both land use and land value impacts by comparing actual land use and/or land value data for two points in time, usually before and then after construction of a highway improvement. The second group attempts to quantify the relationship between land uses and traffic volume for various types of highways, while the third group of methodologies strives to predict land uses resulting from various transportation systems and land development policies.

The individual models within each group of techniques are described and evaluated and, in particular, the types of inputs and outputs of each model are summarized in this section. Each model is evaluated as to its ability to generate accurate estimates or measures of land use and land value changes resulting from changes in highway design which effectively increase a highway's traffic carrying capacity or accessibility.

Although there are varying measurement techniques employed to analyze the effects of highway improvements, the majority of such techniques utilize what is known as the "before-after" study approach. The "before-after" approach is based on the timing of data collected for the analysis. Highway researchers may employ various techniques to determine changes in land uses and land values attributed to the highway facility, but most of the techniques compare economic data from a time period prior to the highway improvement to similar economic data collected after the completion of the improvement in the affected area. Therefore, the effect of the highway change is determined by comparing data from the "before" period to data from the "after" period.

Under this approach, land use and land value information is collected for two separate time periods. The "before" period of the highway improvement (new facility, design change, adding lanes, etc.) is usually considered as a period of time just prior to the contract letting for the construction of the facility or prior to the private sector being made reasonably assured of its construction (i.e. minute order, city council vote, bond election). The "after" period is the length of time passed from the contract letting, minute order, or bond election to the present. Some studies have chosen to distinguish between the construction period, called the "during" period, and the total "after" period. The identification of the time period that begins after contract letting and ends after completion of the project, or "during" period, tends to quantify the speculation that occurs in the real estate market just after the contract letting for the highway project and also helps to quantify the direct effects of its construction on adjacent properties. Having a "during" period enables the investigators to more effectively ascertain the changes in land use and land value attributed to the highway project under study.

The "before-after" approach can be used effectively in determining changes in land uses and land values attributed to highway improvements. Although there may be some problems in determining the proper time periods for the project due to poor governmental (city, county, and state) records, the "before-after" study approach is the most common and widely accepted procedure used to analyze effects of highways.

Land use information may be obtained from existing land use maps maintained by municipal and county governmental agencies. Also, building permit records can be used to estimate land use development in the study area. However, existing land use maps may present several problems to investigators. First, the project's study area may not be properly identified on the maps; and second, the date of the maps may not coincide with the time periods specified. In general, land use maps are likely to be the easiest and cheapest source of land use information available. Land use maps were utilized by Adkins and Thompson [11] and Adkins and Tieken [12].

In situations when land use maps are not available or when the data supplied by the maps are not applicable, land use information may be collected through a survey of the specified areas of impact. This type of primary data collection is costly and time consuming. But when a survey is a viable data source, land use surveys may be conducted through visual observation from the highway, interviews with area residents and real estate brokers, and interviews with governmental personnel (i.e. city planners, tax assessors).

Land value information is easily obtainable from tax offices (city, county, or local school districts) and/or real estate firms. Since land use data are usually listed along with the property assessment on the tax roles, both land use and land value data may be collected from the same source. Researchers must be cautious when using the assessed value of properties quoted on tax roles because in areas experiencing a changing real estate market structure, the assessed property tax value usually lags well behind the current fair market value. In other words, the actual market value of properties under analysis may be well above the assessed value listed on tax roles. Adkins [45] used both assessed valuations and real estate sales to determine land use changes. Buffington used only real estate sales prices in studying land value impacts of the interstate highways in Texas [7, 13, 14, 15, 17, 18, 19, 20, 21].

Land Use - Land Value Measurement Models

The techniques used by researchers in analyzing the effects of highways on land use and land values in a study area vary according to the type of land use and land value information available, the availability of comparable control area(s), and the type of analysis to be performed. The basic land use - land value measurement techniques are:

1. study area - control area comparison;
2. study area - parallel band comparison;
3. study area - lateral band analysis;
4. regression analysis; and
5. case study analysis.

In the review of each individual technique, several studies using the specific methodology are identified and briefly described.

Study Area - Control Area Comparison

The study - control area technique is used to measure the influence of highway improvements by comparing land use and land value data for similar time periods in different areas of the affected community. This procedure is one of the most common methodologies used in land use - land value analysis. The procedure ideally calls for two areas to be exactly alike, a study area situated near the highway project being analyzed and a control area far enough removed from the project to have been unaffected by the highway change. The land use and land value data for the study are collected for each time period and area specified.

To estimate property values in the areas studied, researchers may collect all or a sample of the assessed values or sales prices of the properties involved. The choice between using all or a sample of such data depends upon the number of properties or sales transactions involved.

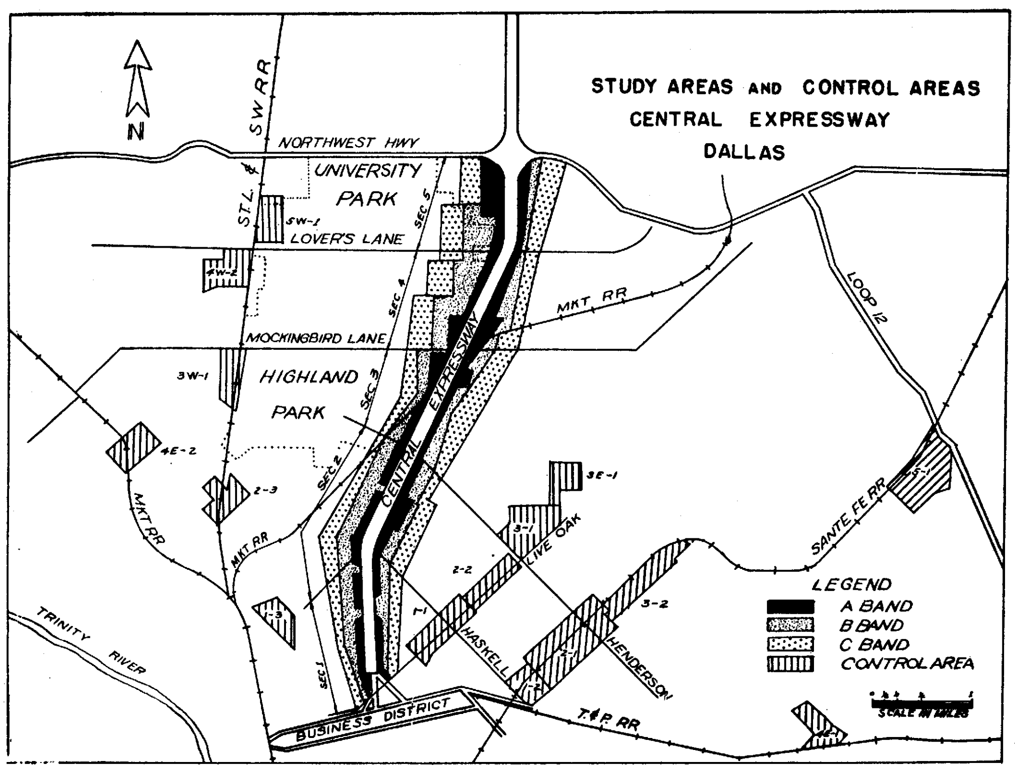
After the land use and land value data have been collected for each project time period and area, the effects of the highway are determined by comparing the data from the study area to the data from the control area for each highway project period. The influence on land use and land value attributed to the highway are represented in the differences in the changes in study and control areas between time periods. Usually, absolute and percentage changes (based on average values) are used for comparative purposes. However, the individual observations may be used in a regression analysis to measure the extent of the relationship between two or more variables.

As indicated above, the rationale for using the study-control area technique is cast in terms of the ideal situation, finding two areas exactly alike. In the real world, no two areas are identical in all respects. To hedge for this fact, it may be desirable to have two or more control areas specified for each highway influence study area. Additional control areas were utilized by Adkins and Tieken's, [12] and in the University of Kentucky's "Certain Economic Effects of the Lexington Northern Belt Line" [22]. Each area possesses its own set of variables that affect land use and land value in varying degrees, and to assume that two areas could be exactly alike would be rather naive.

Study Area - Parallel Band Comparison

When comparable control areas are not available, investigators may choose to implement a technique which uses a large study area which is divided into bands paralleling the highway project (Figure 1).

Figure 1. Schematic Diagram of Study and Control Areas [45]



Source: Adkins, William G. "Effects of the Dallas Central Expressway on Land Values and Land Use." Texas Transportation Institute, Bulletin 6, September 1957, College Station, Texas, p. 7.

The large study area substitutes for the control areas described in the previously stated technique. Due to the size of the study area, it is assumed that the highway improvement under investigation will not have affected the outer reaches or bands. Therefore, to ascertain and measure the influence of the highway, land use and land value data are collected and aggregated in the same ways described in the study-control area technique. Differences in the changes between the outer and abutting bands thus would be attributed to the highway's influence.

Dividing the study area into separate bands parallel to the highway adds more detail to the analysis of the specific areas of influence. The bands situated near the facility should be affected more dramatically, especially the band of properties abutting the highway, than those bands located farther away. The parallel band approach enables researchers to test this hypothesis and quantify the impact differences at increasing distances from the highway right-of-way. In Adkins' study, "Effects of the Dallas Central Expressway on Land Values and Land Use" [45], the parallel band approach was used in conjunction with the study-control area technique. Adkins selected three bands of land, designated A, B, and C, on either side of a new expressway (Figure 1). Band A properties were those abutting the facility and not separated by a street, alley, or other division. Band B properties were those not qualifying as A-Band property and not lying more than three blocks from the right-of-way. Band C properties were those adjacent to Band B and extending outward approximately two blocks. Each band of properties served as an inclusive study area that was compared to the other two bands for three different time periods.

Each band was examined for land value and land use changes. The bands were subdivided according to selected criteria (i.e. unimproved vs. improved land) to identify the effects of the highway on different land use categories. Each band was studied in the terms of two different formulas, Index 1 and Index 2, which computes the absolute and percentage changes between the three study areas and the control areas (Table 7). The Adkins study, [45], is one of the landmark economic studies in highway research and the findings and conclusions made in his analysis are presented in the next major section of this report.

Table 7. Summary of Expressway Effects on Land Prices and Land Tax Valuations (A, B, and C Bands, Portions Annexed to the City Before 1941) [45]

	Net Influence of Expressway					
	A Band		B Band		C Band	
	Index 1	Index 2	Index 1	Index 2	Index 1	Index 2
Prices of All Land[2]						
1941-45 to 1946-50	−121%	−80%	−59%	−64%	−49%	−26%
1946-50 to 1951-55	563	563	64	64	84	84
1941-45 to 1951-55	442	483	5	0	35	58
Prices of Unimproved Land						
1941-45 to 1946-50	−14	−18	−39	15	−71	−28
1946-50 to 1951-55	393	386	133	206	79	133
1941-45 to 1951-55	379	368	94	221	8	105
Land Tax Valuations						
1945 to 1955	286	304	41	42	16	18

[1]Index 1 = (absolute increase in study areas minus absolute increase in control areas) ÷ base value in study areas.

Index 2 = percentage increase in study areas minus percentage increase in control areas.

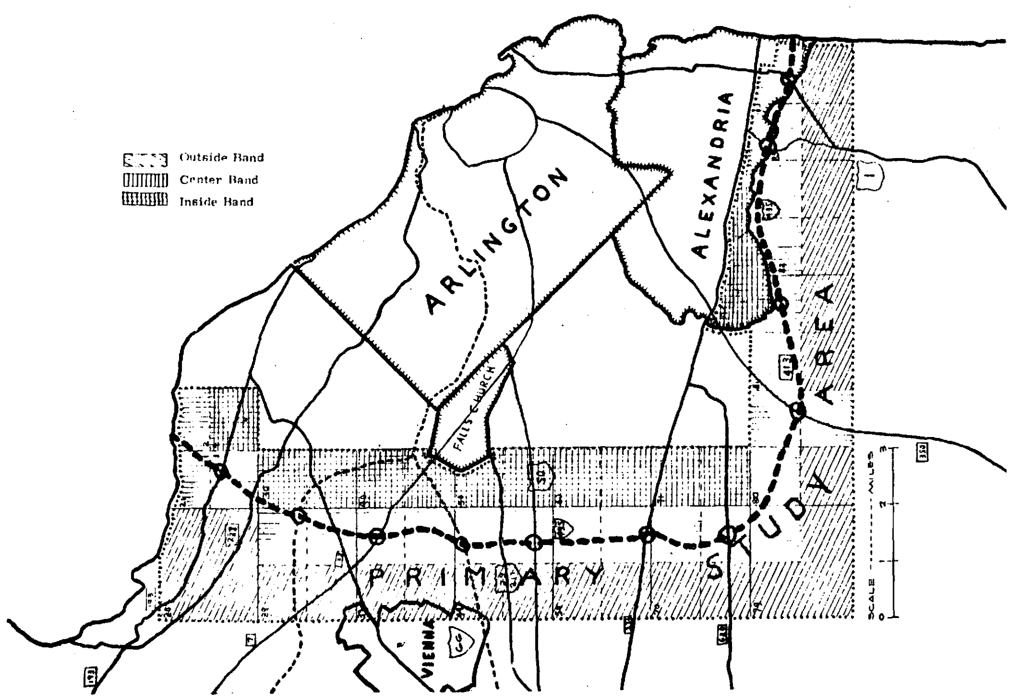
[2]Includes sales of both improved and unimproved land. Improvements are removed from prices by Method II. Method II = Sales prices minus (tax valuations of improvements multiplied by a construction cost factor). The resultant price is theoretically that paid for "bare" land.

Source: Adkins, William G.,"Effects of the Dallas Central Expressway on Land Values and Land Use." Texas Transportation Institute, Bulletin 6, September 1957, College Station, Texas, p. 16.

Several other studies employed basically the same band approach as described above, but because researchers could not locate a separate and comparable control area, an extremely wide band of land was selected for examination. A band extending 7,500 feet (2286 meters) from the facility in both directions was used in "The Effects of a Depressed Expressway - A Detroit Case Study," [23] by Duke. Duke assumed that the most distant part of the band would not be impacted by the expressway and would serve as an accurate control to that part abutting the highway. The band was subdivided into nine smaller bands of varying widths and the data were compared between each band in three project life time periods: before, during, and after.

In urban-fringe areas where large tracts of properties and/or low population densities make examination of small study areas impractical, a larger scale of analysis is necessary. Burton and Knapp [24] described an approach using a three-mile-wide (4.84 kilometers) area divided into three bands to isolate the impact of the Capital Beltway (Figure 2). The study area grid is overlaid so that the band abutting the facility is situated one-half mile (.81 kilometers) on either side of the highway and the two nonabutting bands extend one mile (1.61 kilometer) further. The differences in tax valuations, demography, and land development in the bands are attributed to the improved accessibility provided by the limited-access facility.

Figure 2. Grid Analysis of Rural Land Use Adjacent of Highway



Source: Burton, Robert C., and Knapp, Frederick D. "Socio-Economic Change in Vicinity of Capital Beltway in Virginia." Highway Research Record No. 75, National Research Council, Publication 1259, January 1965, p. 39.

The large area-parallel band technique may be employed when appropriate control areas are not available or in conjunction with other land use-land value analysis techniques. The parallel band technique permits detailed analysis of highway influence in specific areas of impact, but difficulties may arise when segregating the study area into bands. Should the bands be specified by distance or by tiers of properties from the right-of-way? How wide should the various bands be? Each of these factors are significant to the evaluation of the influence of highways on land use and land values.

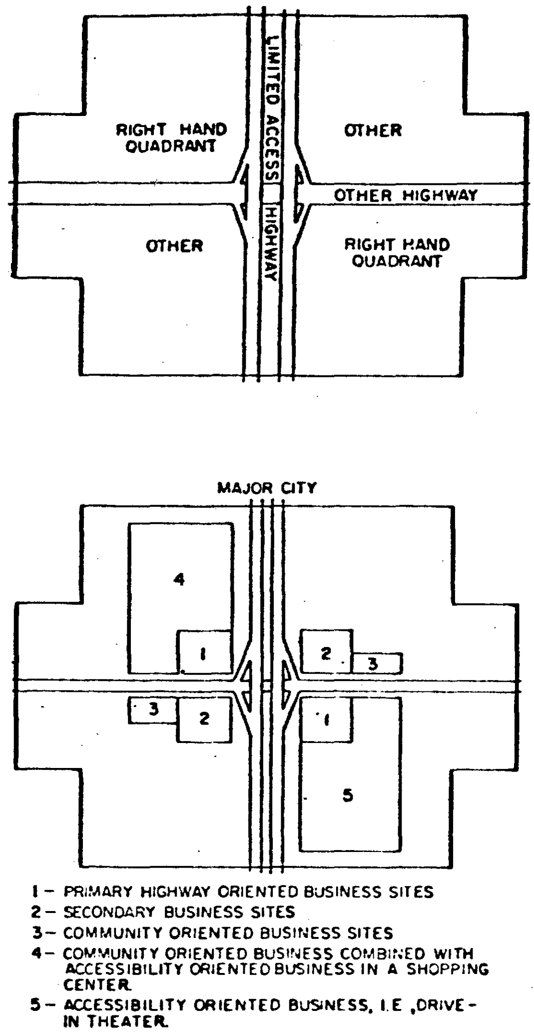
Study Area - Lateral Band Analysis

It is highly desirable to determine land use and land value changes that are attributable to the specific design features of a highway; such as intersection or interchanges, grade levels, alignments, median and marginal accesses, etc. Interchanges of major limited access highways have been studied extensively during the past 20 years to estimate the impact of the improved accessibility provided by the intersection of the highways on land values and development.

Land use changes and development of interchanges have been analyzed through a survey of interchange quadrants. Stein [25], Ashley and Berard [26], Babcock and Khasnabis [37], and Thiel [88] used this technique in the evaluation of interchanges. The interchange quadrants and preferred quadrants for specified land development are illustrated in Figure 3. Generally, land use findings in the above studies are reported in terms of percentage of quadrants with specified types of land use developments (i.e. service station, motels, restaurants). Franklin and Evans [27] also used this approach to estimate land values at interstate highway interchange locations in Texas.

Varga [57], Adkins [45], and Colony [59] adopted the lateral band approach to determine land use and land value change along specified segments of the

Figure 3. Interchange Development,
Preferred Quadrants [25]



Source: Stein, Martin M., "Highway Interchange Area Developments—Some Recent Findings," Public Roads, Vol. 35, No. 11, December, 1969, p. 243.

highway improvement. As in the parallel band technique, dividing the impact area into separate bands lateral to the facility adds more detail and allows researchers to test such hypotheses as the impact of CBD on the study area, and distance from major access points or interchanges.

Regression Analysis

Multiple regression analysis has been used in instances in which appropriate control areas cannot be found or in some instances as a check on the results of the study-control area methodology. Since analysis of land use does not lend itself as well to numerical measurement as does land value and multiple regression analysis requires numerical types of quantifiers, the multiple regression technique is applied to determine the effects of the highway project on land values. The rationale of this techique states that changes in land values near the highway being studied result from many different factors, one of which, presumably, is the highway. Ideally, all factors which influence land values other than the change in the highway (i.e. absence or presence of design feature) facility should be isolated. Then, the remaining effect is that of the highway. In reality, it is impossible to take into account all relevant factors, or in other words, to fully specify the regression model. The common procedure is to select those variables (a priori) which appear to have the most significant effect on land values, test the variables for partial correlation, and use the most significant ones in the regression equation.

Data for all the variables to be used in the analysis are collected for a period of years before and after highway construction. The dependent variable is land value or a substitute, such as: land price, tax assessments, and house prices. The major independent variable of interest - the highway - presents major difficulties. As stated previously, the variables must be represented quantitatively, but the highway effect is a qualitative characteristic. Unless the highway variable can be adapted to a quantitative measurement, the regression analysis is of limited usefulness. One adaptation that may be used is to represent the highway variable in the "before" period by zero (0) and by one (1) in the "after" period, which is known as a "dummy" variable procedure. This procedure may be sufficient to establish a correlation between the highway and land values but it is not a satisfactory approximation of the amount of increase or decrease in land value that may be attributed to the highway project. Extensive research is necessary before any numerical representation of the highway can be utilized with confidence.

For example, in Franklin's and Evans' "The Effect of Access on the Cost of Right-of-Way and the Determination of Special Benefits," [27], an analysis was done to determine the effects of highway access (frontage roads and interchanges) on abutting and non-abutting land values by land use type along the interstate highway system in Texas. The dependent variable used in the analysis is land sales price, while the regression model includes such independent variables (both continuous and discrete) as land use type, distance from central business district, size of parcel, distance to access, and other related variables. The analysis compares the percentage change in land values, by the (5) five land use categories, for each of the ten study areas selected with similar control area properties. A comparison of land value changes is made of abutting properties with and without frontage roads constructed along the highway by land use category.

In "Parkways, Values and Development in the Washington Metropolitan Region," [28] by J. Tait Davis, the regression equation compares the value of land (dependent variable) to the distance from the central city, number of properties from right-of-way, number of feet from right-of-way, and the interaction between the above factors (independent variables). The dependent variable used in "Economic Impact of Selected Sections of Interstate Routes on Land Values and Use," [29] by Cribbens, Hill, and Seagraves is also land value.

The ten (10) independent variables described range from size of parcel and its related land use, the distance to the access, right-of-way, and central business district. The regression equation stated algebraically is as follows:

$$y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_{10}x_{10}$$

where;

y = dependent variable → land value

b_i's = regression coefficients

x_i's = independent variables → i.e. size of parcel, land use, etc.

The dependent variable is different in the analysis by William Pendleton's "Relation of Highway Accessibility to Urban Real Estate Values" [30]. The dependent variable, selling price of houses, is correlated with ten (10) independent variables, of which the most important is accessibility. The accessibility factor is tested three (3) different ways to determine which of the three accessibility factors (job accessibility index, travel time to CBS, and log of distance to White House) had the most significant effect on house prices. For other nine (9) independent variables, the regression analysis assigns constant values to the individual house characteristics (i.e. square footage of house, square footage of lot, number of bathrooms, etc.).

Noise Levels and Residential Property Values. The relationship between traffic noise levels and residential property values was reviewed in Gamble's, et al., "Adverse and Beneficial Effects of Highways on Residential Property Values," [64]. The dependent variable of the regression equation is residential property values while the most important independent variables were residents' conceived noise level and the measured noise level. Other independent variables are used in the equation, but through stepwise regression analysis, the most frequent variables appearing in the estimating equation are the two noise levels variables.

In Toledo, Ohio, Colony [59] conducted a similar analysis to determine the relationship between measured traffic noise levels and the percentage change in property values. The three independent variables are distance from expressway, vertical distance from expressway pavement, and measured sound level. The dependent variable is the 1965 estimated property sales price expressed as a percentage of the 1951 estimated sales price.

As in all multiple regression analysis, logical interpretation of the results is extremely important before any extrapolations or projections are made based on the equation's coefficents. The association between variables (both dependent and independent) must be examined closely for any causal relationships before possible erroneous conclusions are made about the highway effects.

Case Study Analysis

The economic effects which may be sustained by a particular business or a group of businesses may not be disclosed in generalizations or evaluations concerning the over-all impact of the highway project. How a group of businessmen, or developers, react toward the highway is relevant to an understanding of the total influence of the project. The case study deals with a rather detailed analysis of people and events involved in the development of the study area of land affected by the improvement. Because research is usually aimed at estimating highway influence on aggregated parcels of land, the case study technique is not used extensively in highway research.

The landmark case study which used this technique is Massachusetts Institute of Technology's "Economic Impact Study of Massachusetts Route 128" [31]. This study shows the influence that Route 128 had on industrial location in the general area and the associated effects on two (2) area cities. MIT used the case study approach to determine the reasons why the industrial community chose to locate near the facility and what attributes of the region attracted them to the area. MIT also employed the lateral band technique for the highway interchanges to evaluate the influence of accessibility on land use and land values. The two cities, Lexington and Needham, Massachusetts, were examined for changes in population, dwelling units, density, tax structure, and related economic effects. MIT's major contribution is the analysis of industrial location and relocation along Route 128.

Case studies have been done on a variety of highway related subjects. For example, "Commercial Development of Highways in Urbanized Regions: A Case Study" [32] by Grotewold and Grotewold, analyzed the development and changes in commercial establishments along U.S. 41 between Chicago and Milwaukee. Another study by Wuenscher and Lang, "Case Study: Impact of Completion of Interstate Highway - St. Charles County, Missouri," [33] examined the impact of I-70 on the development of residential, commercial, and industrial activities and the influence it had on the socio-economic environment of the county.

A detailed case study of selected remainder parcels of right-of-way takings concentrated on land use and land value impacts of the highway facilities abutting these parcels. Buffington and Adkins analyzed right-of-way remainders in Houston along the Gulf Freeway [34] and in Fort Worth along Interstate Loop 820.

An analysis of selected sectors of the community with emphasis on their relationship to the highway is not only useful in providing information and background data of an institutional nature, but is also helpful in indicating the variety and significance of changes attributable to the facility. For example, the highway project may have contributed to a particular type of industry locating along the highway to a number of factors, such as: abundant supply of land, accessibility to materials and labor, and tax structure.

Therefore, investigation of the relationships between the highway and the development of the affected areas could be important to estimating the total effect of highway on land use and land values.

Study Area Land Use - Land Value Relationship

There is a close relationship between land use changes and land values changes in highway research. Changes in land use are usually preceded by changes in land values. On the other hand, changesin land values are usually preceded by changes in expectations of monetary returns if land use development occurred. A highway improvement can bring about changes in expectations of monetary returns from adjacent properties.

Determining the extent of changes in study area land values that occur between the "before" and "after" construction periods and relating those land value changes to specific land use changes will yield information that is useful in projecting changes in land uses or land values that are likely to result from future highway improvements.

Several economic impact studies which have analyzed highway projects have addressed themselves to the close relationship between land use and land value, either directly or indirectly. Buffington addressed this relationship directly in a series of impact studies conducted along interstate highways in Texas [7, 13, 15, 18]. This was also done in the University of Kentucky's study of the Lexington Northern Belt Line [22].

Although some aspects of the technique are obviously somewhat subjective, the results - particularly when examined in conjunction with the results obtained from other approaches - may be useful. The approach emphasis is directed to the complex relationships between land use and land values. The use to which the land is put, of course, determines the value of land to a large degree. The projected land use - value relationship may be helpful in selecting appropriate control areas in the study-control area methodology or in selecting subjects for analysis in case studies. This approach is also helpful in interpretation of the correlation coefficients in the multiple regression analysis.

Land Use - Traffic Analysis Models

Any study of land use and land use change in an area affected by a highway improvement project must begin with an understanding of the economy of the region involved. Various social, demographic, geographic and infrastructural factors interact with one another and influence land use decisions. Two key components in the process are land use and transportation facilities, each interacting heavily with the other throughout the development and change cycles within an area. This development may occur gradually or rapidly but, the process is dynamic and ubiquitous. Thus, investigating development dynamics and its impact requires isolation of identifiable land use, transportation, and socio-economic variables to better describe the are influenced in order to frame, analyze, and evaluate the effect of the highway.

Researchers have developed several approaches to analyze and forecast the effects of the interrelationship between land uses and transportation facilities. Basically, the two techniques proposed are:

1) Traffic measurement - land use forecasting; and
2) Land use - traffic volume forecasting.

Each forecasting technique employs statistical methods to evaluate the interaction between land use changes and traffic volumes experienced by highway.

Traffic Measurement - Land Use Forecasting

Traditionally, the technique used to analyze the relationship between land uses and highway facilities observes the changes in road inventory data, vehicle count, and traffic volume and attempts to forecast changes in land use in the affected area. This forecasting technique observes the relationship between the changes in land use and accessibility resulting from a highway improvement project. In a recent study of a 35 county region in Northern Georgia located between Atlanta and Chattanooga, Tennessee, entitled, "Land Use and Intra-Regional Transportation: An Appalachian Georgia Analysis," [36] Maggied, et al., examined the impact of improved accessibility attributed to transportation system changes on land uses in the region. The authors collected traffic-related data and land use changes and employed regression correlation, and factor analyses to estimate their relationship during the time period, 1960-1975.

The transportation data collected for each county consists of vehicle counts, daily vehicle miles (DVM) estimates, and section length data for all federal, state, and federal-aid secondary roads in the study region. Of the three types of data collected, the most valuable is daily vehicle mileage (DVM) because it is a composite of the other types of data (vehicle counts and section lengths). The first step calls for performing multiple regression analysis to estimate the relationship between the 13 independent variables (land use categories) and the dependent variable (daily vehicle miles). The analysis for this study was performed for three years: 1960, 1970, and 1975. The second step calls for a comparison of the changes in land use with changes (absolute and percentage) in land use and changes (absolute and percentage) in section length, DVM, and road density by county. The changes in land use are for 1960 to 1970 and 1970 to 1975, while the changes in transportation variables are for 1960 to 1966, 1966 to 1970, and 1970 to 1975. The results show the interrelationships between land uses and transportation network characteristics and are presented in the next major section of this report.

Maggied, et al., also employed factor analysis to identify the major dimensions in land use association and to analyze the variations in spatial distribution among land use variables. To accomplish this objective a data matrix is implemented, m x n in size, where the 35 counties (m) serve as rows and (n) land use categories columns. The analysis was done for the same three years to measure changes in land use over time. This type of analysis indicates the impact of transportation expansion on particular types of land use and discloses patterns that may provide new insights on the development of land in the region.

In another study, "An Analysis of Freeway Impact in Five Urban Areas in North Carolina," [89] by Khasnabis and Babcock, the research methodology consists of collections of historical data on land use, population, and traffic and analyzes these variables to determine possible correlations with the appearance of the highway facility. Khasnabis and Babcock examined each of five areas separately and analyzed the impact of the facility on land use and traffic in the influenced areas. Although the freeways built in each of the five cities are part of the Interstate system and are characterized by having controlled access, each of these facilities could be categorized into one or more of the following types, depending upon its intended function: bypass, beltline, cross-town artery, and radial.

The traffic data collected is average daily traffic (ADT) counts, while the land use data collected conforms to the most commonly used research categories (i.e. vacant, residential, commercial, and industrial) for urban land. Khasnabis and Babcock looked closely for any relationships between land use and traffic data that may provide planners with insight into the development process near various types of controlled-access facilities and in areas in different stages of urban development. The authors also provide general comments regarding the facility, the city, the effect of the facility on the general character of the city, the problems attributed to the facility, and probable solutions to relieve transportation problems.

The basic technique used in the above two reports is a good procedure for regional transportation system analysis. Each of the studies examines the effect of highway facilities on accessibility and land use changes for a region or a city. This technique could be adapted to analyze a specific smaller area of influence if it is used in conjunction with one or more other approaches. To use this technique alone to report impact of highways on land use abutting the facility may produce results that need more reinforcement or analysis.

<u>Land Use - Traffic Volume Forecasting</u>

An approach has been devised to examine the effect of changing land from a lower use (i.e. unimproved) to a higher use (i.e. commercial) on the highway's traffic carrying capacity. The technique analyzes the effect of specific land uses in generating vehicular traffic and congestion on the transportation facility. Frey, et al. [38], developed an approach for analyzing the relationship between highways (especially intersections) and land use. Their thesis is that each parcel of land is a basic unit from which the flow of all goods and persons originates and to which the flow of goods and persons go. Since this flow requires movement between basic land units, transportation is required and therefore, each land unit is connected to a public highway. Because of the land use-highway relationship, Frey postulates that the use of each land unit influences both the practical capacity and the vehicle mix constituting the traffic flow, and thereby, reduces the practical capacity of the facility. The amount of traffic flow restriction is determined in part by variables at each intersection, including intersection design, traffic volume and direction through the intersection, and the vehicular mix of the traffic. These kinds of variables are a function of the physical and socioeconomic characteristics of each particular land use. The total traffic flow varies with the number of land units attached to the highway system, the unit's socioeconomic characteristics (i.e. land use), and the location of every unit relative to other units it interacts with.

Frey's technique is based on highway capacity, highway links, kinds of traffic, and kinds of land use in order to measure or predict land use impacts on highway capacity. Designed highway capacity is defined as the maximum number of vehicular traffic that is able to pass through a highway segment at safe speeds while maintaining safe intervals between vehicles. Symbolically, designed (D_c) is a function of highway width (w), obstructions (o), and surface type (s) with other variables such as traffic volume and vehicular mix being treated as constants (e):

$$D_c = f(w, o, s) + e:$$

where: w = width

o = obstructions

s = surface; and

e = other variables, treated as being constant.

Practical capacity differs from designed capacity in that the values for traffic volume and vehicular mix held constant in the designed capacity function are treated as variables. Since these variables restrict actual highway capacity, practical capacity (P_c) is defined as designed capacity (D_c) minus the variables which restrict or hinder (H) traffic volume:

$$P_c = D_c - H$$

Measurement of variables is conducted in terms of highway links. A highway link is defined as the distance between any two highway intersections of interest whether public or private. The hindrance (H) measured in a link include:

V_e = type of intersection with a given volume of traffic <u>entering</u> the highway segment;

V_L = type of intersection with a given volume of traffic <u>leaving</u> the highway segment;

M_x = product mix or proportion of different classes of vehicles in in the traffic stream; and

E = a unique or special factor which restricts traffic on a highway segment.

Barriers to traffic flow are a function of the physical and socio-economic characteristics of land uses as well as the number of land units attached to the system and the location of each unit relative to other units. A significant part of the impact of traffic flow and, therefore, practical capacity, is determined by the amount of traffic generated and attracted by each kind of land use. As a result, the amount and kind of traffic generated and attracted by each kind of land use will be affected by the social, economic, and physical characteristics of each parcel of land.

Although Frey's, et al., technique for forecasting traffic volume and congestion data based on land uses is adapted for land units attached to the facility, the great amount of data required to establish the coefficients for generated, attracted, and congestion traffic variables would, in most cases, prove to be too costly for consideration. The extensive research and data collection needed to estimate coefficients that may be used with confidence (statistically) would require properly trained personnel, and sophisticated computer facilities. As of yet, the technique has not been properly field tested.

Land Use Forecasting-Urban Development Models

The general problem addressed by regional transportation planning techniques is the heavy usage and subsequent congestion which often closely follows the construction or improvement of urban or suburban highways. Urban highways experience this problem because of the traffic generating characteristics of the changing land use situation along the facility. Therefore, there is abundant evidence reported in the literature of a rather strong relationship between transportation facility development and land development. The relationships that exist between highways and land development have become more important to urban and transportation planners in recent years. The need to protect transportation facilities from congestion, and therefore, obsolescence has brought about the need to integrate both the transportation and land use planning process. As the acceptance and use of computers became widespread, the planning process was expanded in its capabilities to include vast amounts of data associated with the interrelationships of highways and land use. A set of computerized programs evolved that could incorporate the traditional land use planning and forecasting procedures, land-use controls, transportation policies, and the socioeconomic and physical components of the region or area. These computer programs are termed "urban development models."

The urban development model is a mathematical model which attempts to either describe or simulate the process of urban development and growth. A distinction is usually made between the "descriptive" models and the "simulation" models. Simulation, in simple terms, recognizes causes and effects and attempts to represent them as such. Descriptive modeling, on the other hand, is primarily concerned with obtaining an accurate solution by means of certain techniques which are reasonable but do not necessarily parallel the logic or processes of the real-world system. The current operating urban development models are generally descriptive in nature (i.e. EMPIRIC, and PLUM).

Urban development models are useful in urban planning from both the theoretical and the practical viewpoint. Planning, in a broad sense, involves the selection of alternative policies and programs which are most likely to achieve the community's goals. The causal relationships between the transportation programs and urban policies and goals, which provide a rationale for selection of alternatives, are explained by a combination of theory and understanding.

Basically, the purpose of an urban development model is to forecast: (1) the future need for transportation services; and (2) the influence of transportation on urban development and vice versa. The concern of the first item is forecasting normal travel demand in order to define the need for and the character of future highway improvements. Administrators, policy-makers, and planners in both the fields of urban planning and transportation planning are interested in the model's ability to forecast the relationships between urban development and transportation development. The second item indicates that the model has a role in the domain of the comprehensive urban planning process. Although the model may be used primarily as a transportation planning tool, its most valid use is in the joint planning effort (transportation and urban) within a comprehensive planning endeavor.

This section of the report summarizes the basic components, data requirements, and forecasting ability of several urban development models. The models which are briefly summarized include:

1) EMPIRIC Activity Allocation Model;

2) Projective Land Use Model (PLUM);

3) Integrated Transportation and Land Use Models Package (ITLUP);

4) Access and Land Development Model (ALD); and

5) Land Use Allocation Model (LUAM).

In "An Introduction to Urban Development Models and Guidelines for Their Use in Urban Transportation Planning" [39], Moore, et al., reviewed each model's characteristics, background, and capabilities in relation to forecasting land uses and assisting planners in model selection and formulation. Inherently, these urban development models are very comprehensive which requires extensive data collection and are usually aimed at the forecasting of land and transportation development of a large region or urban area. Therefore, the regional nature of the techniques utilized by these models is probably too comprehensive and too unreliable for analyzing smaller areas of influence of specific highway improvement projects.

EMPIRIC Activity Allocation Model

The EMPIRIC model has become one of the more popular urban development models after its use in Boston and its implementation in an Eastern Massachusetts study entitled, "Technique for Relating Transportation Improvements and Urban Development Patterns," [40] by Brand, Barber, and Jacobs. The EMPIRIC model is also one of the few regional planning tools that has reached an operational stage of development. Most of the transportation-land use forecasting models remain in the developmental stage due to the complex and comprehensive nature of the socio-economic and physical variables which affect the results of various transportation policy alternatives.

The three major functions of the EMPIRIC, PLUM, and the other activity allocation models are:

1) To allocate regional projections of future population, employment, and land use (subcategorized) between a set of smaller subregions or zones;

2) To assess the probable impact of alternative regional planning policies on the future distribution of regional growth; and
3) To provide a foundation for the evaluation and coordination of future policy decisions in a variety of different functional areas [39].

Moore, et al. [39], identify the EMPIRIC model as a system of simultaneous linear regression equations which quantify the relationships between the dependent and independent variables. The simultaneous equations model allows for the solution of a number of dependent variables, equal to the number of equations in the model. The model's equations are estimated using historical data for two points in time (a "before" and "after" situation). By utilizing the standard econometric techniques, it identifies the major factors influencing past development and extrapolates into the future.

A brief evaluation of the EMPIRIC model illustrates that the data requirements (collection and variable selection) are very extensive and demanding in quality. Therefore, most of the research effort is allocated to fulfilling the data requirements of the model. Also, due to the regional nature of the model's concept, the forecasting ability (valid statistical relationships) is reduced for small zones or areas within the analysis region. The model's strength lies in forecasting land use changes for selected policy alternatives in a large regional transportation system. The resource requirements in manpower and computer time is also extensive for implementing the EMPIRIC model.

Since the EMPIRIC model is geared for regional land use forcasting, the EMPIRIC model does not seem applicable for forecasting small area land use impacts resulting from specific highway improvements.

Projective Land Use Model - PLUM

The PLUM and its antecedent models are similar to the EMPIRIC model in that it has reached an operational stage. As described by Moore, et al. [39], "the PLUM is designed to yield projections of the future small-area (i.e. zone level) distribution of these characteristics in some base-year, coupled with a series of simple and intuitively appealing allocation algorithms." The PLUM model's forecast of land use is based upon the tripmaking behavior between origins and destinations during the base-year and forecast year transportation networks.

The forecasting algorithms utilized by the PLUM model require a vast amount of data of each zone identified within the region. Traffic (origin-destination) data between households to employment centers or other points is based upon the socio-economic characteristics within and outside each traffic zone, such as: (1) demographic; (2) economic; and (3) land use profile data. Travel demand forecast are derived from these data based upon the accessibility characteristics of the transportation network policy alternatives. Hence, the PLUM forecasts changes in land use within each zone based upon the travel demand forecast and transportation facilities.

The PLUM and IPLUM (Intergrated PLUM) was employed in a San Francisco Bay Area study by Putman, et al., entitled "Interrelationships of Transportation Development and Land Development," Volume I [41]. Putman, et al., modified the PLUM model in an attempt to integrate the transportation and land use policy alternatives for highway protection into one functional decision-making process. The simulation model uses the same trip frequency demand forecast and transportation network forecast as the original PLUM model to estimate land use changes, but the intended purpose of the Putman model is to protect the highway system from congestion and premature obsolescence.

In other words, the model examines alternative land use control policies in conjunction with transportation and other policies that may be enacted to prevent overcapacity on the highway system in the region.

Putman, et al., found that the PLUM model does produce reasonable estimates of the general distribution of activities in a large urban area. As is the case with most urban development models, its reliability for specific small area forecasts is considerably less than that for general regional patterns. The PLUM and its sister models are currently being developed and improved by its originators through additional research projects. Although the model is expected to show continued improvement, PLUM's ability to forecast land use change for specific small areas of highway impact is somewhat limited, especially for specific highway design changes.

Integrated Transportation and Land Use Models Package - ITLUP

As stated by Moore, et al. [39], "The Integrated Transportation and Land Use Models Package is a set of models that have been linked so that transportation and land use interface. The basic components of the package consist of two versions of the Projective Land Use Model (PLUM) and a transportation network models package." The different models which comprise the ITLUP are:

A. PLUM and IPLUM - Land Use Models

B. TGEN - Trip Generation Model

C. NET3 - Network Model

D. INTER - Transportation and Land Use Interface

E. Analysis and Summary Programs AVGT VOLCAP WGTR

Putman, et al. [41] (Volumes I and II), used these basic models in the San Francisco metropolitan area to develop and test the ITLUP, or Models Package. The authors found the models in the package are consistent and that the ITLUP can be used effectively to test the impact of land and transportation related public and private policies.

The Models Package is described as being both in operational and developmental stages. More work is needed to modify the ITLUP to specify highly detailed transportation feedback and activity distribution within the urban region. The ITLUP is a very comprehensive package that entails extensive data collection for each model and work to coordinate the different models. This type of package is not applicable to research along specific highway locations because it is aimed at incorporating many types of information (public and private policies) in a large urban area.

Access and Land Development Model - ALD

The ALD model's only purpose is to estimate the impact that transportation access has on land development. The ALD model is basically a computer model that determines the interrelationships between land use patterns, density of development, trip generation, travel demand, choice of mode, and the accessibility feature of transportation facilities. The design of the model is to distribute a given amount of development among a group of zones in such a way as to reach an equilibrium between the development in each zone and the accessibility of each analysis zone.

The model input requirements, as reported by Moore, et al. [39], are less extensive than the other urban development models, and due to this characteristic, the ALD model may be appropriate for forecasting land use patterns along specific highway projects. The major input requirements include: accessibility information (travel time and cost) of the highway network, amount of development and land in each zone, origin-destination information in the zones and region, and total amount of development in the region.

The output of the ALD model consists of: (1) a set of values which represent potential travel patterns between zones; (2) expected utilization of all sites in the region in terms of floor space to be built in each zone; and (3) trip generation by site and travel mode information. The basic output of the model consists of the location and density of development and the traffic volumes expected to use the transportation network in the region. Another output feature that is quite different from other urban models is that the ALD calculates the total density of development which can be supported by highway. This is usually an input requirement for other forecasting models.

The ALD model does provide a sensitive estimate of trip generation based on accessibility of the highway, but it is questionable as to its reliability in providing small area trip generation forecasts. The model also does not handle different types of land use development resulting from highway accessibility. The only estimate calculated is a measure of floor space, which surrogates land development. While the ALD is operational, it is still in an evolutionary and developmental stage and it would be difficult to implement the model without additional testing and verification.

Land Use Allocation Model - LUAM

LUAM is a computerized mathematical urban planning tool which predicts and identifies future industrial, commercial, residential, and eight other types of land uses. The eleven land use categories described in the model are allocated on the basis of the desirabilities and suitabilities of analysis zones within the region. However, the model does not specify where the particular land uses are to be located within each subarea.

The LUAM has extensive data input requirements which are basically subdivided into three groups: (1) a "data base", which includes 28 variables describing existing conditions; (2) five economic and population projections which describe conditions in the forecast years; and (3) 31 "control" variables which are manipulated by the planners affected the results of the model. The basic procedure used to project future land uses is to consolidate and interpret the input data to meet the requirements of the forecast year (i.e., construction of homes, schools, factories, etc.). The major output of the model is the total land use (in tenths of acres) for the 11 major land use categories in each subarea and in the total region. Moore, et al. [39], list both the input requirements and model outputs in their report.

The LUAM has been used in only one area of study and, therefore, has not been modified, adapted, or developed extensively. The model remains in a developmental stage with no real test of its reliability and value to highway research, but the LUAM appears to be an appropriate model for allocating land uses relative to alternative transportation policies. The originators of the LUAM have recognized several deficiencies and are striving to correct these problems. Once these problems are solved, the LUAM should become an excellent planning and forecasting tool for land use and transportation planners because of the detailed land use forecasts (by categories) supplied for the area.

The recent trend in research techniques used to measure or forecast the relationships between transportation development and land use development has led to the widespread acceptance of urban development models. These models attempt to integrate the transportation and land use planning processes in order to prevent both the congestion and premature obsolesence that has been experienced by highways located in a developing urban region. These land use forecasting models strive to estimate the effect that land use change has on transportation facilities, and vice versa. These models also allow planners to estimate the probable future effects of alternative land-use controls or transportation policies on the travel patterns and demand of the population.

For the most part, urban development models require extensive data inputs and are aimed at forecasting land uses in a large urban region. Because of these factors, land use forecasting for small areas along specific highway facilities would not be suited for urban development models.

FINDINGS OF HIGHWAY IMPACT STUDIES

A review of highway impact literature analyzing the cause and effect interrelationships between transportation system development and land development is necessary to thoroughly understand the impact of highway improvements on land use and land value, and vice versa. Previous impact studies have concentrated their research efforts at locations where the most obvious changes in land use and land value occur as the result of the highway improvement. Therefore, a large portion of the research, so far, has been devoted to investigating the influence of limited access highways (freeways, beltways, and interstates) transversing urban or suburban areas.

In this section of the report, the land use and land value impact findings from previous studies are summarized according to (1) selected "key" characteristics of highway improvements and (2) those areas affected by such improvement projects.

First, the studies are classified according to rural, suburban, and urban locations. Next, within each of the three area descriptions, the studies are classified according to type of highway improvement in terms of the amount of access provided and route location as follows:

1. limited access highway-new route;
2. limited access highway-existing route;
3. full access highway-new route; and
4. full access highway-existing route.

Then, within these four highway and route types, the studies are classified according to the stage of land development and dominant abutting land use which characterizes the impact area presented in Table 8.

Table 8. The Stage of Development and Dominant Land Use Type for Classifying Previous Highway Impact Studies

Stage of Development	Dominant Land Use
1. Undeveloped	Unimproved or agricultural
2. Developing	Unimproved or idle
3. Developing	Residential
4. Developing	Commercial
5. Developing	Industrial
6. Developed	Residential
7. Developed	Commercial
8. Developed	Industrial

Finally, within the eight classifications of Table 8, the studies are classified according to the impact measurement technique used in the study. The technique classifications are as follows: (1) study area-control area comparison, (2) study area-parallel band comparison, (3) study area-lateral analysis (interchanges), (4) regression analysis, and (5) other analyses.

The extensive classification scheme described above is rather detailed, but it should be helpful in using a recommended procedure for predicting land use and land value impacts, as presented in the final section. If no studies are available for any of the above classifications, such classifications are not included. The scheme is altered considerably for the review of rural area studies.

The distinction among rural, suburban, and urban locations is necessary because of the varying degrees of impact on the different land use categories. The same is true for the distinction of types of access and route location, as well as stages of development and dominant abutting land uses.

It is important to know the type of study technique upon which the impact measurements are based. Therefore, the study findings are categorized on that basis.

Rural Locations

Initially, highway building programs were promoted as the means for providing all weather access for farmers. More recently, highway programs have been based on the need to relieve urban congestion. The new emphasis has had the effect of obscuring rural land use and land value impacts arising from highway design features. Research evidence exists that indicates a positive relationship between highway improvement projects and rural land value. Description of the rural studies reviewed are summarized in Table 9.

Due to the urban sprawl trends of metropolitan centers, the effect of improved accessibility has been that lands that were thought as rural are now transformed into urban-fringe areas. Therefore in this report, rural locations are defined as:

- areas located outside of "city limits" of any city or town; and
- at least two miles from any built-up area.

Limited Access Highways

Limited access highways in rural areas are normally part of the interstate highway system. Most of the research projects have investigated and reported the effect of the limited access facility on interchanges in rural locations. Only a few studies have reported the impact on land parallel to the facilities and these studies have found that the highway influence is quite different on properties along "limited access" highways than on properties along "full access" highways.

Table 9. Master Summary Table of the Rural Studies Contained in the Review of the Literature

Study Number	Type of Access	Existing or New Route	Type of Highway	Area Stage of Development	Description of Study Area	Size of Study Area	Distance from CBD	Location of Analysis	Dominant "Before" Land Use	Dominant "After" Land Use	Study Period	Year Facility Opened	Study Technique	Types of Data Collected and Analyzed: Land Use	Land Value	Business Activity	Traffic Analysis	Other
19	Limited	New	Radial	Undeveloped	Large rice producing area & no other routes	3 miles wide and 14 miles long	Unknown	Adjacent Property	Agriculture	Agriculture	1947-65	60-61	Study-Control	Δ in acres & tracts	$/acre	No. of firms and sales	Travel Pattern	Population, Employment
25	Limited	NA	Interstates	Developing	Accessible abutting land-Prime devel. land	1/2 miles radius from center of interchange	NA	Interchange Quadrants	NA	Agriculture	1964-68	NA	Survey of 332 Interchanges	% use by quadrant				
26	Limited	Existing	Radials	Developing	Full interchanges in rural areas & small towns	31 interchanges and 124 quadrants	NA	Interchange Quadrants	NA	Vacant Commercial	Unknown	1960	Survey of 66 Interchanges	% land use	$/acre	Service-Station sales		Type of Interchange
36	Limited	Existing	Radials	Developing	Growth potential area btwn. Atlanta and Chattanooga	35 county region in Northern Georgia	NA	County Development	Agriculture	Agriculture	1960-75	NA	Regression Analysis	Δ acres % Δ			Daily Vehicle Miles	Industrial location Interview
37	Limited	New	Interstates	Developing	Interchanges w/ highway-oriented businesses	550 miles of limited access highways and 221 interchanges	NA	Interchange Quadrants	NA	Vacant	1970	NA	Statistical Analysis	No. of development quadrant			Traffic Generation	Predictability of Development
42	Limited	New	Interstate	Undeveloped	Large ranching area w/ oil & gas exploration	18 miles long & about 1 mile wide	1 to 10 miles	Abutting tracts	Agriculture	Agriculture	1962-66	1965	Study-Control	Acres & % Δ in operation	$/acre	Δ in operating income	Travel Pattern	Land Tenure
43	Limited	New	Interstate	Undeveloped	75% excellent farm land & 25% pastureland	20 miles long & 1/2 to 1 mile wide	NA	Abutting tracts	Agriculture	Agriculture	1963-67	1966	Study-Control	Acres & % Δ in operation	$/acre	Δ in operating income	Travel Pattern	Land Tenure
44	Limited	New	Interstate	Undeveloped	Area of diversified agri. enterprises	10 miles long & about 1 mile wide	NA	Abutting tracts	Agriculture	Agriculture	1964-69	1968	Study-Control	Acres & % Δ in operation	$/acre	Δ in operating income	Travel Pattern	Land Tenure
46	Full	Existing	Rural Road	Undeveloped	Predominantly an area dependent on agriculture	6.3 miles long and 2 to 4 miles wide	NA	Adjacent land	Agriculture	Agriculture	1953-58	1954	Study-Control	Δ in use by acres	$/acre		ADT	Resident's Opinion
49	Full	Existing	Rural Roads	Undeveloped	Rural area with about 50 persons per square mile	Robertson Co., Texas 953 square miles	NA	Adjacent land	Agriculture	Agriculture	1955-58	NA	Regression Analysis	Average Acreage by uses	$/acre		Annual Mileage	Buyer's Characteristics
52	Limited	Existing	Radials	Undeveloped	Grazing land along new & old highway segments	Unknown	NA	Adjacent land	Agriculture	Agriculture	1946-57	1958	Statistical Analysis	Acres Δ'ing uses	$/acre	No. of firms and sales		
53	Full	Existing	Rural Roads	Undeveloped	Farm land along dirt, gravel & hard-surface roads	Rural farm areas in the U.S.	NA	Adjacent land	Agriculture	Agriculture	1958-59	NA	Statistical Analysis	Buildings Value	$/acre			Literature Review
54	Full	Existing	Rural roads	Undeveloped	Rugged terrain area w/ poor farming practice	Six county area in rural Kentucky	NA	Six county area	Agriculture	Agriculture	1950-60	NA	Regression Analysis			No. of firms and sales	Travel Patterns	
57a	Full	Existing	Rural roads	Undeveloped	Prime farming & dairy area	3.5 miles on either side of hard-surfaced roads	NA	Adjacent land	Agriculture	Agriculture	1942-57	NA	Parallel band Statistical Analysis		$/acre	No. of firms and sales	ADT	Population, Employment
57b	Full	New	U.S. Highway	Undeveloped	Prime farming & dairy areas	10 miles long and 6 miles wide	NA	Adjacent Property	Agriculture	Agriculture	1950-58	1956	Lateral Band Analysis		$/acre	No. of firms and sales	ADT	Population, Employment
68	Limited	New	Radial	Undeveloped	Crop & grazing land	28 miles long & 2 miles wide	NA	Adjacent land	Agriculture	Agriculture	1954-63	1958	Study-Control		$/acre		ADT	
71	Limited	New	Radial	Undeveloped	Entirely a farming (ROW crop) area	13 miles long & abutting tracts wide	12 miles	Adjacent land	Agriculture	Agriculture	1957-60	1960	Statistical Analysis Before-After	Δ in crop acreage	Δ in valued leases			

General Impact

Dansereau [56] provides some interesting findings regarding highway improvements in what he terms rural/suburban communities. When accessibility is increased by the introduction of a highway, there is an inward migration of younger, higher income families that raise the community's standard of living by increasing housing demand and increasing the rate of consumption of other goods. Money circulates in greater quantities and more rapidly and tax revenues increase. Dansereau found that this kind of phenomenon occurs more rapidly in communities located on the highway than in those some distance away. The highway also generates additional inmigration because manufacturing firms are attracted to rural communities that have good accessibility.

Undeveloped Agricultural Areas - New Routes

Impact on Land Use. Three studies by Meuth and Buffington [42, 43, 44] analyzed the effect of new limited access highways on rural land located in three Texas counties. The findings indicate that the change in agricultural land use of tracts of property was minimal along the interstate highway's right-of-way. The absolute change in land use on an acreage basis was relatively small between the respective study periods.

Similar findings were reported by Buffington [19] in Chambers County, Texas, along I.H. 10. As in the above studies, the absolute change in land use by category was not very significant; but the percentage increase in rural residential, commercial, and institutional use was shown to be large. Other studies that have reviewed the impact of limited access highways on undeveloped agricultural land were done by Bardwell and Merry [52], Varga [57], and Frankland [71]. (See Table 10).

Impact on Land Values. The highway effect upon agricultural land values as reported by Buffington [19] was insignificant in terms of absolute and

Table 10. Impact of Limited Access Highways on Land Use in Undeveloped-Agricultural Rural Areas

Study Reference Number	Type of Highway Improvement	Location of Land Compared	Dominant Land Use	Before Period Land Use: Type of Land Use	Before Period Land Use: Quantity	Change in Land Use: Absolute Change	Change in Land Use: Percent Change
[19]	New	Study Area	Agriculture	Agriculture	22,620 acres	-107 acres	-0.5%
	Interstate	Study Area	Agriculture	Timberland	1,320 acres	-112 acres	-8 %
	Highway	Study Area	Agriculture	Idle	535 acres	+9 acres	+2 %
		Study Area	Agriculture	Residential	130 acres	+86 acres	+66 %
		Study Area	Agriculture	Commercial	2 acres	+49 acres	+2450 %
		Study Area	Agriculture	Institutional	2 acres	+53 acres	+2650 %
[42]	New	ROW[1] Tracts	Agriculture	Cropland	307 acres	-27 acres	-8.8%
	Interstate	ROW Tracts	Agriculture	Pasture	6,627 acres	-474 acres	-7.2%
	Highway	ROW Tracts	Agriculture	Other	33 acres	+56 acres	+170 %
[43]	New	ROW[1] Tracts	Agriculture	Cropland	6,420 acres	-800 acres	-12.5%
	Interstate	ROW Tracts	Agriculture	Pasture	1,606 acres	+143 acres	+8.9%
	Highway	ROW Tracts	Agriculture	Idle	223 acres	-136 acres	+61 %
[44]	New	ROW[1] Tracts	Agriculture	Cropland	647 acres	-54 acres	-8.2%
	Interstate	ROW Tracts	Agriculture	Pasture	1,715 acres	-259 acres	-15.1%
	Highway	ROW Tracts	Agriculture	Other	27 acres	-2 acres	-7.4%

[1] ROW Tracts are similar to abutting tracts along the improvement.

relative price changes. The overall land values in the area increased approximately 25 percent. Buffington compared land prices of abutting and nonabutting unimproved properties with control area land prices and found that between 1947 and 1965, prices of abutting properties rose 101 percent while nonabutting property prices fell about 17 percent. (See Table 11).

Meuth [42] found that when land sales from the study area adjacent to the new interstate highway were compared to land sales from the control area adjacent to the old U.S. highway that there was very little difference between area land prices. Concerning special highway impacts on abutting properties, the authors reported that abutting interstate land prices were 64.5 percent higher than abutting control area prices. In a similar analysis, Bardwell and Merry [52] reported that land value changes were quite different for abutting improved and unimproved properties in Colorado. The authors found that improved properties abutting the highway improvement, in most cases, decreased in value. Abutting unimproved properties were found to have increased significantly in value between the before and after periods specified by Bardwell and Merry (Table 11).

Table 11. Impact of Limited Access Highways on Property Values in Undeveloped-Agricultural Rural Areas

Study Reference Number	Type of Highway Improvement	Location of Land Compared	Dominant Land Use	Before Period Values: Type of Land Use	Before Period Values: Average Price	Change in Average Price: Absolute Change	Change in Average Price: Percent Change
[19]	New Interstate Highway	Abutting	Agriculture	Unimproved	$66/acre	+$229/acre	+347%
		Nonabutting	Agriculture	Unimproved	56/acre	+ 128/acre	+229%
		Abutting vs. Nonabutting	Agriculture	Unimproved	10/acre	+ 101/acre	+118%
		Abutting vs. Control	Agriculture	Unimproved	12/acre	+ 96/acre	+101%
		Nonabutting vs. Control	Agriculture	Unimproved	2/acre	- 5/acre	-17%
[42]	New Interstate Highway	Study Area	Agriculture	Unimproved	$141/acre	+$102/acre	+72.3%
		Control Area	Agriculture	Unimproved	130/acre	+92/acre	+70.8%
		Study vs. Control	Agriculture	Unimproved	9/acre	+10/acre	+ 1.5%
		ROW[1] Study Area	Agriculture	Unimproved	153/acre	+186/acre	+121.6%
		ROW[1] Control Area	Agriculture	Unimproved	140/acre	+80/acre	+57.1%
		ROW[1] Study vs. Control	Agriculture	Unimproved	7/acre	+106/acre	+64.5%
[43]	New I-H	ROW[1] Tracts	Agriculture	Agriculture	$268/acre	+2/acre	+0.75%
[52]	Improving	Abutting New Highway	Agriculture	Improved	$50.49/acre	+22.20/acre	+44.0%
	Existing 2-lane	Abutting New Highway	Agriculture	Unimproved	34.99/acre	+200.54/acre	+573.1%
	Full Access to	Abutting Improved Existing Highway	Agriculture	Improved	441.41/acre	-306.03/acre	-81.6%
	4-lane Divided	Abutting Improved Existing Highway	Agriculture	Unimproved	9.92/acre	+2.81/acre	+28.3%
	Limited Access	Abutting Highway	Suburban	Improved	16,168/acre	-4,412/acre	-27.3%
	w/ Bypass	Abutting Highway	Suburban	Unimproved	3,974/acre	+3,671/acre	+92.4%

[1]ROW land locations are similar to abutting locations along the improvement.

Rural Interchange Effects - New and Existing Routes

Extensive research has been done in an effort to measure the impact of the interstate highway system on land development and land values at intersections in rural areas. Because of the abundant supply of developable land and the accessibility restriction of the interstate facility, the most significant influence occurs at intersections of highways.

Impact on Land Use. Intersections have long served as focal points for land use development because more traffic passes through them relative to either of the two or more highways creating the intersection. Stein [25] combined land use information from 332 interchanges in 16 states and discovered that land development at these locations is a function of the kinds of intersecting highways and the accessibility of the interchange quadrants. Statistical studies, employing multiple regression analysis and simultaneous linear models, have determined that the additional variables that affect land use near interchanges include: traffic volume, distance from nearest urban center, topography, and population size of nearest urban center. (See Table 12).

Stein found in his analysis of predominantly rural interchanges involving at least one limited access highway that land development consisted of highway-oriented businesses. In general, these businesses include service stations, motels and restaurants which serve motorists using the highway. Tables 13 and 14 provide data on interchanges studied by Stein.

The data is indicative of development trends around intersections. There are proportionately higher amounts of development for free access intersections than for limited access interchanges. This study did not determine, however, if this condition is due to the fact that interstate highways are newer and have had less time to attract development or due to the degree of access provided to abutting properties. Other studies reviewed support the latter reason.

Table 12. Correlations[a] of Variables with Total Highway-Oriented Development [25]

Variable	Correlation Coefficient	Proportion of Variation Explained (percent)
Cross-Route Average Daily Traffic (ADT)	0.514[b]	26.4
Topography (Average Slope)	-0.388[c]	15.1
Distance from Nearest Urban Area	-0.360[c]	13.0
County Population Change	0.333[c]	11.0
Local Municipal Market Value Change	0.320	10.2
Local Municipal Population Change	0.305	9.3
Nearest Urban Area Population	0.289	8.4
Nearest Urban Area Population Change	0.235	5.5
Age of Interchange	-0.195	3.8
County Population	0.188	3.5
Interstate Average Daily Traffic (ADT)	0.174	3.0
Local Municipal Market Value	0.135	1.8
Local Municipal Population	0.099	1.0

[a]Total Units include only service stations, restaurants, and motels. Only complete interchanges were considered.

[b]The correlation coefficient is significant at the 1 percent level.

[c]The correlation coefficient is significant at the 5 percent level.

Source: Stein, Martin M. "Highway Interchange Area Developments - Some Recent Findings." Public Roads, Vol. 35, No. 11, December 1969, pp. 241-250.

Table 13. General Land Development at Interchanges, by Highway Classification (Public Roads Analysis of 1,256 Interchanges Quadrants in 16 States) [25]

Type of Highway Interchange	Interchange quadrants	Type of Land Development			
		Agricultural and/or vacant	Residential	Commercial, industrial, institutional	Total
	Number	Percent	Percent	Percent	Percent
Interstate—Local road	628	43	27	30	100
Interstate—State-numbered	296	60	14	26	100
Interstate—U.S.-numbered	260	48	26	26	100
Non-Interstate—Non-Interstate	52	15	23	62	100
Interstate—Interstate	20	55	25	20	100
Total	1,256	--	--	--	---

Source: Stein, Martin M., "Highway Interchange Area Developments-Some Recent Findings," Public Roads, Vol. 35, No. 11, December, 1969, p. 243.

Table 14 shows that 28 percent of the motels were located at interchanges of two non-interstate highways. This is a relatively large proportion due to the fact that only 4 percent of the total of interchanges studied were non-interstate interchanges. Interchanges involving interstate highways and local roads constitute 50 percent of the interchanges studied and have 32 percent of the motels. Twenty-eight percent of the service stations were at intersections of interstate and U.S. highways, which were 21 percent of the interchanges studied. Also located at the interstate and U.S. highway interchanges were 56 percent of the category "Other tourist-oriented businesses."

He notes that industrial or institutional land development has a proportionately high rate of development around intersections created by two interstate highways. Of the two percent of interstate-interstate interchanges, 17 percent of the warehouses and factories represented in the survey were located at these intersections. This kind of data is too sketchy to produce detailed land use projections for highway interchanges. It does, however, give some indication of the kinds of development that take place around interchanges and the kinds of highways that have attracted development in the past.

Table 14. Distribution of Highway-Related Land Uses at Interchanges, by Highway Classification [25]
(Public Roads Analysis of 332 Interchanges in 16 States)

Type of Highway Interchange[1]	Service Stations	Restaurants	Motels	Other tourist-oriented businesses
	Percent	Percent	Percent	Percent
Interstate— Local road	49	48	32	44
Interstate— State-numbered	23	21	19	--
Interstate— U.S.-numbered	28	22	21	56
Non-Interstate—	--	9	28	--
Total	100	100	100	100

[1]No highway-related uses were recorded at interchanges of 2 interstate highways.

Source: Stein, Martin M., "Highway Interchange Area Developments-Some Recent Findings," Public Roads, Vol. 35, No. 11, December, 1969, p. 243.

Babcock and Khasnabis [37] in a study of interstate highway intersections in North Carolina analyzed 105 interchanges along approximately 310 miles of rural highways. The authors were investigating the possibility of formulating realistic predictions of land development that had already taken place, or might take place along North Carolina's limited access freeways. Figures 4 and 5 illustrate the findings of land development at rural interchanges. The land development that can be attributed to the freeway construction consisted of 117 service stations and 51 miscellaneous developments or a total of 168 developments. Approximately 65 percent of the interchange quadrant were found to possess no land development. Of the remaining 35 percent of the quadrants, service stations were the only major type of development. The 58 miscellaneous developments included industries, motels, restaurants, truck stops and retail sales establishments. These findings agree with the result reported previously by Stein [25].

Babcock and Khasnabis studied the possibility of developing land use prediction models based on past development patterns in an effort to estimate traffic generation and volume for the freeways. Since service stations are the only major type of development in rural areas and this type of land use generates very little traffic for the freeway, the predictability of land-use patterns was not analyzed extensively. However, the analysis indicated that 50 percent of intersection quadrants would remain vacant and there would be one service station, on the average, for each remaining quadrant. Based on statistical analysis, it was not possible to determine where the developments would take place at rural interchange locations.

A study by Ashley and Berard [26] analyzing 66 interchanges along 180 miles of I-94 in Michigan concentrated on the variation in land use impact by interchange design. Three interchange designs were identified: (1) closed

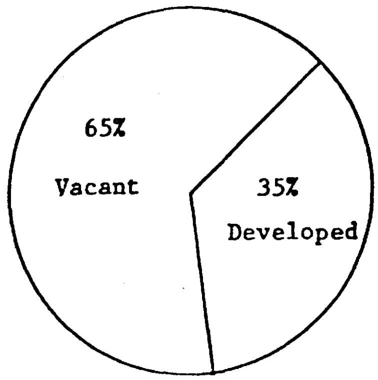


Figure 4. Pie Chart Showing the Distribution Between Vacant and Developed Quadrants in Rural Interchanges [37]

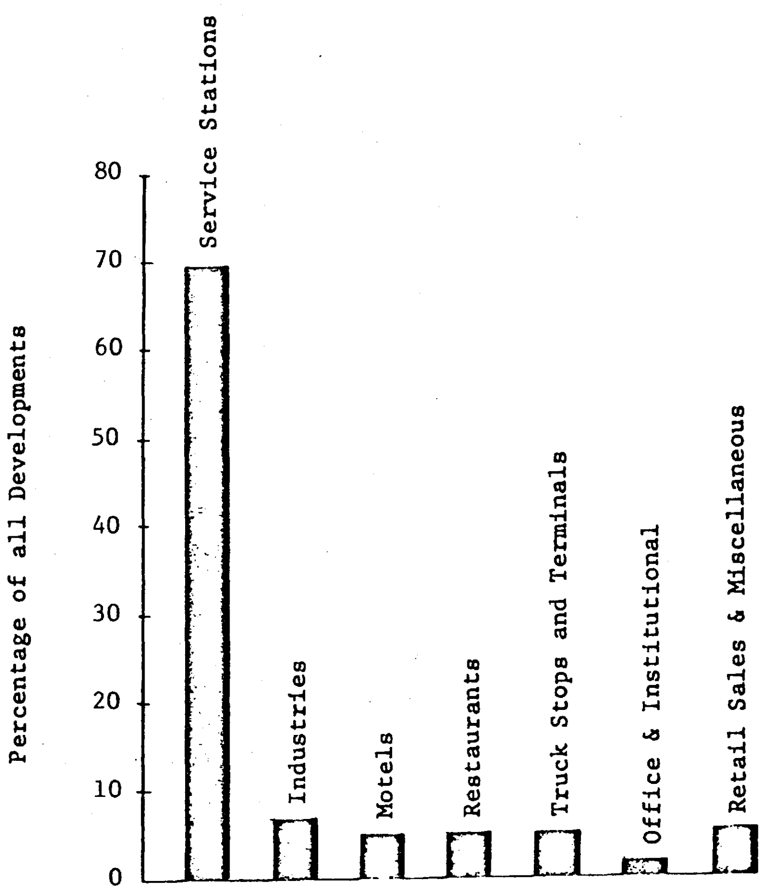


Figure 5. Bar Chart Showing Different Types of Developments as a Percentage of all Developments at Rural Interchanges [37]

Source: Babcock, W. F. and S. Khasnabis, "Land Use Changes and Traffic Generation on Controlled Access Highways in North Carolina," North Carolina State University at Raleigh, July 1971 interchanges; (2) partial interchanges; and (3) full interchanges. The definitions of these interchange designs are in the introductory section of this report. The 66 interchanges are categorized according to the three design features and five land use types in Table 15.

Table 15. Land Development in Percent by Type of Interchange [26]

Interchange Type	Commercial	Industrial	Residential	Governmental	Vacant
Closed Interchanges			14.8		85.2
Partial Interchanges	7.1		7.1	21.5	64.3
Full Interchanges	40.6	5.2	14.1	6.6	33.5

Source: Ashley, Roger H. and W. F. Berard. "Interchange Development Along 180 Miles of I-94." Highway Research Record No. 96, Highway Research Board, 1963, p. 48.

The data supports the finding cited by Stein [25] regarding interchange design and land development. Closed interchanges have some (15 percent) residential development and the remaining land stays vacant. Partial interchanges have more development than closed interchanges (espeically government land uses), and full interchanges experience the most intense land use. The data show that partial interchanges attract less commercial development than full interchanges but experience intense governmental development. Commercial land users pay premium land prices for the most accessible locations, and thereby occupy the majority of full interchange land sites.

Full interchange development. Since full interchanges have the most impact on land use, additional variables were applied to the full interchange data in search of more definite information regarding land use and interchange development. In the Michigan study [26], the interchange locations were identified according to geographical location. Four locational criteria were established: (1) major city routes; (2) secondary city routes; (3) small town; and (4) rural. Major city routes were those interchanges on a major highway in an urban area of greater than 10,000 population. Secondary city routes involved interchanges located on minor highways in urban areas of greater than 10,000 population. The small town designations were major full interchanges in urban areas of less than 10,000 population. The rural locations were all interchange not in urban areas. The percentage breakdown of land uses by interchange location is presented in Table 16.

Table 16. Percentage Breakdown of Quadrant Development for Full Interchanges [26]

Interchange Location	Developed Land in Percent					
	Developed	Vacant	Commercial	Industrial	Residential	Governmental
Major city route	87.5	12.5	78.1		9.4	
Sec. city route	76.9	23.1	40.4	15.4	11.5	9.6
Small town	65.4	34.6	44.2	1.9	15.4	3.9
Rural	51.3	48.7	22.4	2.6	17.1	9.2

Source: Adapted from Ashley, Roger H. and W. F. Berard. "Interchange Development Along 180 Miles of I-94." Highway Research Record No. 96, Highway Research Board, 1965, p. 49.

As expected, the greater the concentration of population and the resulting increased traffic volumes, the higher the percentage of developed land and commercial land use. Major city route interchanges attracted almost double the commercial development as secondary routes despite the similar population sizes. Secondary routes, with much less commercial use, experienced a higher percentage of industrial and governmental land use. Again, the variation in land use is a function of accessibility.

Skorpa, et al.,[10] consolidated the interchange data from the Michigan study [26] and a Pennsylvania study by Sauerlender, et al., to determine the kinds of commercial development at intersections and to establish an average frequency of occurence by type of development. The Pennsylvania and Michigan data are in agreement that the predominant commercial land use is service stations (Table 17). These findings are consistent with the results of other rural interchange studies [25, 37].

Skorpa, et al., developed Figure 6 to illustrate the degree of development at non-urban interchanges. The graph shows how the average units

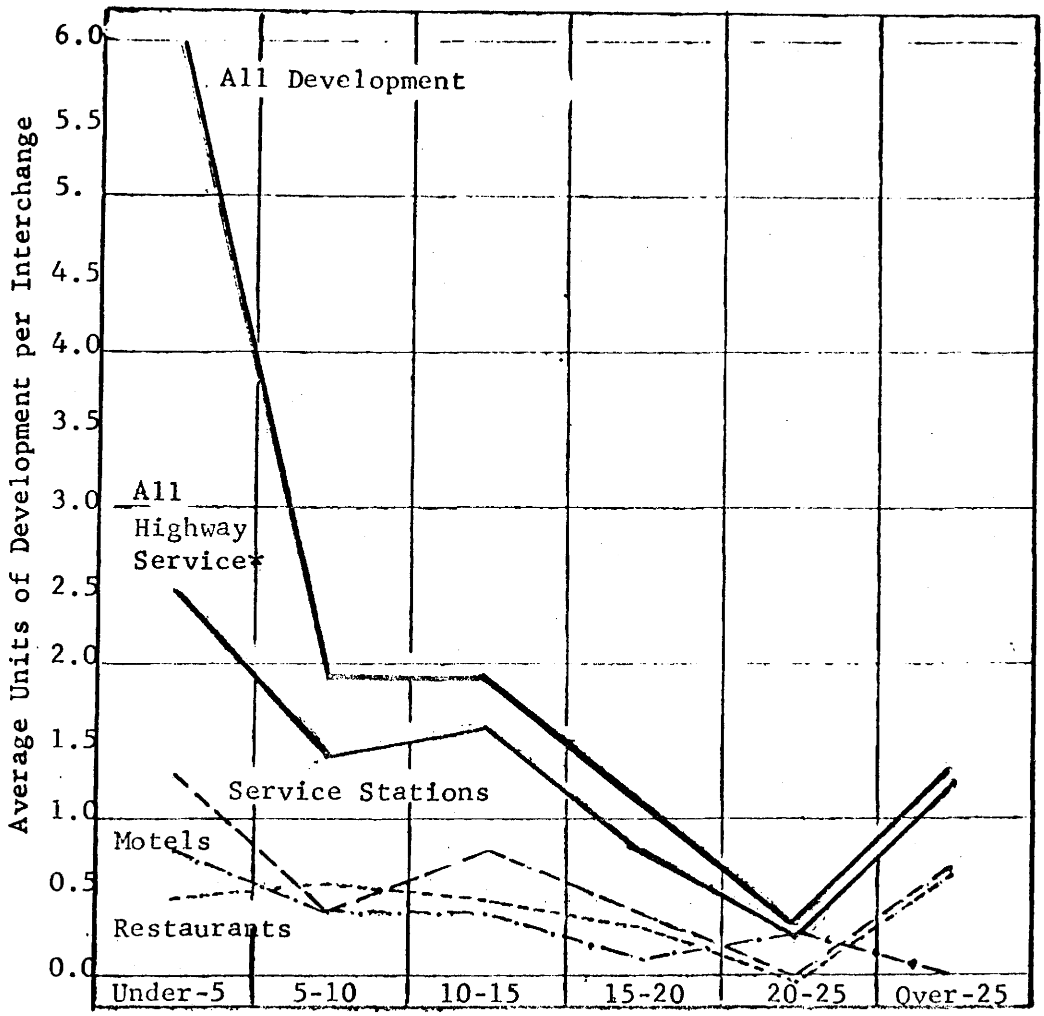
Table 17. Number of Developments (Within 1000 ft.) Per Full Interchange [10]

Interchange Location	Service Stations	Restaurants	Motels	Shopping Centers	Other Sales Uncommitted*
Major city route	3.38	2.38	1.25	0.38	0.38
Sec. city route	1.38	0.46	0.15	0.08	0.54
Small town	1.23	0.54	0	0	0.62
Rural	0.44	0.28	0	0	0.50
Average, Michigan	1.33	0.71	0.31	0.08	0.52
Average, Penn.**	0.6	0.3	0.3	0	0.6

*Known sales where no construction has started

**Figures from 36 non-urban interchanges

Source: Skorpa, Liduard, et al. _Transportation Impact Research: A Review of Previous Studies and a Recommended Methodology for the Study of Rural Communities_, Division of Research, Council for Advanced Transportation Studies, The University of Texas at Austin, March, 1974, p. 9.



Distance in Miles from Population Centers

* Highway Service, Service Stations, Motels, Restaurants

Figure 6. Degree of Development and Distance From Nearest Urban Area [10]

Source: Skorpa, Liduard, et al. Transportation Impact Research: A Review Of Previous Studies and a Recommended Methodology for the Study of Rural Communities, Division of Research, Council for Advanced Transportation Studies, The University of Texas at Austin, March, 1974, p. 13.

of development per interchange decrease for each commercial activity as the distance increases from population centers. Skorpa, et al., [10] found that this was consistent with other study findings.

Impact on Land Values. The reason for the observed increase in land values of rural land located at limited access highway intersection is that accessibility improves the attractiveness of interchange properties for higher land uses. As reported previously, rural intersections attract highway-serving land uses like service stations, motels, restaurants and truck stops. These kinds of businesses are willing to pay more for interchange properties due to the accessibility requirements of their enterprises.

Full interchanges. Ashley and Berard [26] have developed data on the change in land value at interchanges in their study of I-94 in Michigan. Using appraised land values before interchange development as a base, increases in property values were shown for land purchased for service station sites and for land purchased for all other purposes (Table 18).

Table 18. Changes in Land Values By Land Use Type In Full Interchanges [26]

Interchange Location	Average Land Values ($ per acre) 1960 - 1964		Percent Change by Use*	
	Service Stations	Other	Service Stations	Other Uses
Major City Routes	54,653	8,600	441	227
Sec. City Routes	18,650	1,830	388	215
Small Town	11,100	995	641	205
Rural	26,470	512	627	161

* Period 1958 - 1959 compared with period 1960 - 1964

Source: Adapted from Ashley, R. H., and W. F. Berard. "Interchange Development Along 180 Miles of I-94," Highway Research Record 96, 1965, p. 51.

Obviously, land value increased immensely at interchange sites, and service station site development produced the greatest increase in value per acre. Interestingly, secondary city (suburb) land values did not increase relatively as much as small town or rural land values. Also, rural land value increased more than secondary city land values on an absolute basis. The authors point out that interchange land speculation was a new phenomenon at the time and, consequently, prices are not always represenative of true property value. This is a possible explanation for the fact that land values did not increase at the rate as expected in relation to distance from urban centers.

The authors investigated the geographical range of the impact full interchanges have on land values relative to the business activities of service stations. Figure 7 indicates the price range of service station sites and the gallonage of service stations located at each geographical interchange.

Service stations located within 400 feet of major city interchanges sold, on the average, twice as many gallons of gasoline as those stations located between 400 feet and one mile from major intersections. In contrast, distance from interchanges produced very little difference in sales in small towns. As the data in Table 19 shows, there is a statistically significant difference between business activity at major city interchanges and all other interchanges.

The data presented implies that a relationship exists between business activity of commercial developments and the property value of commercial land sites. These findings are consistent with the findings in various urban and rural interchange studies.

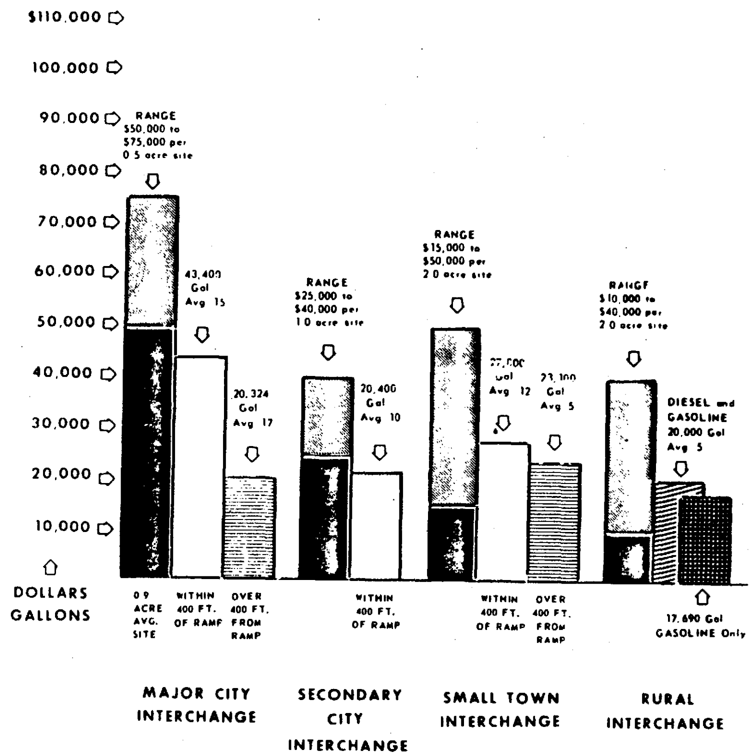


Figure 7. Full Interchange Service Station Activity Showing 1963 Price Range for Sites and 1963 Gallonages [26]

Source: Adapted from Ashley, R. H., and W. F. Berard, "Interchange Development Along 180 Miles of I-94," Highway Research Record No. 96, 1965, p. 52.

Table 19. Service Station Gallonage Comparison, Full Interchange [20]

Interchange Classification	No. Stations	Avg. Gal/Mo. (thousands)	Std. Dev. of Mean[a]	Standard Error of Dif. Between Means[b]: Major City	Secondary City	Small Town	Rural
Major city	15	43.4	21.70	-	6.6 S	6.6 S	7.2 S
Secondary city	10	20.4	9.35	6.3 S	-	4.6NS	5.4NS
Small town	12	27.0	11.11	6.6 S	4.6NS	-	5.7NS
Rural	5	20.0	10.09	7.2 S	5.4NS	5.7NS	-

[a]A standard deviation from the mean brackets approximately 68 percent of the stations

[b]S=significant; NS=not significant

Source: Ashley, R. H., and W. F. Berard, "Interchange Development Along 180 Miles of I-94," Highway Research Record No. 96, 1965, p. 52.

Full Access Highways

The impact of improving primary and secondary roads, or full access highways, on rural land values has been researched extensively since the 1920's. The general results of the research are that land values have been influenced significantly by highway improvement. Land use impacts have received less attention because of the minor changes in land development that has been experienced as a result of rural road improvements.

General Impact

A study of businesses on rural Kentucky roads by Stroup and Varga [54] provides some data on highway improvement impacts. During two study periods, 1938-1950 and 1955-1960, there was an increase in the number of businesses. The data indicates that improvements on intercounty roads and intracounty collector roads were responsible for the increase.

Adkins [46] observed that the existence of the farm-to-market road to Camp Creek reversed the trend of the disintegration of the rural community. The farming community did not move to town as a result of the increased accessibility to the impacted area. The improvement of the road from dirt to a paved surfaced also attracted retired people to build and move to the Camp Creek area. The net effect was that not only did the improved accessibility reverse the trend of out-migration but brought new people to the area.

Undeveloped Agricultural Areas - Existing Routes

Impact on Land Use. Adkins' [46] study on land use changes along Camp Creek road in Robertson County, Texas, found that the most significant change was the addition and improvement of dwellings along the highway improvement. Dwellings increased in number from 24 to 30. Nearby unimproved roads (dirt), in contrast, did not experience the growth that was evident on the farm-to-market road being studied. Other land use changes included increased land clearance and land under cultivation (Table 20).

Adkins, Frierson and Thompson [47] analyzed land uses along several types of roads in Ellis County, Texas. The authors found that there was very little relationship between the type of road and the use of the surrounding land.

Generally, road improvements in rural area had little impact on changing land use of properties near the highway. The only change that was found was an increase in rural residences along the facility. This evidence agrees with the findings in suburban areas in that the distance from urban centers is an important factor in causing land use changes near highway improvements.

Impact on Land Values. In his Camp Creek road study [46], Adkins found that the price of rural dwellings increased an average of 140 percent. Much of this increase was due to road improvement. The difference in impact of primary and secondary roads on land values in rural Ellis County, Texas was studied in detail by Adkins, Frierson, and Thompson [47]. Roads were classified into several categories: (1) dirt, (2) gravel, (3) farm-to-market, and (4) state highway. Two hundred and fourteen farm sales were analyzed in terms of sales price and road type (Table 21).

The data is very clear. The better the quality of right-of-way, the more valuable the land. Statistical analysis of the data was performed to gain more insight into price differentials between land located near the four road types, and the results are presented in Table 22. The results indicate rural road improvements from dirt to gravel, farm-to-market, or state highway dramatically increased the value of properties along the right-of-way. While land along the other three kinds of road improvements

Table 20. Impact of Full Access Highways on Land Use in Undeveloped-Agricultural Rural Areas

Study Reference Number	Type of Highway Improvement	Data Base for Analysis	Location of Land Compared	Before Period Land Use: Type of Land Use	Before Period Land Use: Percent or Quantity	Change in Land Use: Absolute Change	Change in Land Use: Percent Change
[46]	Dirt Road	Opinions	Study Area	Rural Residential	24 dwellings	+6 dwellings	+25%
	To Hard - Surfaced	of Land	Abutting	Cultivated Land	504 Acres	+167 Acres	+33.1%
	Road	Owners	Nonabutting	Wooded Land	1897 Acres	-384 Acres	-20.2%

Table 21. Impact of Full Access Highways On Property Values in Undeveloped-Agricultural Rural Areas

Study Reference Number	Type of Highway Improvement	Data Base for Analysis	Location of Property Compared	Before Period Use: Land Use Type	Before Period Use: Average Price	Change in Price: Absolute Change	Change in Price: Percent Change
[46]	Dirt Road to Hard-Surfaced (Farm-to-Market)	Opinions of Land Owners	Study Area	Agriculture	$ 48.67/Acre	+$23.41/Acre	+48.1%
			Abutting Land	Agriculture	34.40/Acre	+19.92/Acre	+57.9%
			Nonabutting	Agriculture	62.40/Acre	+62.40/Acre	+ 8.3%
			Study Area	Farm Bldg. Value	16.50/Farm	+23.10/Farm	+139.9%
[47]	County Rural Road Surface Analysis	214 Sales of farmland	All Roads	Agriculture	$136.03/Acre		
			Dirt to Gravel	Agriculture	96.71/Acre	+$41.66/Acre	+43.1%
			Dirt to FM[2]	Agriculture	96.71/Acre	+53.65/Acre	+55.5%
			Dirt to SH[3]	Agriculture	96.71/Acre	+71.73/Acre	+74.2%
			Gravel to FM	Agriculture	138.37/Acre	+11.99/Acre	+ 8.7%
			Gravel to SH	Agriculture	138.37/Acre	+30.07/Acre	+21.7%
			FM to SH	Agriculture	150.36/Acre	+18.08/Acre	+12.0%
[53]	U.S. Rural Road Surface Analysis	11.436 Farm land sales	Properties Adjacent to:				
			Dirt Roads	Agriculture	$44/Acre[1]		
			Gravel Roads	Agriculture	74/Acre[1]		
			Hard-Durfaced	Agriculture	96/Acre[1]		
[57]	2-Lane Undivided to a 4-land Divided Highway		Study Area	Agriculture	$ 94/Acre	+$44/Acre	+47.0%
			Zone 1	Agriculture	105/Acre	+20/Acre	+19.0%
			Zone 2	Agriculture	65/Acre	+100/Acre	+100.0%
			Zone 3	Agriculture	110/Acre	+45/Acre	+41.0%

1 Median prices per acre

2 FM - Farm to Market Road

3 SH - State Highway

(gravel to farm-to-market, gravel to state highway, and farm-to-market to state highway) also increased in value, properties along dirt road improvements experienced the most added value. The statistical significance of the three kinds of dirt road improvements on value added of properties were significant at the 99 percent confidence level. The other rural road improvements confidence levels were statistically weaker but still indicated that the rural road improvement would probably increase the value of right-of-way properties.

Table 22. Differences in Average Sales Prices Per Acre of Farms Located on Various Road Types, Ellis County, 1955-58 [47]

Road Type Changed Assumed	Differences in Prices Per Acre: Dollars Added	Differences in Prices Per Acre: Percent Added	Confidence Level*
Dirt to Gravel	$41.66	43.1%	99%
Dirt to Farm-to-Market	53.65	55.5	99
Dirt to Other State Highway	71.73	74.2	99
Gravel to Farm-to-Market	11.99	8.7	73
Gravel to Other State Highway	30.07	21.7	91
Farm-to-Market to Other State Highway	18.08	12.0	67

*Based on sigificance of difference of means.

Source: Adkins, W. G., J. E. Frierson, and R. H. Thompson, "Farm Land Values and Rural Road Service in Ellis County, Texas 1955-58," Texas Transportation Institute, Bulletin 12, June 1960, p. 17.

Historically, studies of rural land use impacts resulting from road improvement have shown a moderate increase in land value. A 1958 study of Camp Creek Road in rural Robertson County, Texas by Adkins [46] obtained similar findings. The land value data were generated by interviewing residents and examining public records. While not objectively derived, the data's congruence with earlier studies suggest a degree of reliability. The findings are of interest partially because they reflect residents' attitudes about land value and land use impacts. Since personal values help determine the desirability of tracts of land and, therefore, land value, some knowledge of attitudes is desirable.

According to those interviewed, market value of properties along the improved road (dirt to farm-to-market) increased an estimated average of 57.9 percent. Residents of land on adjacent dirt roads claimed an estimated average increase in property value of 8.3 percent that was attributed to the improved road.

The United States Department of Agriculture conducted a nation-wide survey of rural land sale prices on hard-surfaced, gravel, and dirt roads in 1958. Longley and Goley [53] calculated the mean price per acre for each category of road surface and developed Table 23 to illustrate their findings. Median prices were used instead of mean sale prices in order to minimize the effect of extreme values. All reported values are based on actual sale prices obtained from 11,436 transactions. The results lend support to the studies cited earlier in this report. The Ellis and Robertson County findings [46, 47] gain credibility in view of their agreement with the more objectively based findings.

After analyzing the land sales data, the median prices for farm land along the three road surface types were found to be $96 per acre for hard-surfaced road properties, $74 per acre for gravel road properties, and $44 per acre for dirt road properties. Two variables, land sales in the corn

Table 23. Comparison of Median Prices Per Acre of Rural Properties and Ratios by Type of Road Surface and by Distance from Nearest Trading Center[1] [53]

Price or Ratio	Miles from Nearest Trading Center									
	1-2	3-4	5-6	7-8	9-10	11-15	16-20	21-30	Over 30	All Distances
Price per acre, total ($):										
Hard-surfaced	164	160	158	58	54	23	43	18	17[2]	96
Gravel	172	138	108	117	78	50	14	35	13	74
Dirt	94	98	72	59	50	40	40	31	9	44
Ratio of total price per acre:										
Hard-surfaced to gravel	0.953	1.159	1.463	0.496	0.692	0.460	3.071	0.514	1.308	1.297
Hard-surfaced to dirt	1.745	1.633	2.194	0.983	1.080	0.575	1.075	0.581	1.889	2.182
Gravel to dirt	1.830	1.408	1.500	1.983	1.560	1.250	0.350	1.129	1.444	1.682
Price per acre excluding corn belt ($):										
Hard-surfaced	151	125	144	53	53	22	43	18	17[2]	83
Gravel	114	90	80	73	65	47	14	35	13	51
Dirt	89	88	55	53	47	40	40	31	9	41
Ratio of price per acre excluding corn belt:										
Hard-surfaced to gravel	1.349	1.389	1.800	0.726	0.815	0.468	3.071	0.514	1.308	1.627
Hard-surfaced to dirt	1.697	1.420	2.618	1.000	1.128	0.550	1.075	0.581	1.889	2.024
Gravel to dirt	1.281	1.023	1.455	1.377	1.383	1.175	0.350	1.129	1.444	1.244
Price per acre excluding sales of tracts over 500 acres ($):										
Hard-surfaced	179	189	158	134	153	94	98	89	50[2]	164
Gravel	172	136	131	117	128	62	79	18	80	128
Dirt	94	98	90	82	68	60	62	38	39	87
Ratio of price per acre excluding sales of tracts over 500 acres:										
Hard-surfaced to gravel	1.041	1.370	1.206	1.145	1.195	1.516	1.241	4.944	0.625	1.281
Hard-surfaced to dirt	1.904	1.929	1.756	1.634	2.250	1.567	1.581	2.342	1.282	1.885
Gravel to dirt	1.830	1.408	1.456	1.427	1.882	1.033	1.274	0.474	2.051	1.471
Price per acre excluding corn belt and sales of tracts over 500 acres ($):										
Hard-surfaced	160	157	144	127	147	84	80	76	50[2]	144
Gravel	119	90	82	73	69	54	71	18	80	90
Dirt	89	89	82	74	63	77	62	38	39	81
Ratio of price per acre excluding corn belt and sales of tracts over 500 acres:										
Hard-surfaced to gravel	1.345	1.744	1.756	1.740	2.130	1.556	1.127	4.222	0.625	1.600
Hard-surfaced to dirt	1.798	1.764	1.756	1.716	2.333	1.091	1.290	2.000	1.282	1.778
Gravel to dirt	1.337	1.011	1.000	0.986	1.095	0.701	1.145	0.474	2.051	1.111

[1]Adapted from tabulations compiled from March 1958 survey.

[2]Two sales were omitted in California specialty at $351 per acre.

Source: Longley, James W. and B.T. Goley, "A Statistical Evaluation of the Influence of Highways on Rural Land Values in the United States," Highway Research Bulletin 327, Highway Research Board (1962), p. 37.

belt and land sales of tracts larger than 500 acres, were discovered to be disproportionately represented in the data. Each variable was excluded from the analysis of the data to determine whether either or both variables distort the findings.

In summary, two things seem clear from the national survey: (1) farm land abutting hard-surfaced roads is consistently more valuable than land beside gravel and dirt roads; and (2) with the exception of corn belt property values and land parcel sales exceeding 500 acres, there is little difference in land values on gravel roads and land values on dirt roads.

Varga [57] implemented a parallel band approach to analyze the effects of improving an existing 2-lane undivided highway to a 4-land divided full access facility. Zone 1 extended one mile from either side of the facility, Zone 2 properties were adjacent to Zone 1 and included properties one to two miles distant from the improvement, and Zone 3 consisted of those properties two to three miles distant and parallel to the facility's right-of-way. Table 21 illustrates Varga's findings within the study area.

Suburban Locations

Suburban lands within the influence of highways have been studied during the past decade in an effort to estimate the impact of improved accessibility on land use and land value. Land immediately adjacent to the improved facility usually experiences the most intensive and extensive impacts. The degree of highway influence varies according to the physical and socioeconomic characteristics of the area and the kind of highway improvement. Whether the transportation improvement is a newly constructed limited-access freeway or adding lanes to an existing full-access traffic artery, the effect on land use and land value change is expected to be excellerated. This section reviews the limited access and full access facility improvement suburban studies separately and attempts to summarize the findings presented in the highway research literature (see Table 24).

Although the literature classifies land types differently (rural, suburban, and urban), suburban land will include:

- land located on the fringe of a town or city which has at least 10,000 population;
- land located in the city limits of a town or city with less than 10,000 population; and/or
- land that is within two miles of a built-up area.

Limited Access Highways

Most of the research done in the past has analyzed the impact of limited-access highways on the economic condition of suburban areas. This research has been done because of the profound changes that normally are experienced in the use and value of land situated near a freeway. The scale of the impact varies from a few downtown blocks to several miles of highway, depending on the location and type of highway improvement taking place.

Table 24. Master Summary Table of the Suburban Studies Contained in the Review of the Literature

Study Number	Type of Access	Existing or New Route	Type of Highway	Area Stage of Development	Description of Study Area	Size of Study Area	Distance from CBD	Location of Analysis	Dominant "Before" Land Use	Dominant "After" Land Use	Study Period	Year Facility Opened	Study Technique	Types of Data Collected and Analyzed: Land Use	Land Value	Business Activity	Traffic Analysis	Other
7	Limited	New and Existing	Bypass	Developing	Rural-Urban fringe about ½ in city limits	Approx. 5 mile section & 1 mile on both sides	4 miles	Land along both routes	Agriculture	Residential	1941-61	1954	Study-control	Δ in acre	$/acre	No. of firms and sales	ADT	Land use - value relationship
11	Limited	New	Radial	Developing	Open agri. land and small agri. town	8.1 miles long ½ about 1 mile wide	6 - 15 miles	Adjacent land	Agriculture	Residential	1949-59	1955	Study-control	% Δ in use	$/acre	No. of manu. plants	ADT	Bank deposits, building permits
13	Limited	New	Bypass	Undeveloped	Large agri. area transversed by railroad	3 miles long and 1 3/4 miles wide	1-2 miles	Adjacent land	Agriculture	Unimproved	1943-61	1955	Study-control	No. of tracts	$/acre	No. of firms and sales	ADT	Land use - value relationship
14	Limited	New	Bypass	Undeveloped	Fringe area with rolling forest ½ in city limits	6.5 miles long & 3 miles wide	Unknown	Land adjacent to bypass	Agriculture	Agriculture	1950-64	1959	Study-control	No. Δ in acres	$/acre	No. of firms and sales	ADT	Travel pattern
15	Limited	New	Bypass	Developing	Large tracts of agric. land with rural residence	11.5 miles long and 3/4 to 1.5 mile wide	Unknown	Land adjacent to bypass	Agriculture	Agriculture	1951-62	1959	Study-control	No. of tracts Δ use	$/acre	No. of firms and sales	ADT	Land use - value relationship
16	Limited	New	Radial	Developing	Largely unimproved areas w/ rapid changes	10-4 square mile area at interchanges	NA	Quadrant Development	Vacant Agriculture	Vacant Residential	1951-61	NA	Before-after	No. and % acres		Commercial Development	Traffic Generation	Case study of Big Town - Dallas
17	Limited	New	Bypass	Developing	Wooded recreational area for Houston	Approx. 7. miles long and 4 miles wide	Less than 1 mile	Adjacent Property	Timberland Agriculture	Unimproved	1952-65	1962	Study-control	No. of acres & tracts	$/acre	No. of firms and sales	ADT	Travel patterns
18	Limited	New	Bypass	Undeveloped	Largely an agricultural area	14.5 miles long and 3 miles wide	Unknown	Adjacent Property	Agriculture	Agriculture	1944-61	1959	Study-control	No. of tracts	$/acre		ADT	Land use - value relationship
20	Limited	Existing	Radial	Developing	Rice producing area with rural subdivisions	9 miles long and about 3 miles wide	6 miles North	Adjacent Property	Agriculture	Unimproved	1950-62	1959	Study-control	No. Δ in acres	$/acre	No. of firms and sales		
21	Limited	New and Existing	Bypass	Developing Developed	Small town outside of Abilene	The town & rural fringe areas of Merkel	Within Area	The town of Merkel	Unimproved and Residential	Commercial Residential	1950-62	1959	Before-after	No. Δ in Development	$/acre	No. of firms and sales	Travel Habits	Resident's Opinion
22	Full	New	Beltway	Undeveloped	Largely undeveloped with some rural residences	1000 feet on both sides of the Beltway	2-5 miles	Adjacent Properties	Agriculture	Agriculture Commercial Industrial	1940-58	1950	Study-control	% Δ in use	% Δ by use		ADT Accident	Population and growth
24	Limited	New	Beltway	Developing	Large unimproved tracts with scattered res.	22 miles long & 3 miles wide	6-12 miles	3 mile wide adjacent bands	Unimproved Vacant	Residential	1951-62	1964	Parallel Band	No. of apts.	$/acre	No. of firms and sales	ADT	Population, Travel Pattern
27	Limited	New	Radial	Developing	Rural-urban fringe areas	10 study areas (Texas) adjacent to IHs	NA	Adjacent Land	NA	NA	Unknown	NA	Regression Analysis		$/acre			
28	Full vs. Limited	Existing	Parkways vs Radial	Developing	Rapidly developing residential & commercial fringe	3 adjacent areas along Wash., D.C. highways	NA	Adjacent land	Vacant	Residential	1950-61	NA	Regression Analysis	Index of development	$/sq. ft.			Distance to CBD
29	Limited	New	Radial	Developing	Rural-urban fringe areas in North Carolina	1-10 mi. part of I-95, I-5 mi part of I-40, 1-5 mi. part of I-85	NA	Adjacent land	Agriculture	Vacant	1947-61	NA	Regression Analysis	Land use Pattern	% Δ by use			
30	Limited	New	Radials	Developing	Suburban residential areas near Wash., D.C.	Metropolitan area of Washington, D.C.	NA	3 accessibility indexes	NA	NA	1961	NA	Regression Analysis		House Values			Travel times Distance to CBD
31	Limited	Existing	Beltway	Developing	Unimproved land outside of developed areas	55 mile long area around Boston	10 miles	Adjacent land	Vacant	Industrial and Residential	1945-57	1956	Industrial Case Study	Res. urban development	$ Δ by people		ADT	
32	Full	Existing	Radial	Developed	Largely an agricultural area w/ highway develop.	60 miles of U.S. 41 between Chicago & Milwaukee	NA	Adjacent land	NA	Agriculture	1956	NA	Commercial Case Study	% land in use		No. of commerical development	Traffic Volume	
33	Limited	New	Radial	Developing	Residential area with Ind. (new) growth	Large geographical area NW of St. Louis	Unknown	St. Charles County	Agriculture	Residential	1960-74	1958	Case Study	Building Permits	Assessed Values	Retail Sales	ADT	Income, Population, Employment
35	Limited	New	Beltway	Developing	Single-family residences with unimproved land	Remainder parcels along 8 miles of highway	about 6 miles	Abutting remainder parcels	Residential	Vacant	1954-61	Projected 1963	Case Study	Succession of uses	$/sq. ft.			
37	Limited	New	Interstate	Developing	Prime land for prospective development	76 interchanges and the quadrants	NA	Interchange	NA	Commercial	1950-58	1958	Regression Analysis	No. of Developments			Traffic Generation	
48	Limited	New and Existing	Beltway	Developing	Undeveloped area with several residential subdivisions	20 miles long and 1 mile wide	About 7 miles	Adjacent land	Agriculture	NA	1950-58	1958	Before-After	% Δ by use	$/acre			

Table 24 (Continued)

Study Number	Type of Access	Existing or New Route	Type of Highway	Area Stage of Development	Description of Study Area	Size of Study Area	Distance from CBD	Location of Analysis	Dominant "Before" Land Use	Dominant "After" Land Use	Study Period	Year Facility Opened	Study Technique	Types of Data Collected and Analyzed: Land Use	Land Value	Business Activity	Traffic Analysis	Other
55	Limited	New	Beltway	Developing	Urban fringe area w/ agri. & resi. uses	About 1000 feet on both sides or 2,175 acres	About 5 miles SE	Adjacent land	Vacant Agriculture	Agriculture Residential	1940-58	1955	Study-Control	% Δ and acre Δ	$ Δ by use			
56	Limited	New	Interstate	Developing	Land near the interstate hwy. system	Areas within 5 miles of IH facilities	NA	Frontage roads	NA	NA	1956-63	NA	Industrial Case Study					Industrial development by location & types
61	Limited	New	Bypass	Undeveloped	City serves as a center for agri. area	Business in city & property adjacent to old highway	through CBD	Former route	Unknown	Unknown	1955-58	1956	Before-After		Δ in values	Sales Tax	ADT	
62	Limited	New	Bypass	Developing	Wide diversity of land+small to large town	35.2 miles along I-40 in Tennessee	NA	Adjacent land	Unknown	Unknown	1951-62	1961	Study-Control	No. of firms		Index of gross sale	Volume of Traffic	
63	Limited	New	Bypass	Developing	Fringe areas w/ good potential for growth	3 suburban communities in Washington state	NA	General areas	Unknown	Unknown	1956-61	1958			Property Values	Sales Tax	Travel Patterns	
65	Limited	New	Beltway	Developed	Fringe area w/ several rail facilities	12 miles x 1 mile, 7680 acres	About 3 miles	Adjacent land	Residential	Residential	1940-59	1938	Case Study Before-After	Δ in acres		Types of Businesses		Commercial and Industrial area Development
67	Limited	New	Radial	Developing	Area experiencing intense development	About 5.25 miles long and 2.5 miles wide	7 to 10 miles	Residential subdivision	Agriculture	Residential	1956-66	1962	Residential Case Study	% of area developed	% Δ house prices		Travel Time	
68	Limited	New	Bypass	Developing	2 medium-size towns w/ unimproved land	overall region-two cities and the area between	NA	General areas	Agriculture	Agriculture	1954-63	1958	Study-Control		$/acre	Sales Tax	ADT	
69	Partial	New	Bypass	Developing	Medium-size city experiencing traffic problem	The city of Rolla, MO (all businesses)	NA	General area	NA	NA	1953-56	1954	Before-After			Retail Sales	Accident Rates	
70	Limited	New	Bypass	Developed	Primarily a logging area w/ some agri.	6 communities and their by-passed firms	NA	Former route	NA	NA	Various Periods	Various Years	Before-After			Retail Sales	Traffic Volumes	
72	Limited	New	Bypass	Developing	Rapidly developing fringe area	7.5 miles long	13 miles	Adjacent land	Agriculture	Residential	1946-60	1956	Study-Control		$/acre			
74	Limited	Existing	Bypass	Developed	Commercial market center for area farmers	The businesses adjacent to old highway & general area	Near CBD	Former route	Commercial	Ripe Commercial	1950-55	1954	Study-Control	No. of new firms	$/sq. ft.	% Δ Sales	ADT	
75	Limited	New	Bypass	Developing	Center of large agric. region	General area transversed by highway	Unknown	Former route	Commercial	Ripe Commercial	1952-58	1956	Before-After	Building Permits	% Δ value	% Δ sales	ADT	Population, building value
79	Limited	New	Radial	Developing	Unimproved area w/ excellent access	9.5 miles long & adjacent property	Unknown	Adjacent land	Vacant	Industrial	1946-49	1948	Before-After	No. of Industries	$/acre			
80	Limited	New	Bypass	Undeveloped	Market center for farmers in area	Town and the general area	2 miles	Former route	NA	NA	1952-54	1953	Before-After			Retail sales	ADT	
81	Limited	New	Bypass	Developing	Extensive commercial strip development	7.9 miles of old highway & adjacent proper-ty	About 4 miles	Former route	Commercial	Commercial	1950-55	1953	Before-After	% Δ Building Activity	% Δ value	Retail sales	% Δ in ADT	Population employment
82	Limited	Existing	Artery	Developed	Rapidly changing suburb of L.A., Cal.	Incorporated city limits of Glendale	8 to 10 miles-L.A.	General community	Residential	Residential	1959-63	1961	Parallel Band	Building Permits	% and $ Δ			Population
83	Limited	NA	NA	Developed	Established res. area adjacent to freeway	4 Res. areas - at least 2 blocks along freeway	NA	Adjacent property	Residential	Residential	1954-56	NA	Parallel Band		% Δ value		ADT	Resident's opinion
84	Limited	Existing	Radial	Developed	Established strip development along old route	Abutting properties along 7 city blocks	through CBD	Frontage roads	Strip Commercial	Commercial	1948-52	1950	Study-Control		% Δ value	Retail sales	ADT	
85	Limited	Existing	Radial	Developing	Unique established roadside comm. area	Abutting property along 1/2 mile of highway	NA	Frontage roads	Vacant	Strip Commercial	1953-55	1954	Case Study	No. of Businesses		Retail sales		
87	Limited	New	Beltway	Developing	Rapidly developing fringe area of Washington	22 miles long and 3 miles wide	6 to 12 miles	Adjacent land	Vacant	Residential	1951-66	1964	Parallel band	Δ in acres	% Δ $/acre	Retail sales	Pattern Volume	Population, Employment

General Impact

The impact of a limited-access highway in an urban or suburban area may affect not only the land uses and land values, but the facility could also affect such factors as: business activity, industry location, social habits, and community organization. Although this report is mainly concerned with land use and land value effects, various studies indicate that changes in the general make-up of the community can be attributed to highways.

Suburban communities that prior to the change in the highway have been oriented toward agriculture, experienced changes in every sector of the community. Wuenscher and Lang [33] studied an area influenced not only by an interstate highway but also by the city of St. Louis, Missouri. The authors report that the area soon transformed itself from an agricultural area to a residential suburb of the larger city. The report estimates the changes in retail sales, income of families, population, employment, and traffic along with estimates of land use and land value changes which are attributed to the improved accessibility of the area. Retail sales increased 57.4% in 5 years, employment rose 6.1% from 1970 to 1972, families with incomes over $10,800 increased from 21.3% in 1968 to 33.8% in 1973, and population in the area rose 75% between 1960 and 1970 and approximately 20% between 1970 and 1975. Buffington also reports changes in business activity for suburban communities influenced by interstate highways [17, 18, 20, 21].

Undeveloped Agricultural Areas - New Routes

Impact on Land Use. Suburban or urban-fringe areas transversed by a new highway normally experience significant land use changes. Extensive research has been devoted to the study of the impact highways have on land development in areas characterized by large amounts of unimproved or vacant land. Most of the research concludes that a new highway through an undeveloped area usually brings about the greatest amount of change in both land use and land value.

Thompson and Adkins [11] examined land use change along several miles of expressway between Dallas and Richardson, Texas. This area of open land experienced extensive amounts of residential and industrial development on land that was previously used for agricultural purposes or had been idle. Through the use of aerial photographs taken in 1949 (before period) and in 1959 (after period), the authors found that most of the development had occurred near Richardson, which had fewer zoning restrictions than Dallas. Table 25 shows the percentage change in land use for the study area.

Buffington [7, 13, 14, 15, 17, 18,20, 21] analyzed the impact of interstate highway bypass routes on land use change in suburban areas. The land uses were determined by personal inspection and with conferences with local tax offices and real estate developers. Buffington's studies indicate that land abutting the interstate bypass route changed to higher uses in greater quantity than did nonabutting land. Nonabutting land, even so, changed from agricultural use to such uses as residential, commercial, and industrial. This was found to occur more often on the built-up or "town side" of the facility than on the "outside" or opposite side.

The number of acres in agricultural and timberland uses declined dramatically in most study areas as accessibility to abutting land increased. In most cases, commercial traffic-serving establishments were the first developments followed by industrial and scattered residential uses (Table 25).

Other highway impact studies that are similar to the ones mentioned above are [27, 29, 33, 48, 67]. These studies reviewed the impact of limited access highway improvement in undeveloped suburban areas.

Table 25. Impact of Limited Access Highways On Land Use in Undeveloped-Agricultural Suburban Acres

Study Reference Number	Type of Highway Improvement	Location of Land Compared	Dominant Before Land Use	Before Period Use		After Period Use	
				Land Use Type	Percent or Quantity	Absolute Change	Percent or Percent Change
[11]	New Limited Access Expressway	Study Area	Agriculture	Agriculture	94%		74%
		Study Area		Residential	1%		13%
		Study Area		Industrial			7%
		Study Area		Public	5%		5%
		Study Area		Commercial			1%
[14]	New Location Interstate Bypass	Study Area	Agriculture	Agriculture	5600 Acres	-619 Acres	-11.1%
		Study Area		Vacant	1416 Acres	+44 Acres	+3.1%
		Study Area		Residential	520 Acres	+309 Acres	+59.4%
		Study Area		Commercial	29 Acres	+27 Acres	+93.1%
		Study Area		Industrial	1 Acres	0	0
				Institutional	1007 Acres	-102 Acres	-10.1%
[20]	New Location Interstate Bypass	Study Area	Agriculture	Agriculture	6000 Acres	-2629 Acres	-43.8%
		Study Area		Vacant	5500 Acres	+2100 Acres	+38.2%
		Study Area		Residential	1000 Acres	+174 Acres	+17.4%
		Study Area		Commercial	20 Acres	+6 Acres	+30%
		Study Area		Industrial	50 Acres	+310 Acres	+620%
		Study Area		Institutional	5 Acres	+12 Acres	+240%
[36]	Analysis of Transportation Network Improvements in a 35 county Region	Study Area	Forest	Forest	77.19%	-490,673 Acres	-9.1%
		Study Area		Agriculture	14.79%	+330,364 Acres	+31.9%
		Study Area		Residential	1.35%	+150,752 Acres	+159.3%
		Study Area		Commercial	0.14%	+ 8,724 Acres	+90.0%
		Study Area		Industrial	0.06%	+8,128 Acres	+173.0%

Impact on Land Values. Thompson and Adkins [11] analyzed the influence of a new expressway through an undeveloped suburban area near Dallas. The expressway studied is the same facility analyzed in Adkins' [45] previously discussed report, but this portion of the freeway transverses open land being primarily used for agriculture or lying idle. The facility segment being studied extends northward 8.1 miles from Loop 12 in Dallas to past the suburban city of Richardson, Texas. The purpose of the study is to ascertain the impact of the freeway on land values of largely undeveloped properties near the right-of-way and on property values in Richardson (see Table 26).

Using the "before and after" approach in conjunction with the study and control area method, the authors report that the expressway had a profound impact on abutting unimproved properties. These properties increased in constant dollars an average of about 269 percent while comparable nonabutting properties indicated only a 17 percent increase above control area unimproved land. Dallas' unimproved property values during the before construction period were found to be over twice as high as unimproved property values in Richardson. These same properties during the after construction period showed that Dallas values were approximately the same as Richardson values; the facility tended to "equalize" the value of unimproved properties in the two locations.

Franklin and Evans [27] compared the effect of access to a limited access highway on land values of abutting and nonabutting properties for various types of land uses. Comparing properties along highways with frontage roads with similar properties along highways without frontage roads, the authors found that the effect of access on sales prices of various land use types were quite different. Analysis of 715 remainder sales of right-of-way properties indicated that unimproved properties with access showed a net differential

Table 26. Impact of Limited Access Highways On Property Values in Undeveloped-Agricultural Suburban Areas

Study Reference Number	Type of Highway Improvement	Dominant Before Land Use	Location of Land Compared	Before Period Value		Change In Values	
				Land Use	Average Price	Absolute Change	Average Percent Change
[11]	New Limited Access Expressway	Agri.	Study vs Control	Unimproved	$1,012/Acre	+$ 961/Acre	+95%
			Study vs Control	Improved	4,276/Acre	+18,643/Acre	+436%
			Study vs Control	Unimproved	947/Acre[1]	+1,004/Acre[1]	+106%
			Study vs Control	Improved	4,136/Acre[1]	+15,469/Acre[1]	+374%
			Abutting	Unimproved	1,068/Acre	+3,119/Acre	+292%
			Nonabutting	Unimproved	996/Acre	-60/Acre	-6%
			Abutting	Unimproved	1,023/Acre[1]	+2,752/Acre[1]	+269%
			Nonabutting	Unimproved	927/Acre[1]	-158/Acre[1]	-17%
[20]	New Location Interstate Bypass	Agri.	Study vs Control	Unimproved	$ 535/Acre[1]	+$ 388/Acre[1]	+72.1%
			Abutting	Unimproved	299/Acre[1]	+312/Acre[1]	+104.4%
			Nonabutting	Unimproved	627/Acre[1]	+400/Acre[1]	+63.8%
			Study Area Subdivided	Unimproved	$.0411/sq.ft.[1]	+.0093/sq.ft.[1]	+22.6%
			Study Area Subdivided	Improved	.1944/sq.ft.[1]	-.1096/sq.ft.[1]	-56.4%
[14]	New Location Interstate Bypass	Agri.	Study vs Control	Unimproved	$939/Acre[1]	+2,376/Acre[1]	+253%
			Study vs Control	Improved	4479/Acre[1]	+2,105/Acre[1]	+47%
			Abutting	Unimproved	1179/Acre[1]	+5,853/Acre[1]	+489%
			Nonabutting	Unimproved	891/Acre[1]	+18/Acre[1]	+2%
			Study Area Subdivided	Improved	$.8819/sq.ft.[1]	-.0001/sq.ft.[1]	0
			Study Area Subdivided	Unimproved	.1122/sq.ft.[1]	+.0600/sq.ft.[1]	+53%

1 In Constant Dollars (1947-49 = 100)

increase of 153 percent, while agricultural and commercial properties with access rose 12 and 97 percent respectively above properties without access. On the other hand, residential properties with access experienced a negative 89 percent indifferential in land value.

Buffington analyzed the impact of interstate highway bypass routes on land values at several locations in Texas. Buffington [13, 14, 15, 17, 18, 20, 21] used the study-control area technique to determine the degree of influence the new highway has on property values along the facility. Generally, the interstate routes studied passed through undeveloped agricultural land located in suburban fringe areas of nearby cities and towns.

The studies indicate that the increase in land values for improved properties is smaller than the increase for unimproved areas. Buffington suggests that one reason for this may be that improved lots have a fixed land use and their prices normally do not respond as quickly to changing surroundings as do unimproved properties.

Buffington found that the degree of impact a new bypass has on property values in urban-fringe areas depends not only on the type of land use, but also the location of the property relative to the right-of-way. Generally, the highway will cause land values to increase along the facility.

Developing Agricultural Areas - New Routes

Impact on Land Use. Circumferential highways are normally located approximately five to ten miles from the city's central business district through largely undeveloped urban-fringe areas. Land uses in the area are changed dramatically because the improved accessibility provided by the facility makes properties near the highway the most attractive sites for not only residential development, but also for industrial and commercial uses. A circumferential highway may affect both the immediate area surrounding the facility and the distribution and growth of land development in the metropolitan area as a whole.

The Capital Beltway, located six to twelve miles from the nation's Capital and bypassing the Washington, D.C. commercial district has had a profound effect on land development patterns in northern Virginia. Connally [87] found that in the areas adjacent to the facility industrial, commercial, and multi-unit residential development was significant during the time period, 1958-1966. Table 27 shows land use change (by acreage) in the primary study area. Connally, through land use maps, concluded the beltway has not caused a major shift in single-family residential growth but has definitely made land between major highway arterials more accessible.

In summary, Connally indicated that without the beltway, most of the growth would have continued outward along the major arterial highways. Large tracts of land would probably have remained vacant as a result of leap-frogging along the arterials, and industrial development would have had little choice of locating in the region other than near railroads or the waterfront. The beltway altered the pattern of development and the type of land uses in the study area.

The Watterson Expressway in Louisville, Kentucky, at the time of the study (1960), was a newly constructed limited access highway similar to a circumferential facility in that it bypassed the central business district and much of it passed through large tracts of unimproved and agricultural land. The University of Kentucky [55] studied the impact of the expressway in an area which had experienced some development prior to the highway's construction. This portion of the expressway's route is termed as a developing area. The research staff employed city and county maps to estimate the amount of change devoted to each land use category in 1947, 1954, and 1959 (Table 27).

Table 27. Impact of Limited Access Highways on Land Use in Developing-Agricultural Suburban Areas

Study Reference Number	Type of Highway Improvement	Location of Land Compared	Dominant Before Land Use	Before Period Use		Change In Use	
				Land Use Type	Percent or Quantity	Absolute Change	Percent Change
[17]	New Location Interstate Bypass	Study Area	Agriculture	Agriculture	14,350 Acres	-5,421 Acres	-37.8%
		Study Area		Vacant	3,087 Acres	+4,269 Acres	+138.3%
		Study Area		Residential	944 Acres	+516 Acres	+51.9%
		Study Area		Commercial	67 Acres	+115 Acres	+171.6%
		Study Area		Industrial	57 Acres	+16 Acres	+28.1%
		Study Area		Institutional	1,743 Acres	+178 Acres	+10.2%
[55]	New Limited Access Expressway	1000' Study Band on Either side of Highway	Agriculture	Res-Vacant	94 Acres	+88 Acres	+93.6%
				Idle	266 Acres	-48 Acres	-18.0%
				Agriculture	1,271 Acres	-805 Acres	+63.3%
				Residential	379 Acres	+579 Acres	+152.3%
				Commercial	106 Acres	+64 Acres	+60.4%
				Industrial	45 Acres	0	0
				Institutional	17 Acres	+100 Acres	+588.2%
[87]	New Limited Access Belt-Way	3-Mile-Wide Study Area	Vacant	Residential	10,262 Acres	+5,106 Acres	+50%
				Single-Family	10,216 Acres	+4,389 Acres	+43%
				Multi-Family	46 Acres	+714 Acres	+1,559%
				Commercial	313 Acres	+404 Acres	+129%
				Industrial	209 Acres	+637 Acres	+305%
				Inst. & Other	29,751 Acres	-6,147 Acres	-21%

Buffington and Adkins [35] studied 25 remainder parcels along I-820 in Fort Worth to determine the impact of the new freeway on land use succession of abutting properties. Of the remainder properties that were studied only seven remainders moved to higher uses; seven changed from residential to vacant, five remained residential, four remained vacant, one changed from a church site to vacant, and one changed from a combination of commercial and residential to vacant. Of the seven parcels which did change to higher uses, five succeeded to residential use and two moved from vacant to commercial use. Generally, the authors concluded that not enough time had elapsed for the succession of land use to be complete; hence, 13 parcels remained vacant at the time of the study.

Since remainder parcels abut the highway facility, these two studies indicate the impact on property immediately adjacent to the freeway. In summary, land uses usually succeed to higher uses after several years (as was evidenced by these two studies). The majority of the improved parcels changed from residential to multi-unit apartment and commercial use.

Existing routes. Massachusetts Institute of Technology (MIT), in a landmark study [31], examined the impact of Route 128 on industrial and residential development. Route 128 is a 55-mile circumferential 4-lane limited access highway which transverses the existing route of a 2-lane full access highway of obsolete design. The highway is located about 10 miles from Boston's central business district and passes through large sectors of undeveloped land between major radials leading to/from Boston. The dominant land use in the effected area prior to the improvement of the old road was either agricultural or vacant. The centers of towns surrounding Boston were bypassed by the facility through vacant areas just outside of developed areas to avoid disturbing property owners.

MIT analyzed industrial development, using the case study approach, in both the area adjacent to Route 128 and the Boston metropolitan area to determine the role the facility played in the location of industrial plants. Two cities, Lexington and Needham, located along the highway were also studied to determine any changes in land use that may be attributable to the improved highway.

Their analysis reports that Route 128 has had a significant impact on industrial development in the Boston area. At the time of the study (1957), many industrial plants formerly located in Boston's CBD were relocated along Route 128 and new industrial firms to the Boston area located near the limited access facility. Through a questionnaire to the management of newly located companies, the five most common reasons given for locating on Route 128 were:

1. need of land for expansion;
2. accessibility for commercial purposes;
3. attractiveness of site;
4. labor market considerations; and
5. accessibility for employees.

In the cities of Lexington and Needham, detailed information was gathered regarding the effect of Route 128 on residential development. Building permits and housing densities show that a more rapid growth was experienced in areas close to the road than in those farther away. Also, most towns and cities along the highway were active in the promotion of available industrial and commercial sites, especially near the highway.

Rates of land development along three limited access highways were compared to the rate of regional development to estimate the impact different types of roadways -- parkways and non-parkways -- have on land use changes in individual highway study areas. Davis [28] used average land values per square foot as a surrogate for development (assuming the low values represent unimproved land and the high values represent advanced land uses). Values have been expressed in terms of indexes, which are simple ratios that measure the extent that a given value exceeds or fails to exceed the regional average. The index values for the various highways and their absolute and percentage change from 1951 to 1960 are shown in Table 28.

Table 28. Washington Metropolitan Regional Development and Selected Highway Area Development Indices [28]

Area of Study	Index 1951	Index 1960	Absolute Change	Percent Change
Metropolitan Index	1.00	1.00	-	-
George Washington Parkway	1.67	3.27	+1.60	+95
Baltimore-Washington Parkway	3.60	5.50	+1.90	+53
Shirley Memorial Highway	3.73	2.97	-0.76	-20

Source: Adapted from Davis, J. Tait. "Parkways, Values and Development in the Washington Metropolitan Region." Highway Research Record, No. 75, Highway Research Board (1963) pp. 32-43.

The findings indicate that the two parkways have increased their share whereas the non-parkway has decreased its share of total development. Davis concluded that the parkways proceeded in their development more rapidly than non-parkway properties. The parkway development was also associated with single-family units, while the non-parkway development was associated with apartment houses.

Impact on Land Values. The Watterson Expressway, which serves as a beltline in Louisville, Kentucky, was analyzed by the University of Kentucky [55] to determine the effect of the newly constructed facility on land values of various types of land uses near the highway right-of-way. Researchers utilized the study-control area approach to estimate the percentage change in property value of land adjacent to the expressway during the time period 1946-1958.

Table 29 illustrates the impact that the expressway had on the various land use types property values. Commercial properties were influenced greatly by the facility. All commercial land indicated an increase in value of over 500 percent, while large commercial tracts (over 250,000 sq. ft.) increased about 250 percent. Property values declined slightly for old residential areas, new residential properties showed no change, while unimproved farm land indicated a 15 percent increase above comparable control area property values.

These results agree, in part, with other studies examining similar highway improvements and geographic areas. The congruence of the reported findings can only reinforce the results of the various studies that conclude that highway improvements do have an effect on property values near the facility.

Buffington [7, 17] studied the impact of interstate highway bypasses in Austin and Conroe, Texas, respectively. In summary, Buffington reported that abutting properties experienced a significant positive influence from the highway improvement, especially unimproved abutting properties. In Austin, nonabutting properties suffered a negative influence from the bypass. The land value findings are reported in Table 29.

Burton and Knapp [24] modified the parallel band approach used in other reports [23, 45] to analyze large scale impact areas. The approach was employed to determine the impact of 22 miles of limited access highway through an urban fringe area of Virginia. A three-mile-wide area was overlaid with a grid so that low density suburban impacts parallel to the beltway could be

Table 29. Impact of Limited Access Highways On Property Values in Developing-Agricultural Suburban Areas

Study Reference Number	Type of Highway Improvement	Dominant Before Land Use	Location of Land Compared	Before Period Value: Land Use Type	Before Period Value: Average Price	Change in Value: Absolute Change	Change in Value: Average Percent Change
[7]	New Location Interstate Bypass	Agriculture	Study vs Control	Unimproved	$525/Acre[1]	+$856/Acre[1]	+163%
			Section 1	Unimproved	620/Acre	+806/Acre	+130%
			Section 2	Unimproved	337/Acre	+1,230/Acre	+365%
			Abutting	Unimproved	455/Acre	+1,652/Acre	+363%
			Nonabutting	Unimproved	592/Acre	-657/Acre	-111%
			Subdivision lots	Unimproved	$.0165/sq.ft.	-.0045/sq.ft.	-13%
[17]	New Location Interstate Bypass	Agriculture	Study vs Control	Unimproved	$739/Acre[1]	+$702/Acre[1]	+95%
			Study vs Control	Improved	9,182/Acre	+1,377/Acre	+15%
			Abutting	Unimproved	749/Acre	+1,917/Acre	+256%
			Nonabutting	Unimproved	738/Acre	+444/Acre	+59%
			Subdivided lots	Unimproved	$.0971/sq.ft.	+.1223/sq.ft.	+126%
			Subdivided lots	Improved	.7307/sq.ft.	+.0658/sq.ft.	+9%
[55]	New Location Limited Access Expressway	Agriculture	Study Area	Farm Land	unknown	unknown	+15%
				Old Res.	$.098/sq.ft.	$-.006/sq.ft.	-6.1%
				New Res.	unknown	unknown	0
				Commercial	$.052/sq.ft.	+.278/sq.ft.	+535%
			(Large Tracts)	Commercial	$.043/sq.ft.	+.110/sq.ft.	+256%
[24]	New Location Limited Access Bypass	Vacant	Study Area	Res. & Vacant	$1,620/Acre	+$7,646/Acre	+472%
			Inside Band	Res. & Vacant	3,157/Acre	+9,343/Acre	+296%
			Center Band	Res. & Vacant	1,706/Acre	+11,184/Acre	+656%
			Outside Band	Res. & Vacant	1,165/Acre	+4,589/Acre	+394%

1 In Constant Dollars (1947-49 = 100)

analyzed up to one and one-half miles from the right-of-way in units as large as a square mile. (See Figure 2, Techniques Section). By comparing changes in tax valuations and price changes of land parcels in the square mile grid, it was possible to gather information about the influence of the Capital Beltway on land values.

The beltway was situated approximately 6 to 12 miles from the Capital. The center square-mile grid straddled the highway facility and extended one-half mile in either direction from the facility. The inside grids lay on the Capital side of the facility and lay adjacent to the center grid area. The outside grid areas were situated on the opposite side of the center study area and were the most distant from the Capital. A great deal of land value change was found in the vicinity of the beltway.

Considerable enhancement of property values occurred between 1951 and 1962. For residential and vacant land uses, the center band land prices increased five-fold since 1951 and doubled between 1958 and 1962. The increases were about the same for the inside and outside bands until 1960, but prices for land increased only slightly in the inside band and decreased in the outside band since 1960. The authors cite overspeculation, in some instances, as a probable cause for this occurrence. Generally, the great increase in land prices in the area can be attributed to the increased accessibility to the region because of the Capital Beltway.

Existing routes. Massachusetts Institute of Technology [31] analyzed residential property values in two cities located on a 55 mile-long circumferential highway situated about eight miles from Boston's central business district. Lexington and Needham, Massachusetts real estate values were collected from land deed records and real estate brokers and a comparison was made for properties located various distances from the facility and for control area properties. The technique used by MIT is similar to the technique used by Adkins' [45] study of Dallas, but the type of highway facility is different-radial and circumferential. MIT used the projected land value approach to determine the highway's impact on the rate of growth in the area. In other words, determine how the rate of increase in land values prevailing before the facility might be affected after the highway was constructed.

The findings were basicially the same for the two cities. Lexington's rate of growth in value of properties for 1947-1949 was projected to 1957 to estimate total land values. The projected 1957 land values were compared to actual land values in 1957 and the difference in growth was attributed to the highway. The actual rate of growth for selected control areas was 228 percent higher than the projected rate of growth. Therefore, the highway was found to benefit the value of properties adjacent to the right-of-way more than control area residential land.

Land value patterns along parkways were compared to non-parkway land value patterns in the Washington, D.C., area by J.Tait Davis [28]. A regression analysis was employed by the author to determine any significant differences in land values between selected road types -- parkways and non-parkways. This type of analysis permits researchers to determine the effects of highway design and intended purpose on land values. Parkways design are "based primarily on recreational, interpretative, and preservation factors..., rather than on traffic demands." Non-parkways normally are based on serving traffic demand requirements of the community. Davis examined three different roadways in his analysis: two were parkways, while the other was a bypass highway.

Davis reviewed land value patterns associated with these facilities during the time period 1951-1960. Regression analysis was employed to estimate variation in land values of properties located along the two parkways. It was found that distance from the central city is the most important factor in explaining values of properties adjacent to the parkways. The other variable that is also important is distance from the right-of-way although the number of properties from the right-of-way seems to be more useful than distance in feet from the facility. In the case of the non-parkway highway, values decreased abruptly as the distance from the central city increased. The value of land seems to be related more to the amount of development along the non-parkway rather than the distance from the central city or from the right-of-way.

William C. Pendelton [30] performed a statistical analysis on the relationships between highway accessibility and urban real estate values in the Washington, D.C., area. The purpose of his study was to determine, statistically, the relationships that have developed between house prices and three measures of accessibility: (1) driving time, (2) distance to central business district (CBD), and (3) proportion of job trips to CBD and driving time to CBD. Accessibility information was derived from a 1955 transportation study and house prices were provided by the Federal Housing Administration. All data are drawn from the Washington, D.C., metropolitan area.

Pendleton used regression analysis to determine the correlations between house price, the dependent variable, and 12 independent variables, one of which is a measure of accessibility. All but one of the independent variables had t-ratios exceeding 3.0, and the variable which did not was not related to an accessibility measure. All three regressions proved to have a high R^2, with the job accessibility index showing the highest R^2 value (Table 30). The independent variable which represented accessibility measures was X_3 while the others represented house characteristics, such as square feet of house and

Table 30. Coefficients of Regressions Relating Sales Price to Accessibility Measures and Other Independent Variables, Pooled Samples [30]

Building Type Sales Price	Variable X_1	Job Accessibility Index		1959 Driving Time to CBD		Log of Distance to White House	
		Regress. Coeff.	Std. Error	Regress. Coeff.	Std. Error	Regress. Coeff.	Std. Error
Square foot of house	X_2	24,465	1,549	24,682	1,568	24,520	1,553
Accessibility	X_3	2.33	0.47	-63.68	15.69	3,552	748
Square foot of lot	X_4	1,208	711	973	716	1,126	712
Construction materials	X_5	1,551	234	1,541	237	1,562	235
Basement	X_6	1,192	282	1,230	285	1,225	282
Number of bathrooms	X_7	5,082	915	5,130	928	5,038	919
Extras (Garage, etc.)	X_8	797	195	781	198	766	196
Median income	X_9	0.337	0.065	0.335	0.066	0.326	0.065
Age of house	X_{10}	-81.11	26.44	-77.31	26.78	-84.08	26.65
2-story	X_{11}	-1,632	298	-1,601	302	1,628	299
1 1/2 story	X_{12}	-2,345	315	-2,345	319	-2,338	316
Semidetached	X_{13}	-3,885	400	-3,932	408	-3,960	403
R^2		0.868		0.864		0.867	

Source: Pendleton, William C. "Relation of Highway Accessibility To Urban Real Estate Values," Highway Research Record 16, 1963, p. 19.

lot, number of bathrooms, age of house, and construction materials for example.

In summary, Pendleton found that real estate market prices do reflect accessibility differences and accessibility values may be estimated by prices of houses. These data have limited use until more is known about demand for trips to the CBD and how real estate market prices react to new transportation facilities.

Full Access Highways

Full access highway improvements in suburban locations have not received much attention in land use and land value literature. As a result, very little is known about the impact of various full-access highway improvements on land use and land values along the facility. The suburban land affected by full access highways is identical to the land described previously in the limited access highway suburban land description.

Undeveloped Agricultural Areas - New Routes

Impact on Land Use. The University of Kentucky [22] studied a full access circumferential highway located about two or three miles from Lexington, Kentucky's central business district. The authors concluded that the Northern Belt Line was responsible for the succession of much of the land lying in between related radials and along the highway from agricultural to commercial and industrial use. There was no commercial or industrial development in the impact area prior to construction, but several years after the highway's opening, 40 percent of the properties within 500 feet of the facility was being used for either commercial or industrial uses.

In Table 31, the percentage of land for each land use type is illustrated for a study area which is 6.1 miles long and extends 1000 feet on either side

Table 31. Impact of Full Access Highways on Land Use in Undeveloped-Agricultural Suburban Areas

Study Reference Number	Type of Highway Improvement	Dominant Before Land Use	Location of Land Compared	Before Period Use: Land Use Type	Before Period Use: Quantity	After Period Use: Absolute Change[1]	After Period Use: Percent Change
[22]	New 4-lane Full Access Belt Line	Agri.	Study Area	Agri.	1418 Acres	-528 Acres	- 37%
			Study Area	Comm. & Ind.	0	+345 Acres	NA
				Res.	61 Acres	+148 Acres	+243%
				Instit.	0	+ 35 Acres	NA
					686 Acres	-329 Acres	- 48%
		Agri.	"City-side" band	Agri.			
				Comm. & Ind.	0	+200 Acres	NA
				Res.	52 Acres	+129 Acres	+248%
				Instit.	0	0	0
					732 Acres	-199 Acres	- 27%
		Agri.	"Outside" band	Agri.			
				Comm. & Ind.	0	+144 Acres	NA
				Res.	9 Acres	+ 19 Acres	+211%
				Instit.	0	+ 36 Acres	NA

[1] Assuming a 6.1 mile long and 2000 feet wide study area, the study area should contain approximately 1,479 acres.

of the beltline. An analysis of the bands of properties on the "city-side" of the highway and on the "outside" of the belt line is also presented. Most of the residential development occurred on the "city-side" while the commercial and industrial development seemed fairly balanced between the two bands of properties.

Impact on Land Values. The Northern Belt Line in Lexington, Kentucky has had substantial influence on abutting and nearby property values. The University of Kentucky [22] reported that commercial and industrial properties adjacent to the full access highway experienced a positive impact on property values. As illustrated in Table 32, the increase in commercial and industrial land values ranged from 21 percent to 230 percent, depending on the parcel size. Residential properties, on the other hand, did not show any significant influence from the highway. The value of nearby residential land indicated a slight decrease but the authors believed that the negative influence was too small to draw any conclusions about the possible detrimental effect of the belt line.

The evidence indicates that the effect on commercial and industrial property was distinctly positive, within 500 feet of the facility. The positive influence seems to decrease sharply beyond that point, and it practically disappears at about 1,500 feet from the highway.

Table 32. Impact of Full Access Highways on Property Values in Undeveloped-Agricultural Suburban Areas

Study Reference Number	Type of Highway Improvement	Dominant Before Land Use	Location of Land Compared	Before Period Value		After Period Value	
				Land Use Type	Average Price	Absolute Change	Percent Change
[22]	New 4-lane Full Access Belt Line	Agri.	Study vs. Control	Comm. & Ind.	$.030/sq.ft.	$+.028/sq.ft.	+ 93%
			Study vs. Control	Tract Size[1]			
			Study vs. Control	Fewer Than 100,000	.093/sq.ft.	+.214/sq.ft.	+230%
			Study vs. Control	100,000 to 1,000,000	.029/sq.ft.	+.050/sq.ft.	+172%
			Study vs. Control	More Than 1,000,000	.019/sq.ft.	+.004/sq/ft.	+ 21%
			Study vs. Control	Old Res.	.057 /sq.ft.	-.003/sq.ft.	- 5%
			Study vs. Control	New Res.			
			Study vs. Control	Lower-Priced	.149 /sq.ft.	-.006/sq.ft.	- 4%
			Study vs. Control	Higher-Priced	.151 /sq.ft.	-.024/sq.ft.	- 16%

[1]Tract Size - area in square feet.

Urban Locations

Urban areas tend to be affected less dramatically by highway improvements than suburban areas. Established or developed urban locations resist land use and land value change primarily because of the general absence of unimproved properties that are suitable for additional development. Table 33 summarizes the general description of the studies to be briefly discussed in the following paragraphs.

In this report, urban land affected by highway improvements will include:

- land located within the "city limits" of a town or city which has a population of at least 10,000; and
- land in the developed or developing stage.

Limited Access Highways

The impact of urban limited access freeways on established residential areas has received the bulk of the urban area research effort. Most of the study areas analyzed are deteriorating blighted residential areas in the older sections of the population center.

General Impact

Many highway improvement projects such as limited access highways can alter the social make-up of the people living in the neighborhood as well as the community as a whole. Guseman, et al., [9] review social assessment techniques to determine or measure the impact of highway improvements on the social characteristics of the area.

Evidence in the following studies [12, 23, 45, 59] indicates that highway improvements in deteriorating housing areas cause slum clearing and the general socioeconomic characteristics to improve on adjacent properties.

Table 33. Master Summary Table of the Urban Studies Contained in the Review of the Literature

Study Number	Type of Access	Existing or New Route	Type of Highway	Area Stage of Development	Description of Study Area	Size of Study Area	Distance from CBD	Location of Analysis	Dominant "Before" Land Use	Dominant "After" Land Use	Study Period	Year Facility Opened	Study Technique	Types of Data Collected and Analyzed				
														Land Use	Land Value	Business Activity	Traffic Analysis	Other
9	Limited	New	Radial	Developed	Established urban Residential Areas		NA	Adjacent Residential Locations	Residential	Residential	NA	NA	Survey of Prediction tech.					Literature Review
12	Limited	Existing	Cross-Town Artery	Developed	Latin-American area with 40% blighted housing	Two block on either side along the 3.7 mile expressway	passes through	Adjacent Land and interchange	Older Residential	Multi-Unit Residential	1941-56	1950	Study-Control	No. of Property Δing use	$/foot	Opinion survey	Average Daily Traffic	Zoning Districts Changes - pop.
23	Limited	New	Artery	Developed	Non-white Residential area -- one of the oldest sections in town	7500 feet on either side of facility	4 miles NW	parallel bands	Older Residential	Residential and Commercial	1945-54	unknown	Parallel Band	Building Permits	% Δ by use			Population Characteristics
34	Limited	New	Radial	Developing	Single-family subdivisions built in 1930's	Selected remainder parcels involved in the ROW taking	unknown	Abutting remainders	Single-unit Residential and Vacant	Multi-Unit Apartment & Commercial	1945-60	1952	Case Study	change in use	$/sq. ft			Detailed land use and value analysis
37	Limited	Existing New	IH and US Highway	Developed	Highly accessible commercial areas	Interchange area	NA	Interchange Quadrants	NA	Commercial	1970	NA	Survey of 40 Interchange	% land in uses			Traffic Generation	Literature Review
45	Limited	New	Radial	Developed	Blighted Black Community	5.4 miles long and about 10 blocks wide	originate at CBD	Adjacent Properties	Residential	Residential	1941-55	1953	Study-Control Parallel Band	change by zone and area	$/sq ft	Opinion survey	Average Daily Traffic	Detailed land use
49	Full	Existing	Loop Highway	Developed	Strip commercial development (local)	Abutting properties along 1.5 miles of highway	5 miles South	Businesses along route	Commercial	Commercial	1959-63	1962	Study-Control			Monthly Sales	Very Detailed	Accident and left-turn analysis
50	Full	Existing	State Highway	Developed	Strip local and traffic-serving community	Not given	at CBD	Businesses along route	Commercial	Commercial	1959-61	1961	Study-control			Monthly Sales	Very Detailed	Accident and left-turn analysis
51	Full	Existing	State Highway	Developed	Strip local and traffic-serving community	Commercial properties along 2 miles of SH 146	Just South	Businesses along route	Commercial	Commercial	1957-60	1959	Study-control			Monthly Sales	Very Detailed	Accident and left-turn analysis
59	Limited	New	Radial	Developed Developing	Old deteriorating single-unit residents	1000 feet on either side of facility	Unknown	Land adjacent (parallel)	Blighted Residential	Residential	1949-65	1957	Before-After adjacent Lands	Building permits	% value change			Pop. characteristics noise level
64	Limited	New	Interstate	Developed	Single-family residences (4 areas)	1000 feet from ambient noise zone	NA	Adjacent Residential Land >	Residential	Residential	1969-71	NA	Regression Analysis		$ Δ in land			Noise levels
66	Full	Existing	One-Way Street	Developed	Heavily developed commercial district	Properties fronting one-way streets	at CBD	Adjacent Properties	Commercial	Commercial	1954-62	1958	Before-After		Average $/sq ft	Retail Sales		
76	Limited	New	Cross-Town Artery	Developed	City experiencing rapid ind. growth	The town of El Monte, Calif.	Near CBD	General area	NA	NA	1955-57	1956	Before-After	Building Permits		% Δ Retail Sales		
86	Full	Existing	One-Way Street	Developed	Commerical district located in CBD	Properties fronting 2.4 miles of street	at CBD	Businesses fronting	Commercial	Commercial	1949-51	1950	Before-After	No. of New Businesses	Compared to other sales	Retail Firms	Volume Speed	Accidents, etc.
89	Limited	Existing New	Interstates	Developing Developed	5 Urban cities in North Caro.	The city and its surrounding area	various locations	General area	NA	NA	NA	NA	Before-After	Δ in Uses			Average Daily Traffic	General growth Characteristics
60	Limited	New	Radial	Developing	Flood plain area to levees-Zoned Industrial	5000 acres	Borders CBD	Adjacent land	Idle	Idle	1946-59	1959	Before-After	% Δ in use	$/sq. ft.		ADT	

NA - Non Applicable

Developed Residential Areas - New and Existing Routes

Both the new and existing route highway improvements are reviewed together in this part of the report because the influence on land use and land values is very similar for both types of improvements in developed residential urban areas. As mentioned previously, the impact of most highway improvements in areas possessing a limited supply of unimproved properties is not significant.

Impact on Land Use. Adkins studied land use changes along expressways in San Antonio [12] and Dallas [45], Texas. These two studies employed basically the same methodology to determine the influence that the highways had on land use development. Differences in the design and characteristics of the two expressways will allow researchers to compare the impacts on land use changes. The San Antonio expressway transverses the same route as existing U.S. highways and is characterized by limited frontage roads and three grade designs: (1) depressed, (2) on-grade, and (3) elevated. The Dallas facility was constructed over a new route part of which was a railroad right-of-way, and is an on-grade design with frontage roads along the entire length.

In San Antonio, Adkins found that land use changes relative to the 3.7 mile improvement were far from spectacular. Significant amounts of land use change did not occur because of the lack of vacant or unimproved land and the lack of new homes or businesses in the general area. Since the study area transversed existing U.S. highway routes, the best sites for development had been improved already, usually dwellings, which makes change to higher uses more expensive and more slowly to occur. The most numerous changes were related to roadside advertising, as abutting properties had billboards. Twelve new business structures and an equal number of expansions of existing businesses were attributable to the expressway. There remained some potential for additional land use changes that would probably occur along the frontage roads and secondary city streets.

Along the Dallas Expressway which did have an ample supply of unimproved land, abutting properties experienced an extensive amount of land use change. Removal of existing improvements and construction of commercial, industrial, and multi-family residences occurred where slum housing had once been. Unimproved properties were also developed, usually into single-family residences. Although Band B and C did not receive as much land use impacts as the abutting band, re-use of land and slum clearance was evident and the potential for land use change was tremendous.

Two similar studies examined the influence that new route urban expressways have on land use development and change in blighted socioeconomic areas. Duke [23] studied the impact that the Ford Expressway had on land use change in Detroit, while Colony [59] analyzed residential land use changes along the Detroit-Toledo Expressway in Toledo, Ohio.

Duke reported that commercial land use changes were the only extensive type of new development. Commercial building activity increased over 300 percent during the study period with ribbon-type strip development being the predominant alignment. Residential land use changes were limited to the movement of displaced houses from the expressway's right-of-way to vacant lots in the area. Industrial changes in land use were slight and usually occurred through additions and expansions to existing plants. The author believed that the influence of the expressway was limited to 1000 feet either side of the highway.

Colony found that land use changes within the study areas affected by the Detroit-Toledo Expressway were relatively insignificant except for the construction of new residences. The author took the point of view that the new highway had not inhibited the establishment of neighborhoods or new subdivisions. From an analysis of building permits during the years 1940-1965, Colony concluded that property owners were reluctant to improve their residences during the highway's construction, but several years after completion this reluctance tended to disappear. Very little commercial or industrial development was apparent in the study areas. In addition to collecting building permit data, expressway noise level data were collected to determine if land use patterns were influenced by noise levels. The research could not conclude that land use development was affected by expressway traffic noise levels, although there were some indications.

Buffington and Adkins [34] reported land use changes of selected remainder parcels along Houston's Gulf Freeway. In Houston, 18 remainder parcels were examined for changes in land use and all except four remainders were put to uses superior to those which existed prior to the partial taking of the property. The four parcels not in higher use were vacant. The other 14 remainders changed uses from unimproved and residential to multi-unit apartment and commercial uses. The authors found that the land use succession process required several years to fully develop.

Babcock and Khasnabis [37] surveyed land use development at 40 urban interchanges along 71.5 miles of interstate highway in North Carolina. They indicated that only 21 percent of the 160 total interchange quadrants were vacant. Of the vacant quadrants, approximately one-half were undevelopable because of physical or ownership (state-owned) characteristics. The remaining 79 percent of the quadrants (and related service roads) contained 262 land developments, or 2.1 developments per interchange. The urban developments consisted of 70 service stations (26.7%), 20 motels (7.6%), 15 truck stops (5.7%), 61 industries (23.2%), 6 shopping centers (2.3%), 58 retail sales (22.1%), and 26 office and miscellaneous developments (10%).

The objective of Babcock and Khasnabis' study was to derive a procedure, through regression analysis, to precisely predict land development at and around urban interchanges. Generally, the authors found that land development will take place in all quadrants of interchanges if such land is available and suitable for development. They concluded that a regression analysis could not precisely predict the type of development near urban interchanges because of zoning changes within the study areas.

Impact on Land Values. Adkins [45] used the parallel band approach to determine the effect of a new radial expressway on property values in Dallas, Texas. The new expressway, 5.4 miles long, originated at the central business district and extended out into partially developed areas at the city's fringe. In order to determine how widely dispersed the freeway's effects were, the study area was delineated into three parallel bands of increasing distance from the right-of-way. Adkins found that statistically significant differences between bands could be identified and that statistically reliable conclusions could be made about the impact differences as distance from the facility increased.

The bands were subdivided according to the method described in the techniques section of the report (Figure 2). The author discovered that the most influential land value variables were distance from right-of-way, amount of unimproved land within the band, value of improvements, and zoning. As expected, Band A properties (abutting the facility) were influenced more especially in terms of land prices, than were Band B and C properties. In addition, the most sensitive subareas were those with a high percentage of unimproved land and those zoned for commercial or retail use.

Land price and tax valuation analyses are shown in Table 34. Each band's property values were studied in terms of two different indexes

Table 34. Summary of Expressway Effects on Land Prices and Land Tax Valuations (A, B, and C Bands, Portions Annexed to the City Before 1941)[1] [45]

	Net Influence of Expressway					
	A Band		B Band		C Band	
	Index 1	Index 2	Index 1	Index 2	Index 1	Index 2
Prices of All Land[2]						
1941-45 to 1946-50	−121%	−80%	−59%	−64%	−49%	−26%
1946-50 to 1951-55	563	563	64	64	84	84
1941-45 to 1951-55	442	483	5	0	35	58
Prices of Unimproved Land						
1941-45 to 1946-50	−14	−18	−39	15	−71	−28
1946-50 to 1951-55	393	386	133	206	79	133
1941-45 to 1951-55	379	368	94	221	8	105
Land Tax Valuations						
1945 to 1955	286	304	41	42	16	18

[1]Index 1 = (absolute increase in study areas minus absolute increase in control areas) ÷ base value in study areas.

Index 2 = percentage increase in study areas minus percentage increase in control areas.

[2]Includes sales of both improved and unimproved land. Improvements are removed from prices by Method II. Method II = Sales prices minus (tax valuations of improvements multiplied by a construction cost factor). The resultant price is theoretically that paid for "bare" land.

Source: Adkins, William G. "Effects of the Dallas Central Expressway on Land Values and Land Use." Texas Transportation Institute, Bulletin 6, September, 1957, College Station, Texas, p. 16.

which are explained in the notes beneath the table. The left side of Table 34 contains the variables which are of interest to the researcher. All land price and unimproved land price changes are reported for three time periods and three subareas, while changes in tax valuations are reported for only one time period and three subareas. Two way tables, such as Table 34, can be used to summarize and correlate detailed information and are excellent formats for examining and presenting report findings. Adkins' findings are summarized in Table 35.

Adkins drew several conclusions concerning the impact of the expressway on land values: (1) prices rose substantially for property abutting the right-of-way; (2) tax valuations rose for land abutting the facility; (3) initially, market values fell due to uncertain conditions about the expressway but prices rebounded as confidence in the highway grew; and (4) existing land uses and zoning regulations tended to control the influence of the expressway on land values. In summary, the impacts were generally beneficial but limited to pre-existing conditions.

Findings Table 35. Impact Of Limited Access Highways On Property Values In Developed-Residential Urban Areas

Study Reference Number	Type of Highway Improvement	Location of Property Analyzed	Before Period: Land Use	Before Period: Average Price	Change In Values: Absolute Change	Change In Values: Percent Change Index 1	Change In Values: Percent Change Index 2
[12]	2 Lane Full Access to 4-6 lane Limited Access	Study Area	Older Residential	$0.502/sq.ft.	$+.825/sq.ft.		+164%
		Along U.S.87	All Uses	0.371/sq.ft.	+0.545/sq.ft.		+147%
		Along U.S.81	All Uses	0.756/sq.ft.	+1.070/sq.ft.		+142%
		Control Areas	All Uses	0.588/sq.ft.	+0.513/sq.ft.		+87%
		Study Area	One Family Residential	0.532/sq.ft.	-0.177/sq.ft.	-33%	-18%
		Study Area	Apartments	0.644/sq.ft.	+0.338/sq.ft.	+52%	+72%
		Study Area	Non-Res.	0.589/sq.ft.	+1.380/sq.ft.	+235%	+219%
		Study Area	Unimproved	0.167/sq.ft.	+0.529/sq.ft.	+317%	+310%
		Abutting	Residential	0.474/sq.ft.	+0.317/sq.ft.	+67%	+100%
		Abutting	Non-Res.	0.444/sq.ft.	+2.161/sq.ft.	+487%	+463%
		With Frontage Rds.	Residential	0.510/sq.ft.	+0.524/sq.ft.	+103%	+128%
		With Frontage Rds.	Non-Res.	0.344/sq.ft.	+2.704/sq.ft.	+786%	+752%
		Without Frontage Rd.	Residential	0.449/sq.ft.	+0.122/sq.ft.	+27%	+67%
		Without Frontage Rd.	Non-Res.	0.612/sq.ft.	+1.902/sq.ft.	+311%	+296%
		Abutting	Unimproved	0.095/sq.ft.	+0.629/sq.ft.	+662%	+710%
[45]	New 4-6 Lane Limited Access	Parallel Band	Older Residential				
		Band A	Unimproved[1]	unknown	+1.012/sq.ft.	+379%	+368%
		Band A	Unimproved[2]	unknown	+1.000/sq.ft.	+1087%	+1040%
		Band B	Unimproved[1]	unknown	+0.129/sq.ft.	+94%	+221%
		Band B	Unimproved[2]	unknown	+0.761/sq.ft.	+692%	+632%
		Band C	Unimproved[1]	unknown	+0.013/sq.ft.	+8%	+105%
		Band A	Improved[1]	unknown	+0.459/sq.ft.	+265%	+322%
		Band A	Improved[2]	unknown	+0.372/sq.ft.	+90%	+77%
		Band B	Improved[1]	unknown	-0.006/sq.ft.	-2%	-9%
		Band B	Improved[2]	unknown	-0.028/sq.ft.	-6%	-13%
		Band C	Improved[1]	unknown	+0.086/sq.ft.	+25%	+39%
		Band C	Improved[2]	unknown	-0.134/sq.ft.	-21%	-19%

[1] Properties annexed by Dallas before 1941.
[2] Properties annexed by Dallas during 1946.

In another study utilizing the parallel band approach and reviewed in the previous section, Duke [23] employed the band technique to analyze land values in an area affected by a new depressed expressway in Detroit, Michigan. This research project is of interest because the study area is located in a city which, unlike Dallas, was stagnating during the study's time period. The existence of a study of an expressway similar in concept and design to the Dallas Expressway but located in a contrasting socioeconomic environment provides an opportunity to examine highway impacts under varying conditions.

Duke selected a wide study band extending 7500 feet in either direction from the expressway and assumed that the most distant part of the study band would not be influenced and would serve as a control area. The band was divided into nine smaller bands and land values were collected for each band and for three time periods. The land values were plotted on the bar graph presented in Figure 8. In this manner, changes in property values resulting from expressway construction and operation could be identified and evaluated.

The results indicated that the degree of the expressway's influence depends on the type of land use. Residential property values declined up to 500 percent, commercial property values rose up to 100 percent, while industrial land values increased at the same rate as the control area. The net effect of the impact has been a halt in declining values within 1,000 feet of the right-of-way and, in some cases, a slight increase in property values. However, the impact of the expressway has not been noticeable in subareas situated beyond 1,000 feet from the freeway.

A detailed study of residential properties contiguous to, and within short distances of, the Toledo-Detroit Expressway in Toledo, Ohio, was done by David C. Colony [59]. A large portion of the expressway passes through a part of the city known as the "Older City Area" which is an area

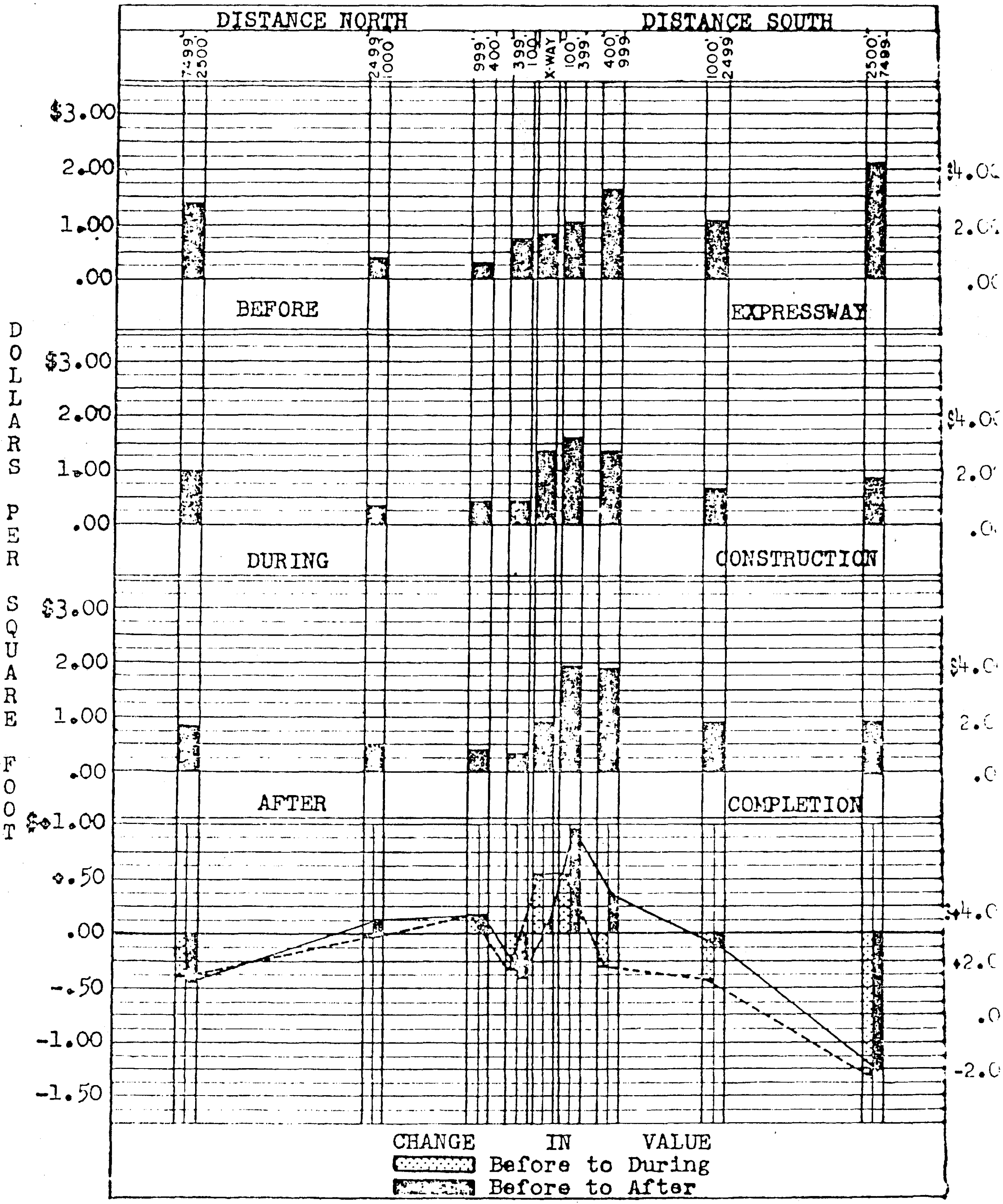


Figure 8. Average Sales Value Per Square Foot All Sales [23]

Source: Duke, Richard de la Barre, "The Effects of a Depressed Expressway--A Detroit Case Study," The Appraisal Journal, October, 1958, p. 504.

characterized by deteriorating or dilapidated housing. Not all subareas along the facility are suffering from poor socioeconomic conditions; therefore, Colony implemented the lateral band approach to estimate the different degrees of impact that the highway had on property values in residential areas. The impacted area of the city was divided into 15 study areas which the expressway transverses. Study Area Nos. 4 through 11 are located in the Older City Area, Study Area Nos. 1, 2, and 3 contain neighborhoods which are relatively free of socioeconomic problems, while Area Nos. 12 and 13 are largely devoted to agriculture, and Area Nos. 14 and 15 are part of a special study. After using regression analysis procedures to determine the reliability of assessed property valuations made by the county auditor as an index of market value, Colony concluded that assessed values were suitable for measuring the impact of the freeway on actual property values for the years 1951-1965.

Changes in residential property values were estimated at varying distances from the expressway to determine the degree of influence. The greatest effect on property values was felt in the 50-200 foot band from the right-of-way. This tendency, as noted by Colony, has been reported in several other studies.

Adkins and Tieken [12] studied a 3.7 mile cross-town expressway in San Antonio which was constructed over an existing U.S. highway route. The design of the expressway was similar, in part, to both the Dallas and Detroit expressways. The facility was similar to the Dallas freeway in that part of it was at the same grade level as adjacent property, but only 18 percent of its length was an "on-grade" design. Detroit's expressway was a "depressed" facility and 47 percent of the San Antonio facility is elevated. Frontage roads are also limited to about 32 percent of the abutting property and were generally old city streets paralleling the expressway. The San Antonio Expressway was also similar in that the route passed through an established area of the city near the central business district.

Employing the study-control area comparison approach, the authors report the findings of their analysis in Table 35. The influence of the expressway was measured not only for the overall study area, but also was measured for abutting properties, with and without frontage roads, for the various major land use categories. Generally, the expressway had a positive influence on land values for all land use categories except for single-family residences. When compared with similar control area land value changes, a slight negative influence on single-family residential property was attributed to the expressway.

In California, the influence of freeways on residential land values were reported by Hill [82] and Kelly [83]. Hill studied the impact of a planned freeway through an established residential area of Glendale, California. Hill concluded that the freeway, at the time of the study, had no effect on single-family residential property values. Kelly's study was a state-wide survey of residential land sales to determine how the market value of residential property was influenced by freeway construction. Kelly found that resales of properties adjoining the freeway averaged from one to two percent less than similar properties one or more blocks away. The market value analysis indicated only a slight depreciation in marketability for those houses adjoining the freeway.

Noise pollution and land values. The effects of regional accessibility and highway generated disturbances on property values were studied by Gamble, et al., [64] in four residential communities bisected by an interstate highway. The types of disturbances which were measured included noise, hydrocarbon, carbon monoxide, oxides of nitrogen, and particulates. The study made an attempt to determine the adverse effects of highway originating disturbances and the beneficial effects from improved accessibility on property values within the highway communities, simultaneously.

Gamble, et al., examined North Springfield in detail to determine the net effect of adverse highway noises and improved accessibility on property values as the result of the highway facility. The authors found that the advser environmental highway effects on abutting properties reduced the value by about 4.5 percent, while the benefits of improved accessibility conferred to property value averaged almost 9 percent. Gamble, et al., indicated the total net effects on the entire community amount to, and showed that the benefits induced by highway total about $5 million, while the highway disbenefits or cost amounted to only $303,000. The net gain, to all North Springfield property owners, totalled about $4.7 million.

The findings show conclusively that, in general, residential properties are adversely effected by a major limited access highway. Values of properties near the facility are normally lower than those comparable properties more distant from the freeway. Gamble, et al., found in a regression analysis of property values that one or more highway-related variables (all with negative coefficients) were significant in explaining residential property price variation. (Noise was found to be the single most disturbing effect from the highway and the factor that most residents objected to most often.

Colony [59], in a similar study of developed residential areas, investigated the impact of expressway noise levels on property values. Although no conclusive evidence was found, properties which experienced very large (1000%) increases in value tended to be concentrated in areas of comparatively low noise level.

Developing Industrial Areas - New Routes

Impact on Land Use. A 7.3 mile section of the Stemmons Freeway, located just west of Dallas' central business district, was studied by Thompson, et al., [60] to determine the influence of the newly constructed limited access highway on land use development in a 5000 acre area. The authors examined land use patterns during the period 1951-1960 through the aid of land use and zoning maps. Their findings indicated clearly that the pattern of development was toward commercial and industrial uses. This occurred because in 1951 the entire study area was zoned for commercial and light manufacturing developments. Thompson, et al., suggested that the idle land in the study area would be developed in the near future in either commercial or light industry uses. The findings of this study are shown in Table 36.

Impact on Land Values. Thompson, et al., [60] attempted to collect all real estate sales transaction data during a 14-year period, 1946-1959, to determine whether or not Stemmons Freeway had any measurable effect on land values in the study area. Analyses were made for: (1) the before period, 1946-1955, versus the construction period, 1956-1959; and (2) unimproved versus improved property. Their land value findings are illustrated in Table 37. In summary, the unimproved properties were positively influenced while improved properties experienced a slight negative influence. The findings of this study are in congruence with findings of similar studies in developing or developed areas.

Table 36. Impact Of Limited Access Highways On Land Use In Developing-Industrial Urban Areas

Study Reference Number	Type of Highway Improvement	Dominant "Before" Land Use	Location of Land Compared	Before Period Use: Land Use Type	Before Period Use: Quantity[2]	Change In Use: Absolute Change	Change In Use: Percent Change
[60]	New Location Limited Access Freeway	Idle	Study Area[1]	Commercial & Industrial	250 Acres	+1500 Acres	+600%
				Agriculture	2000 Acres	-2000 Acres	-100%
				Idle	2750 Acres	+500 Acres	+18%

[1]5,000 acre study area.

[2]Estimated Land Use Acreage.

Table 37. Impact Of Limited Access Highways On Property Values In Developing-Industrial Urban Areas

Study Reference Number	Type of Highway Improvement	Dominant Before Land Use	Location of Land Compared	Before Period Value: Land Use Type	Before Period Value: Average Price Per sq.ft.	Change In Value: Absolute Change Per sq.ft.	Change In Value: Percent Change
[60]	New Location Limited Access Freeway	Idle	Study Area	Unimproved	$0.43	+.09	+21%
			Study Area	Unimproved	0.48	+.15	+31%
			Study Area	Improved	4.04[1]	-.28	-7%
			Study Area	Improved	4.61	-.01	0
			Abutting	Unimproved	.43[1]	+.40	+93%
			1-1000 ft.	Unimproved	.43[1]	-.01	-2%
			1001-2000 ft.	Unimproved	.43[1]	+.05	+12%
			2001-3000 ft.	Unimproved	.43[1]	+.11	+26%
			3001-4000 ft.	Umimproved	.43[1]	+.03	+7%
			Over 4000 ft.	Unimproved	.43[1]	+.05	+12%
			Abutting	Improved	4.04	No Sales	
			1-1000 ft.	Improved	4.04	-.12	-3%
			1001-2000 ft.	Improved	4.04	-.78	-19%
			2000-3000 ft.	Improved	4.04	-.15	-4%
			3001-4000 ft.	Improved	4.04	-.43	-11%
			Over 4000 ft.	Improved	4.04	-.14	-3%

1 In Constant Dollars (1947-49 = 100)

Full Access Highways

After reviewing the available highway impact literature, it was discovered that the impact of full access facilities on land use and land value in urban areas had not been addressed directly in any of the research studies. This general absence of land use and land value analysis indicates that there is an obvious gap in the literature.

As an alternative, several studies were included in this review that have analyzed the impact of highway changes on business activity along the affected facility. Although these studies do not directly estimate or measure land use and land value change attributed to the improvement, business activity data such as retail or gross sales volume, business openings and closings, and types of business may be used as a surrogate for land use and land value data.

Developed Commercial Areas - Existing Routes

Median Studies. Wootan, et al., [49, 50, 51] have studied the changes in business activity along heavily developed ribbon commercial areas in three Texas cities as the result of adding a median to the highway. The raised median affected business activity by restricting the amount of left-turn traffic to businesses situated at mid-block locations. Wootan, et al. concluded that the street improvement (median) program created attractive and desirable commercial sites in each of the three areas. The desirability of these sites was indicated by the influx of new businesses into the areas immediately after the facility was reopened to traffic.

Although Wootan, et al., did not address land use and land value changes directly, they did collect and analyze data which may be used as a base for which land development changes may be derived.

SUGGESTED PROCEDURES FOR PREDICTING HIGHWAY IMPACTS ON LAND USE AND LAND VALUE

In the introductory section of this report, the purpose, objectives, and method of study are stated. The authors indicate that two bodies of non-user information are of interest to this study: (1) the available literature regarding the impact of highway improvements on land use and land value; and (2) existing impact assessment techniques that are applicable or adaptable to assessment of land use and land value impacts resulting from highway improvements. The second section reviews what is involved in the assessment of highway impacts, particularly the elements of highway impact assessment and the factors which control the relationship between highways and land development and land use. The third section reviews the techniques available for measuring previous highway impacts on land use and land value, as well as forecasting or predicting future highway impacts on land use and land value. The fourth section summarizes the findings of previous studies of highway impact on land use and land value. In this section of the report, two procedures are suggested to predict future impacts on land use and land value resulting from proposed highway improvements.

Criteria for Selecting Predictive Procedures

Before a specific technique is selected to predict or measure highway impacts on land use and land value, careful consideration should be given to the following criteria: (1) availability of comparable data from previous studies; (2) accuracy of the procedure's predictions; and (3) costs and personnel requirements to implement a predictive procedure.

Availability of Comparable Data from Previous Studies

Of the three criteria, the first one is the most critical in the selection of a suitable predictive technique. The accuracy of predictions depends heavily on the availability of comparable data collected from previous research studies. The "key" word to stress here is comparability. Determining the comparability of the data of previous studies before using such data in making predictions of the impact of a proposed highway improvement is a critical task. In many cases, it will be very difficult to establish comparability. To aid the users in this respect, the results of previous studies summarized in the last section have been catalogued according to "key" identifying characteristics. In many cases, inadequate information is given to establish comparability.

Comparability of the "before" situation is the most critical to establish because this is the base from which impact measurements are made and upon which impact projections begin. The type of data required to establish comparability of the "before" situation for highway improvements previously studied versus proposed highway improvements being studied are discussed as follows: (1) description of highway improvement; (2) description of alternate and intersecting routes; and (3) description of project impact area and nearest urban area. Table 38 shows a suggested format for comparing the characteristics of the "subject" and "comparative" facilities to ascertain significant differences. Unfortunately, if no comparable research studies can be found in the literature pertaining to the proposed highway improvement, the highway analyst has little to go on in predicting highway impacts. In such cases, the prediction must be inferred from related studies, general knowledge, etc. Hopefully, additional studies will be made to fill in the data gaps that exist in the literature.

Table 38. Format for Comparing the Before Period Characteristics of Subject and Comparable Facilities and Impact Areas to Ascertain Differences

Name of Comparative Characteristic	Description of Characteristics		
	Subject Facility or Area	Comparable Facility or Area	Difference Between Facilities or Areas
Proposed Route Location (new or old)	______	______	______
Type of Highway Facilities			
Existing Facility[a]	______	______	______
Type of access (full or limited)	______	______	______
Number of lanes	______	______	______
Type of interchanges (full or partial)	______	______	______
Type of intersections (stop light or sign)	______	______	______
Type of left-turn (protected or not)			
At intersection	______	______	______
Between intersection	______	______	______
Type of median (flush, ditch, etc.)	______	______	______
Margins (curbed or ditch)	______	______	______
Capacity (vehicle/hour)	______	______	______
Volume (vehicle/hour)			
Last year	______	______	______
5 years ago	______	______	______
Proposed Facility (improvement)			
Type of accesss (full or limited)	______	______	______
Number of lanes	______	______	______
Type of interchanges (full or partial)	______	______	______
Type of intersections (stop light or sign)	______	______	______
Type of left-turn (protected or not)			
At intersection	______	______	______
Between intersections	______	______	______
Type of median (flush, ditch, etc.)	______	______	______
Margins (curbed or ditch)	______	______	______
Capacity (vehicle/hour)	______	______	______
Volume (vehicle/hour)			
First year	______	______	______
Next 5 years	______	______	______
Type of Alternate Facilities (Existing)			
Primary Alternate			
Type of access (full or limited)	______	______	______
Number of lanes	______	______	______
Capacity (vehicle/hour)	______	______	______
Volume (vehicle/hour)			
Last year	______	______	______
5 years ago	______	______	______
Secondary Alternate			
Type of access (full or limited)	______	______	______
Number of lanes	______	______	______
Capacity (vehicle/hour)	______	______	______
Volume (vehicle/hour)			
Last year	______	______	______
5 years ago	______	______	______

Table 38 (continued)

Name of Comparative Characteristics	Description of Characteristics: Subject Facility or Area	Comparable Facility or Area	Difference Between Facilities or Areas
Type of Intersection Facilities			
Limited access type (number)	________	________	________
Full access type			
2-lane (number)	________	________	________
4-lane (number)	________	________	________
Type of Project Area (Before Period)			
Impact Area Size (feet)			
Width (both sides of highway)	________	________	________
Length (feet)	________	________	________
Stage of Land Development	________	________	________
Dominant Abutting Land Use	________	________	________
Distance to CBD (miles)	________	________	________
Distance to major employment (miles)	________	________	________
Population Density (number/sq. mile)			
Last year	________	________	________
Last census year	________	________	________
Employment			
Last year	________	________	________
Last census year	________	________	________
Disposable Income ($/capita)[b]	________	________	________
Value of Dwelling ($/unit)[b]	________	________	________
Rent of Dwelling ($/unit)[b]	________	________	________
Land Use Impediments (zoning, etc.)	________	________	________
Location (urban, suburban, rural)	________	________	________
Type of City or Urban Area			
Population Density (number/sq. mile)			
Last year	________	________	________
Last census year	________	________	________
Disposable Income ($/capita)[b]	________	________	________
Value of Dwelling ($/unit)[b]	________	________	________
Rent of Dwelling ($/unit)[b]	________	________	________
Land Use Impediments (zoning, etc.)	________	________	________

[a] If proposed route is a new location, put "None Applicable" (N.A.) in the blanks.

[b] Latest census data.

Description of Highway Improvement. A description of the proposed highway improvement must be matched up as nearly as possible with similar improvements previously studied. Detailed information is needed on the "before" construction (on existing facility) designs, capacities, types of access, and traffic volume trends. Also, the design changes should be the same for both facilities.

Description of Alternate and Intersecting Routes. A description of alternate and intersecting facilities for the proposed and previously studied highway improvement should be similar. The "before" period locations, designs, capacities, types of access, and traffic volumes should be determined for these facilities. However, such data is not as crucial for a determination of comparability as data describing the proposed highway improvement.

Description of Project Impact Areas. A description of project impact areas is very important information to obtain. Here is where the real test of comparability is made with respect to size of project impact area; location of project areas in relation to central business district and employment centers; population, employment, and per capita income trends in project areas relative to city-wide trends; and dominant land use, types of land use controls, stages of land development, and land values or rents in the project impact areas. Also, such data should be collected on the nearest urban area or city involved.

The two most crucial of these project area characteristics are the dominant abutting land use and stage of development. Stages of land development and abutting land use categories defined according to type and extent of land use change in highway impact areas are presented in Table 6 of the second section of this report. However, it may be difficult to classify the previous impact studies according to this scheme due to the lack of such information in reports of findings. But this classification is being followed in the development of new land use impact data relative to improvements on existing highways under this research study.

If the analyst can find previous impact studies which have highly similar impact areas for the same type of highway improvement, he can place a great deal of confidence in using the findings of these studies to predict the estimated impact of the proposed facilities.

Accuracy of Procedure's Predictions

The accuracy of a procedure's predictions depends not only on the availability of relevant impact findings and other input data but also on what variables or factors are employed and how they are defined and measured. In the case of multiple regression analysis, many independent variables may be used. However, the estimating coefficients may not have the correct algebraic sign and/or may not be statistically significant. In contrast, independent variables do not have to be defined when using data developed from the study area - control area comparative technique to measure land value impacts. However, the regression technique is not confined to variables using only data collected in a study area near the highway. Distance from the central business district and distance to major employment centers are examples.

Defining the relevant zone of influence (study area) in which to obtain data can be, and likely is, a major source of error in predicting highway impacts. Even after many land use and land value impact studies have been completed, the zone of highway influence has not been clearly delineated, especially for each type of highway improvement. The zone of influence may range in width from a few hundred feet to two miles on either side of the facility. If the area is too large, the data may be influenced too greatly by other factors. If it is too small, the extent of highway impact may not be fully known.

As indicated in the second section of the report, the length of time period used in which to measure short-run, immediate-term, and/or long-run impacts is important and may affect the accuracy of impact predictions, regardless of the prediction technique used. However, the multiple regression technique can more easily separate out specific impacts, such as that due to time, than can the study area-control area comparative technique.

The choice of units in which variables, both independent and dependent, are defined affects the accuracy of impact predictions. Stating a variable in smaller units to make it more sensitive to measure minute changes, can increase measurement errors. Also, some of the variables used in a regression model may not be capable of being stated in continuous units. Some have to be stated in discrete units which does not conform well with regression analyses. As an example, land use must be described in discrete units.

Last, but not least, accurate predictions depend on the number of observations and the representativeness of the data used to quantify each variable or to compute a statistic used to measure and explain an impact in a given area. Considerable attention must be given to determining the adequate size of a sample to use in collecting the data for each variable.

Costs and Personnel Needed to Implement Procedure

Costs and personnel needed to implement alternative predictive procedures must be considered before a particular procedure is selected for use. Unfortunately, little information is presented in the literature to give the highway analyst guidance in such an evaluation. Therefore, the statements made here are based on the general knowledge and experience of the researchers concerning the relative costs and personnel requirements of candidate predictive procedures.

A procedure which uses study area-control area or study area-parallel band comparative data to predict the absolute and relative land use and land value changes resulting from a highway improvement is less costly and requires fewer personnel to implement than any other procedure. This statement is probably true even if the costs of the original base (before and after) studies producing the comparative data are included. Such a procedure does not require the use of computer hardware. Only a desk calculator is needed to "massage" the data used in making the projections. A predictive procedure, based on one or more multiple variable equations, requires the use of a computer to generate the desired projections. Data collection is also more costly. Generally, the costs and personnel requirements increase in direct proportion to the amount of detailed input data required by the predictive model.

Of the models reviewed in the third section of this report, the more complex regional land use models are the most costly to implement and use. Before such models can be used, pilot studies will have to be conducted to alter and adapt them to making projections in small areas directly affected by a specific type of highway improvement. Of course, if the analyst desires or needs to know the extent to which a particular independent variable (i.e. change in highway design) influences land use and land value changes, then multiple variable equations may have to be used.

Suggested Procedure for Predicting Impacts

Considering the above mentioned selection criteria, two procedures are suggested for the highway analyst's use in predicting land use and land value impacts of proposed highway improvements. The first procedure is used when highly comparable data are available from previous studies. This technique is called the Comparable Data Prediction Procedure (CDPP). The second procedure is used when less comparable data are available from previous studies. This procedure is called the Inferred Data Prediction Procedure (IDPP).

The CDPP uses data from previous studies that must be comparable in the following ways:

- Type of highway improvement (design and route location)
- Dominant abutting land use
- Stage of land development in area

Comparable Data Prediction Procedure

The CDPP uses directly the absolute and relative changes in land use and/or land value attributed to a previously studied highway improvement for predicting the magnitude of absolute and relative changes in land use and/or land value attributable to a similar proposed highway improvement. One goal to attain is to avoid altering or adjusting the magnitude of the reported impacts any more than is absolutely necessary. Another goal to attain is to use differential data from comparative area studies, i.e. those which compare study area with control area, parallel band with parallel band in study area, or lateral band with lateral band in study area. As was indicated before, the differential highway effects measured in this way may be more completely accounted for than in cases where the differential impacts are measured through, say, multiple regression analysis.

Achieving the above goals will be hindered by the lack of completely comparable data. The "before" period characteristics of the "subject" and comparable impact areas (stage of land development, dominant land use, type of highway facilities, traffic volume trends, population trends, location with respect to the central business district, time lapse, etc.) will differ in some way. The extent of differences between the "subject" and previously studied facilities (impact areas) can be determined by using the suggested form in Table 38. Then, adjustments can be made in the initial differential impact estimates to account for the most critical differences. Table 39 shows the adjustment procedure.

Therefore, it is the task of the highway analyst to take the following steps:

Step 1. Select studies that are comparable with respect to the three "key" comparative characteristics.

Step 2. Determine the extent to which the "before" period characteristics of each study differ with those of the "subject". (Use Table 38.)

Step 3. Select the most comparable study. (Use Step 2 results.)

Step 4. Adjust the initial differential impact estimates of the most comparable study to account for the Step 2 differences. (Use Table 39.)

The steps taken in this procedure are similar to those taken by the real estate appraiser. He selects recently sold properties that are the most comparable to the subject property which he is appraising. Next, he determines the extent of the differences between the subject property and each comparable property. Then, he adjusts the comparable property sales prices to account for these differences. The end result is an estimate of market value of the subject property. In the appraisal process, the appraiser must be careful not to adjust for a particular difference more than once. The same thing applies here. So the selection of characteristics to adjust for differences is very important.

Table 39. Form Suggested for Adjusting Initial Impact Estimates from Comparable Studies

Type of Adjustment		Amount *Specify units here* ( )
Intial Impact Estimate		____
Adjustments:		
1. ____	±	____
2. ____	±	____
3. ____	±	____
4. ____	±	____
5. ____	±	____
6. ____	±	____
7. ____	±	____
8. ____	±	____
Adjusted Impact Estimate		____

The results of other studies based on regression analysis, case studies, and trend analysis may be helpful in adjusting the initial differential impact estimates to account for subject area and comparable area differences. For instance, coefficients from these studies can indicate rates of changes in, say, land values due to trend analysis, distance to the central business district, distance from the highway, distance from interchanges, etc.

As is the case with the appraiser, the highway analyst may find more than one comparable study with impact estimates that could be used to predict the impact of the "subject" highway improvement. When this is the case, the analyst should carefully examine the extent to which each "comparable" differs from the "subject" and decide which is the most comparable for adjustment purposes. A separate form, as shown in Table 38, should be filled out on each "comparable". Such a procedure forces the analyst to choose which "comparable" is really the most comparable to the "subject".

As shown in Table 39, the adjusted impact estimate is computed by adding algebraically the separate adjustment values to the unadjusted or initial impact estimate of the "comparable". The formula for this computation is as follows:

$$AIE = IIE \pm A \pm A_2 \pm A_3 \pm \ldots \pm A_N$$

where:

AIE = Adjusted Impact Estimate,

IIE = Initial Impact Estimate,

A, thru A_N = Adjustment values (absolute or relative)

Obviously, all of the adjustment values must be in the same units, i.e., dollars, acres, dollars per acre, percentages, etc., and each value must have a positive (+) or negative (-) sign in front of it.

In predicting land use impacts, the units in which the impacts are stated depend upon the absolute or relative units used in previous studies, or more specifically, on the study chosen as the "comparable" to furnish the initial impact estimate. Usually, absolute land use impact units are stated in acres (hectares) or number of tracts in each land use. Other land use units, such as number of dwellings, businesses, etc. and number of square feet (meters) of floor area serve as proxies to these units. Actually, the latter units are excellent measures of the intensity of land use and should be used to measure the land use impacts of minor highway improvements on existing routes. The larger the number of land use categories, especially for land uses with buildings, the more detailed land use measurements or predictions may become. Of course, it makes the land use impact predictive process more complex. For each land use category, a separate impact adjustment form (Table 39) will have to be used.

The absolute units used to indicate land value impacts are usually stated in dollars per acre (hectares) or dollars per square foot (meters). Occasionally dollars per tract are used. In most instances dollar units represent market sales prices. Sometimes they represent assessed tax valuations. Care should be taken to indicate whether the dollar impact predictions are based on adjusted (real) dollars or unadjusted (actual) dollars. Also, it may be desirable to have the impact estimates represent current land values. If so, the initial impact estimates can be updated by using current land value information.

Separating the land value impacts according to specific land uses, especially into unimproved and improved categories, makes the land value impacts more accurate. But again, the more detailed the breakdown, the more complex the impact predictive process becomes. Also, for each land value category, a separate impact adjustment form will be needed.

Inferred Data Prediction Procedure

As stated earlier in this section, the IDPP is used to predict land use and land value impacts of highway improvements when data from previous studies are not comparable with respect to one or more of the following "key" characteristics: (1) type of highway improvement (design and route location), (2) dominant abutting land use, and (3) stage of land development in project area. With increased emphasis being placed on improving or upgrading existing highways and the scarcity of impact studies on such improvements, IDPP will have to be used more often than CDPP.

IDPP does use the absolute and relative impact estimates of the most comparable previous studies. In that sense, IDPP and CDPP are the same. Also, the same forms (Table 38 and 39) can be used to select the most comparable studies and adjust the initial impact estimates. The main difference between the two procedures lies in the fact that IDPP uses estimates which fail to meet all three of the above comparability requirements, especially the specific type of highway improvement. Another difference is that a single impact estimate, measured in absolute and/or relative terms, is not selected by IDPP to be adjusted directly to arrive at a predicted impact estimate. In this sense, the predictions of IDPP are likely to be less accurate than those of CDPP. Also, IDPP relies less on impact estimates generated from the study area-control area comparative technique than does CDPP. However, estimates from such studies are still preferred over the others. At least, data from other types of studies must be relied on more heavily in adjusting the initial impact estimate.

When it is established that all previous studies lack comparability with respect to at least one of the three "key" characteristics listed above, the procedure suggested to infer the extent of highway impact is accomplished by going through the following steps.

Step 1. Select studies that are most comparable with respect to the remaining "key" characteristics.

Step 2. Determine the extent to which the "before" characteristics of each study differ with those of the "subject". (Use Table 38.)

Step 3. Select the two most comparable studies in the group. (Use Step 2 results).

Step 4. Adjust the initial differential impact estimates of each of the most comparable studies selected in Step 3. (Use Table 39.)

Step 5. Compare the adjusted impact estimates and choose a differential impact estimate within the limits set by the two adjusted impact estimates.

As can be seen, IDPP leans more heavily on the analyst's judgement than does the CDPP. Since directly comparable study estimates are not available, he has to infer the extent of highway impact from the two most comparable studies available. Both the IDPP and CDPP require that the analyst be very knowledgeable of the available highway impact studies, as well as, related land use and land value studies. Also, the analyst must know how to use the available data in the appropriate procedure.

Conclusions and Recommendations

Ideally, the literature should contain impact studies which could be used as "direct" comparables for predicting the land use and/or land value impacts of any proposed highway improvement. But such is not the case. The vast majority of the highway impact studies deal with essentially one highway type, namely, new limited access highways. In most of these studies, land use impacts are not measured as vigorously as are land value impacts.

There is little agreement on the size of impact areas by type of highway improvement. No procedure is reported in the literature on how to systematically utilize impact data from previous studies to predict impacts of proposed highway improvements.

Additional research is needed to solve the above problems. Consequently, the following studies are recommended:

- *Conduct land use impact studies on different types of highway improvements, particularly on existing routes.*
- *Conduct additional land value impact studies involving highway improvements on existing routes.*
- *Conduct a study to more accurately define the highway impact area due to different types of highway improvement.*
- *Test accuracy of the impact prediction procedures proposed in this report.*

CITED REFERENCES

1. McKinsey and Company, Inc. "Responding to the Changing Environment: Summary Report." Prepared to Texas State Department of Highways and Public Transportation, July 1976.

2. Highway Research Board. "Highway Capacity Manual." National Academy of Sciences, Special Report 87, 1965.

3. Contilli, E.J., J.M. Cassin, M. Hair, J.C. Falcocchio, and S. Lehmann. "Toward Environmental Benefit/Cost: Measurement Methodology - Final Report." National Cooperative Highway Research Program, Project 20-11, June 1974.

4. Lane, J.S., L.R. Grenzeback, T.J. Martin, and S.C. Lockwood. "Impact Assessment Guidelines: The Role of the No-Build Alternative in the Evaluation of Transportation Projects." National Cooperative Highway Research Program, Project 8-11, October 1976.

5. Winfrey, Robley and Carl Zellner. "Summary and Evaluation of Economic Consequences of Highway Improvements." National Cooperative Highway Report Program, Report 122, 1971.

6. Urban Systems Research and Engineering, Inc. "The Growth Shapers: The Land Use Impacts of Infrastructure Investments." Council of Environmental Quality, May 1976.

7. Buffington, J.L. "Restudy of Changes in Land Value, Land Use, and Business Activity Along a Section of Interstate Highway 35, Austin, Texas." Texas Transportation Institute, Bulletin No. 26, June 1964.

8. Bigelow-Crain Associates. "State and Regional Transportation Impact Identification and Measurement: Phase 1 Report." National Cooperative Highway Research Program, Project 8-15, 1976.

9. Guseman, P.K., T.K. Fuller, J.M. Hall, and Dock Burke. "Social Impacts: Evaluation of Highway Project Development in Urban Residential Areas." Texas Transportation Institute, Research Project 190-1, August 1975.

10. Skorpa, Lidavard, Richard Dodge, C. Michael Walton, and John Huddleston. Transportation Impact Research: A Review of Previous Studies and a Recommended Methodology for the Study of Rural Communities, Division of Research, Council for Advanced Transportation Studies, The University of Texas at Austin, March 1974.

11. Adkins, William G. and Russell H. Thompson. "Some Economic Effects of the Suburban Portion of North Central Expressway." Texas Transportation Institute, Bulletin 15, 1961.

12. Adkins, W.G. and A.W. Tieken. "Economic Impacts of Expressways in San Antonio." Texas Transportation Institute, Bulletin No. 11, August 1958.

13. Buffington, J.L. and H.G. Meuth. "Economic Impact Restudy, Temple, Texas." Texas Transportation Institute, Bulletin 14, 1960.

14. Buffington, J.L. "Economic Impact Study, Huntsville, Texas." Texas Transportation Institute, Bulletin 38, 1967.

15. Buffington, J.L. "Economic Impact Study, Waxahachie, Texas." Texas Transportation Institute, Bulletin 35, 1966.

16. Adkins, William G. "Studies of Land Development at Interchanges." Texas Transportation Institute, June 1962.

17. Buffington, J.L. "Economic Impact Study, Conroe, Texas." Texas Transportation Institute, Bulletin 40, 1967.

18. Buffington, J.L. and C.V. Wootan. "Economic Impact Study, Rockwall, Texas." Texas Transportation Institute, Bulletin 24, 1963.

19. Buffington, J.L. "Economic Impact Study, Chambers County, Texas." Texas Transportation Institute, Bulletin 39, 1967.

20. Buffington, J.L. "Economic Impact Study, Rural Area East of Houston, Texas." Texas Transportation Institute, Bulletin 37, 1967.

21. Buffington, J.L. "Economic Impact Study, Merkel, Texas." Texas Transportation Institute, Bulletin 36, 1966.

22. University of Kentucky. "Certain Economic Effects of the Lexington Northern Belt Line." Bureau of Business Research, 1960.

23. Duke, Richard. "The Effects of a Depressed Expressway - A Detroit Case Study." The Appraisal Journal, October 1958, pp. 487-507.

24. Burton, Robert C. and F.D. Knapp. "Socio-Economic Change in Vicinity of Capital Beltway in Virginia." Highway Research Record No. 75, Highway Research Board (1965), pp. 32-47.

25. Stein, Martin M. "Highway Interchange Area Development - Some Recent Findings." Public Roads, Vol. 35, No. 11, December 1969, pp. 241-250.

26. Ashley, Roger H. and W.F. Berard. "Interchange Development Along 180 Miles of I-94." Highway Research Record No. 96, Highway Research Board (1965) pp. 46-58.

27. Franklin W.D. and Lynn A. Evans. "The Effect of Access on Highway Right of Way Costs and the Determination of Special Benefits." Texas Transportation Institute, Research Report No. 82-1F, October 1968.

28. Davis, J. Tait. "Parkways, Values and Development in the Washington Metropolitan Region." Highway Research Record No. 16, Highway Research Board (1963), pp. 32-43.

29. Cribbens, P.D., W.T. Hill, and H.O. Seagraves. "Economic Impact of Selected Sections of Interstate Routes on Land Value and Use." Highway Research Record No. 75, Highway Research Board (1965), pp. 1-31.

30. Pendleton, William C. "Relation of Highway Accessibility to Urban Real Estate Values." Highway Research Record No. 16, Highway Research Board (1963), pp. 14-23.

31. Massachusetts Institute of Technology. "Economic Impact Study of Massachusetts Route 128." Transportation Engineering Division, Department of Civil and Sanitary Engineering, 1958.

32. Grotewold, A. and L. Grotewold. "Commercial Development of Highways in Urbanized Regions: A Case Study." Land Economics, pp. 236-244.

33. Wuenscher, David E. and D.E. Lang. "Case Study: Impact of Completion of Interstate Highway-St. Charles County, Missouri." Discussion Paper for Transportation Research Board, 1976.

34. Buffington, J.L. and W.G. Adkins. "A Study of 18 Remainder Parcel Along Houston's Gulf Freeway." Texas Transportation Institute, Report E 21-61, 1961.

35. Buffington, J.L. and W.G. Adkins. "Case Studies of Twenty-five Remainder Parcels Along Interstate Loop 820, Fort Worth, Texas." Texas Transportation Institute, Bulletin No. 17, 1961.

36. Maggied, Hal, C.W. Pannell, Z.A. Farkas, and J.D. Wheeler. "Land Use and Intra-Regional Transportation: An Appalachian Georgia Analysis." Georgia Department of Transportation and University of Georgia, 1976.

37. Babcock, W.F. and S. Khasnabis. "Land Use Changes and Traffic Generation on Controlled Access Highways in North Carolina." North Carolina State University at Raleigh, July 1971.

38. Frey, John C., H.K. Dansereau, R.D. Pashek, and A. Twark. "Land Use Planning and the Interchange Community." Highway Research Board Bulletin 327, (1962) pp. 56-66.

39. Moore, W.T., F.J. Ridel, and C.G. Rodriquez. "An Introduction To Urban Development Models and Guidelines For Their Use in Urban Transportation Planning." U.S. Department of Transportation, Federal Highway Administration, October 1975.

40. Brand, Daniel, B. Barber, and M. Jacobs. "Technique For Relating Transportation Improvements and Urban Development Patterns." Highway Research Record 207, Highway Research Board (1967) pp. 53-67.

41. Putman, Stephen H., et al. "The Interrelationship of Transportation Development and Land Development." U.S. Department of Transportation, Federal Highway Administration, June 1973.

42. Meuth, H.G. "Right of Way Effects of Controlled Access Type Highway on a Ranching Area in Madison County, Texas." Texas Transportation Institute, Research Report 58-4, 1968.

43. Meuth, H.G. and J.L. Buffington. "Right of Way Effects of Controlled Access Type Highway on a Farming Area in Ellis County, Texas." Texas Transportation Institute, Research Report 58-5, 1969.

44. Meuth, H.G. "Right of Way Effects of Controlled Access Type Highway on a Farming Area in Colorado and Fayette Counties, Texas." Texas Transportation Institute, Research Report 58-6, 1970.

45. Adkins, W.G. "Effects of the Dallas Central Expressway on Land Values and Land Use." Texas Transportation Institute, Bulletin 6, September 1957.

46. Adkins, W.G. "Economic Effects of the Camp Creek Road Improvement." Texas Transportation Institute, September 1958

47. Adkins, W.G., J.E. Frierson, and R.H. Thompson. "Farm Land Values and Rural Road Service in Ellis County, Texas 1955-58." Texas Transportation Institute, Bulletin 12, June 1960.

48. Thompson, R.H., W.G. Adkins, and D.R. Davis. "Preliminary Study of the Economic Impact of a Section of San Antonio's Loop 13 Expressway." Texas Transportation Institute, E67-60, June 1960.

49. Wootan, C.V., H.G. Meuth, N.J. Rowan, and T.G. Williams, "A Median Study in San Antonio, Texas" Texas Transportation Institute, Bulletin 31, August 1964.

50. Wootan, C.V., H.G. Meuth, N.J. Rowan, and T.G. Williams. "A Median Study in Pleasanton, Texas." Texas Transportation Institute, Bulletin 30, August 1964.

51. Wootan, C.V., H. G. Meuth, N.J. Rowan, and T.G. Williams. "A Median Study in Baytown, Texas." Texas Transportation Institute, Bulletin 29, August 1964.

52. Bardwell, G.E. and P.R. Merry. "Measuring the Economic Impact of Limited Access Highway on Communities, Land Use, and Land Value." Highway Research Board Bulletin 268, Highway Research Board (1960), pp. 37-73.

53. Longley, J.W. and B.T. Goley. "A Statistical Evaluation of the Influence of Highways on Rural Land Values in the United States." Highway Research Board Bulletin 327, Highway Research Board (1962), pp. 21-55.

54. Stroup, R.H. and L.A. Varga. "Economic Impact of Secondary Road Improvements." Highway Research Record 16, Highway Research Board (1963), pp. 13-28.

55. University of Kentucky. "The Effect of the Louisville Watterson Expressway On Land Use and Land Values." Bureau of Business Research, College of Commerce, 1960.

56. Dansereau, H. Kirk, J.C. Frey, and R.D. Pashek. "Highway Development: Community Attitudes and Organization." Highway Research Record 16, Highway Research Board (1963), pp. 44-59.

57. Varga, Louis A. "Effects of Highway Development on Rural Lands." Michigan State University, Joint Research, 1960.

58. Richards, Hoy A., J.P. Miller, and W.H. Allio. "A Study of Interstate Highways, Frontage Roads and Industry Location." Texas Transportation Institute, Research Report 66-2, October 1968.

59. Colony, David A. "Study of the Effect, If Any, of an Urban Freeway Upon Residential Properties Contiguous to the Right of Way." University of Toledo, Research Foundation, 1966.

60. Thompson, R.H., W.G. Adkins, and J.E. Frierson. "A Preliminary Study of the Economic Impact of Stemmons Freeway - A Section of Interstate 35E, Dallas, Texas." Texas Transportation Institute, E 59-60, 1960.

61. Hampton, J.H. "Petaluma Bypass: Effect on Specific Businesses and the Community is Analyzed." California Highways and Public Works, Vol. 41, Nos. 7 and 8 (July-August 1962) pp. 37-44.

62. Hendrix, Frank L. "The Economic Impact of the Interstate Highway Program On By-Passed Businesses and Adjacent Areas." Department Of Transportation, University of Tennessee.

63. Washington State Highway Commission. "The Effect of a Bypass On Retail Trade." Department of Highways, October 1965.

64. Gamble, Hays B., O.H. Sauerlender, and C.J. Langley. "Adverse and Beneficial Effects of Highways on Residential Property Values." Pennsylvania State University.

65. Borchert, John R. "Beltline-Commercial Industrial Development." University of Minnesota, November 1960.

66. Louisiana Department of Highways. "Opelousas Economic Impact Study." Traffic and Planning Section, 1964.

67. Ohio Department of Highways. "Factors Influencing Land Development-Subdivision Development Study - Interstate 71 - Franklin County." Division of Right-of-Way, Economic Research Section, September 1970.

68. North Dakota State Highway Department. "Interstate Highway Impact in the Jamestown-Valley City Area: A Statistical Analysis." Planning and Research, May 1966.

69. Missouri State Highway Department. "Economic Study Route U.S. 66 By-Pass Rolla, Missouri." Division of Highway Planning, 1957.

70. Shindler, R.L. and L.I. Lindas. "Economic Impact of Highway Change On Six Communities in Oregon." Oregon State Highway Department, December 1958.

71. Frankland, Bamford. "Farmlands." California Highways and Public Works, Vol. 40, Nos. 5 and 6, May-June 1961.

72. Frankland, Bamford. "Rural Fringe." California Highways and Public Works, Vol. 40, Nos. 3 and 4, March-April 1961.

73. Young, W. Stanley. "Imperial." California Highways and Public Works, Vol, 30., Nos. 5 and 6, May-June 1951, pp. 27-31.

74. Kelly, John F. "Camarillo Study." California Highways and Public Works, Vol. 34, Nos. 9 and 10, September-October 1955, pp. 287-290.

75. Phillips, Hudson R. "Delano." California Highways and Public Works, Vol. 38, Nos. 3 and 4, March-April 1959, pp. 21-26.

76. Kimota, James K. "El Monte." California Highways and Public Works, Vol. 38, Nos. 1 and 2, January-February 1959, pp. 15-19.

77. Young, W. Stanley. "North Sacromento." California Highways and Public Works, Vol. 29, Nos. 1 and 2, January-February 1950, pp. 3-8.

78. Kelly, John F. "Fairfield (Concluding Study)." California Highways and Public Works, Vol. 32, Nos. 5 and 6, May-June 1953, pp. 34-38.

79. Bangs, Robert L. "Fresno." California Highways and Public Works, Vol. 28, Nos. 10 and 11, November-December 1949, pp. 29-33.

80. Kelly, John F. "Templeton Bypass." California Highways and Public Works, Vol. 34, Nos. 7 and 8, July-August 1955, pp. 23-27.

81. Kelly, John F. "Tulare Bypass." Calfornia Highways and Public Works, Vol. 35, Nos. 5 and 6, May-June 1956, pp. 39-43.

82. Hill, Stewart L. "Glendale Report." California Highways and Public Works, Vol. 43, Nos. 3 and 4, March-April 1964, pp. 42-47.

83. Kelly, John F. "Residences and Freeways." California Highways and Public Works, Vol. 36, Nos. 3 and 4, March-April 1957, pp. 23-31.

84. Kelly, John F. "Anderson Study." California Highways and Public Works, Vol. 32, Nos. 1 and 2, January-February 1953, pp. 24-29.

85. Kelly, John F. "Santa Claus." California Highways and Public Works, Vol. 35, Nos. 3 and 4, March-April 1956, pp. 25-26.

86. Kelly, John F. "The One-Way Street (Sacromento)." California Highways and Public Works, Vol. 32, Nos. 3 and 4, March-April 1953, pp. 24-25.

87. Connally, Julia A. "The Socio-Economic Impact of the Capital Beltway on Northern Virginia." Virginia University, PB 179 274, 1968.

88. Thiel, Floyd I. "Highway Interchange Area Development." Highway Research Record 96, Highway Research Board (1965) pp. 24-45.

89. Khasnabis, Shehamay and W.F. Babcock. "An Analysis of Freeway Impact in Fine Urban Areas in North Carolina." Submitted at TRB Annual Meeting, January 1977.