IMPACT OF A BELTWAY ON A MEDIUM-SIZED URBAN AREA IN NORTH CAROLINA: A CASE STUDY

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ABRIDGMENT

The case study reported in this paper is a part of a larger research project investigating land developments and traffic generation on controlled-access highways in North Carolina. This paper focuses on a particular aspect of of the research, the impact of a beltway on the growth patterns of the Raleigh, North Carolina, urban area. The study included an investigation of the land developments within the immediate interchange areas as well as an analysis of all major urban developments in the standard metropolitan statistical area between 1961 and 1972. Multiple regression analysis was used to relate these developments (dependent variables) with a measure of the distance from the nearest beltway interchange with inputs from major demographic, socioeconomic, and physical factors (independent variables) that could conceivably contribute to the process of land development. The factor measuring the effect of the beltway was found to contribute significantly to regression, which indicates a strong relationship between the freeway and the developments. The predictive equations that were developed by regression analysis can be used directly to evaluate the impact of the proposed southern loop of the existing beltway on the same urban area. Also a series of guidelines that might help the transportation planner better understand the impact of a freeway on the total urban environment was developed as an outcome of this research.

•ONE of the critical problems encountered by a highway planner during the planning of a controlled-access freeway is predicting future land use patterns along the freeway. The close interrelationship of land developments and generated traffic makes the task of forecasting such land use changes extremely important. Generally, traffic estimates are based on adopted land development plans and current zoning ordinances. However, increasing value of land around freeway interchanges and gradual decentralization of urban activities bring about changes in the original zoning patterns and development of dense urban complexes not foreseen in the original land development plan. In many cases, traffic generated by developments completely overloads the freeway interchanges. Thus the question is how to make a judgment decision regarding future land development. The idea of using the existing land development plan may be misleading if it does not recognize the attractor characteristics of the freeway. For this reason, a study was undertaken to analyze land developments and the resulting traffic generation along the 600-mile-long (960-km-long) freeway system in North Carolina.

This paper focuses on a particular aspect of the study, an in-depth investigation of the impact of a beltway on the urban environment of a medium-sized city in North Carolina. The impact study was conducted as a part of 2 larger research projects conducted from 1970 to 1973 in the Civil Engineering Department under the Highway Research Program, North Carolina State University, and sponsored by the North Carolina Department of Transportation and Highway Safety in cooperation with the Federal Highway Administration, U.S. Department of Transportation.

STUDY OBJECTIVES

The specific objectives of the research reported in this paper are

1. To evaluate the impact of a beltway on the land uses, traffic, and general environment of a medium-sized urban area in North Carolina;
2. To develop predictive models to be used by highway planners to assess the long-range impact of a proposed highway on the land development potentials of the urban area.
3. To provide a major input to the development of a series of procedural guidelines that will aid the planner to understand better the impact of the freeway on the total urban environment.

STUDY AREA DESCRIPTION

The city of Raleigh, North Carolina (1970 population, 121,000), which was selected as the test site for the impact study, can be categorized as a typical medium-sized urban area in the South whose population doubled from 1940 to 1970. The history of the beltway dates back to the early 1950s. Plans for a complete beltway around Raleigh approximately 4 or 5 miles (6.4 or 8 km) from the central business area were adopted in 1950. Construction of the northern segment of the beltway as a 4-lane divided freeway, with full control of access, was begun in 1956 and completed in 1961. It is 13 miles (20.8 km) long and has 8 interchanges. Construction of the southern loop of the beltway is expected to be started soon.

METHODOLOGY

Land Use Changes Around Interchanges

Base maps for the freeway were prepared to a scale of 4 in. to 1 mile (1.58 cm to 1 km). Land use data up to 0.5 mile (0.8 km) on either side of the interchanges were plotted from aerial photographs taken in 1960, 1964, and 1970. These were then updated by a field survey in 1974. Data thus collected were used to evaluate the impact of the beltway on the immediate interchange area. Also, the zoning changes that occurred in areas around the beltway after its opening were analyzed and related to the relevant land developments.

Land Use Changes for Entire Study Area

To assess the impact of the freeway on the entire urban area, we considered all past developments within the standard metropolitan statistical area (SMSA) during the 12-year period from 1961 to 1972. These were analyzed in 4 separate categories: residential, commercial, industrial, and office and institutional developments. Each census tract was treated as an analytical unit. Relevant land use data were collected from monthly building reports published by the city and analyzed by plotting the percentile values of developments against the distance from the beltway and by multiple regression.

Traffic Generation on the Beltway

Traffic data along the freeway and the crossroads were obtained from the files of the North Carolina Department of Transportation and Highway Safety and analyzed on a historical basis between 1963 and 1971. The changes in traffic volumes were related to the changed land use patterns around the interchange areas.

RESULTS

Land Developments and Zoning Changes Related to the Beltway Interchanges

The historical analysis of the land developments within 0.5 mile (0.8 km) of each of the 8 interchanges produced the following results:

1. Little development around the beltway occurred in 1960;
2. By 1964, 3 years after the facility had opened, the developments that could be attributed to the highway included 5 service stations, 1 moderate-sized industry, and 1 apartment complex with 60 units;
3. Between 1964 and 1970, the newer developments included 1 service station, 1 major chain motel, 17 industries of varying sizes, 1 regional shopping center, 7 office and institutional developments, and 7 apartment complexes with about 1,850 units;
4. From 1970 to 1972, developments included 1 additional chain motel, 2 new industries, 1 moderate-sized shopping center, 2 large shopping centers, 38 office and institutional developments, and 3 apartment complexes with 200 units.

The zoning case files revealed that from 1960 to 1970 approximately 100 cases were filed for rezoning along the beltway. About 95 percent of these related to requests for zoning from a lower to a higher density use. Fifty percent of the cases were requests to change from a residential development to some form of a high-density commercial activity. Another 40 percent were requests to change residential use from a lower to a higher density. In general, the zoning status of single-family residential areas was changed to permit the development of apartment complexes, and areas zoned for dense residential use were rezoned for office, institutional, and commercial use.

Impact of the Beltway on Types of Activity and Percentile Distributions

The results presented in the previous section were indicative of the impact of the beltway on its immediate surroundings. The impact, however, extended much farther than the interchange areas, and the percentile curves to be discussed in this section show overall impact on the urban environment.

Apartment Development

The analysis indicated that more than 50 percent of all the apartments built in the Raleigh SMSA during the 12-year period were located within 7,000 ft (2100 m) of the beltway. A discussion with municipal officials corroborated the percentile findings that indicated that more than 3,400 apartment units, almost half of all apartments constructed during the same period, were completely oriented to the Raleigh beltway.

Industrial Development

More than half of all the industrial developments were found to be located within 4,000 ft (1200 m) of the beltway. These were generally the "prestige areas" on service roads along the eastern part of the beltway. Except for certain developments of heavy industries that were located in the southern area of the city, practically all new industries were developed along the beltway in areas either zoned for industrial development or in rezoned areas near major railroad spurs.

Office and Institutional Development

From 1960 to 1972, the Raleigh urban area was growing very rapidly and was creating a great demand for distribution, wholesale, and office facilities. More than half of such office and institutional developments (excluding the new state and federal buildings constructed in the CBD area) were found to be located within 1 mile (1.6 km) of the beltway interchanges, and 80 percent were within a distance of 2 miles (3.2 km).

Commercial Development

Shopping centers predominated in Raleigh during the 1960 to 1970 decade; 2 new regional centers were located on interchanges with the beltway. More than 50 percent of all such developments took place within 1,000 ft (300 m) of the beltway, and 80 percent were within a distance of 2 miles (3.2 km).

Statistical Study of Land Developments by Multiple Regression

The study area includes a total of 38 census tracts that were used as analytical units. These tracks were divided into northern or southern subsamples.

A series of regression analyses was conducted with different combinations of the independent variables. Results of the final analysis presented here provided the best correlation. The criteria were maximum r^2 value, an acceptable F-value, and a small standard error of the estimate.

All Housing Units

The analysis indicated that the independent variable measuring the effect of the beltway (distance of the tract centroid to the nearest interchange) contributed significantly to regression ($t = 3.48$); r^2 was 0.73 and calculated F was much higher than F.01 for the relevant degrees of freedom. When the tracts in the southern part of the city were considered together, r^2 improved from 0.72 to 0.78 with a significant drop in the standard error of the estimate.

Apartment Units

The same set of independent variables was used in the analysis of apartment units as was used for all housing units. The factor measuring the effect of the beltway showed significant correlation with the dependent variable with an r^2 of 0.41. r^2 increased from 0.41 to 0.89 when the southern tracts were considered together.

Industrial Developments

For industrial developments, the critical independent variable used was a composite measure of available land and proximity of the area to the beltway. The high t-value (12.38) obtained from testing the significance of this composite variable indicated that, when sufficient land is available for industrial development, the closer the tract is to a freeway interchange, the higher the propensity is for such development.

Commercial Developments

The critical independent variable used in regression analysis is a composite measure of available land (corrected for accessibility and economic condition) and proximity of

the area to the beltway. The t-test (t = 5.00) indicated that the beltway had been a significant factor in determining the location of commercial developments. An r^2 of 0.63 at 1 percent level of significance was obtained when all the census tracts were considered together. r^2 improved to 0.93 with a very sharp drop in the value of the standard error when the southern tracts were considered alone.

Office and Institutional Developments

The same set of independent variables was used in this analysis as was used for commercial developments with an r^2 of 0.74. The t-test illustrated the significance of the beltway in the location of such developments (t = 7.90).

Traffic Generation Characteristics of the Raleigh Beltway

The 1963 traffic volumes on the beltway were around 5,000 vehicles/day. In 1971, they were generally more than 20,000 vehicles/day. This substantial increase is primarily attributable to the large growth in land developments near the beltway and because the facility provided a new route of travel for both through and local traffic. An analysis of the traffic volumes on the beltway and on the crossroads at the interchange indicated conclusively the impact thereon of the major traffic generators located in the interchange area. For example, the current average daily traffic on the crossroads near the interchange area is almost double that for sections of the roads about 0.5 mile (0.8 km) away from the interchange for 2 critical interchanges where 2 regional shopping centers were developed. This is indicative of the tremendous traffic pressures that the interchanges are subjected to as a result of these special generators.

CONCLUSIONS

The analysis presented in this paper illustrates the tremendous influence that the beltway had exerted on the entire urban environment of the Raleigh area since its opening in 1961. The improved accessibility provided by the freeway, particularly at interchanges with major radial routes, contributed very significantly to these developments. Within 10 years of the opening date of the freeway, about 70 percent of the interchange quadrants were completely developed with varied types of land activities; another 20 percent are now being developed. The remaining quadrants cannot be developed in the immediate future because these are generally owned by the state.

The analysis of the zoning case files clearly indicated that the beltway was instrumental in a large number of zoning changes from a lower to a higher density type of land activity. The original zoning plan of the city did not contemplate the beltway; therefore, the city was under pressure from the developers for rezoning requests. In most cases, the developments that followed such zoning changes caused severe traffic problems. This clearly points to the need for a more strict degree of control on land use policy on the part of the municipal agency.

A before and after type of analysis illustrates how the beltway acted as a very forceful "catalyst" in promoting urban growth in the northern part of the city, although, even from the early 1950s, the city had been generally growing in the north. During the prebeltway period between 1956 and 1960, the census tracts lying on either side of the proposed beltline that included approximately 50 percent of the entire SMSA accounted for 55 percent of the increase in population. During the postbeltway period between 1960 and 1970, the same tracts accounted for almost 90 percent of the total increase in population. A large percentage of the area within these tracts was owned by the state of North Carolina, and therefore, had no possibility of residential growth. If a proper discount was allowed for these nondevelopable areas, the effect of the beltway would appear even more significant.

Predictive Model

The purpose of performing the regression analysis was to test the statistical significance of the beltway in urban developments and to develop predictive equations for future growth. The regression results were quite significant when one considers that many important factors that contribute to the process of land development cannot be formulated in mathematical terms. Such factors include topography of land, availability of municipal services, and ability of the developers to assemble large parcels of land and to obtain the necessary funding.

The analysis showed that the beltway did act as a significant factor in the developments. Generally, the predictive capability of the model increased when the northern and southern tracts were considered separately. The use of a particular model for predictive purposes was recommended based on maximum r^2 value and a small standard error at an acceptable level of significance.

Guidelines for Analysis of Proposed Major Highway Facilities

One of the most important conclusions emerging out of the larger research project is the need for recognizing that, in project planning, a detailed and careful analysis must be made of the possible impact of a proposed freeway in influencing land use patterns. Based on this, a series of procedural guidelines was developed to aid the planner in investigating these influences and impacts. These were developed as an outcome of the examination of the entire freeway system in North Carolina in rural, suburban, and urban areas. The Raleigh case study provided significant inputs to the development of the guidelines.

The guidelines center around the concept that a new urban freeway may change the growth pattern not only within the immediate interchange area but also for the urban area as a whole. A reasonable factor of safety should be incorporated into the interchange design to allow staged construction when necessary. Purchasing additional right-of-way at the outset would be more economic in the long term than reconstructing the interchanges much ahead of their design life because of traffic that was not originally anticipated. In essence, careful consideration should be given to all the proposed interchanges. Adequate consideration should be given to what may take place because of the freeway rather than what is shown on any existing plan or zoning map.

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