

INTERCHANGE DEVELOPMENT PATTERNS ON INTERSTATE HIGHWAYS IN SOUTH CAROLINA

James W. Epps, Mississippi State University; and
Donald B. Stafford, Clemson University

This paper describes the results of a study of interchange development patterns on Interstate highways in South Carolina. Data obtained at 131 interchanges were used to examine the relationships between the number of service stations, restaurants, motels, and non-highway-oriented businesses located at interchanges and five interchange characteristics. The interchange characteristics were ADT on the Interstate, ADT on the intersecting highway, distance to and population of communities within 10 miles of the intersection, distance to nearest major urban center, and distances to adjacent interchanges on the Interstate highway. The relationships between interchange development and interchange characteristics can be used to obtain rough estimates of anticipated development at proposed interchanges. Although the interchange development patterns and the relationships between development and interchange characteristics are directly applicable only in South Carolina, the data can be applied in other states with similar economic, geographic, and demographic conditions, especially in the southeastern United States.

•THE LARGEST highway construction program ever initiated was that authorized by the 1956 Federal-Aid Highway Act: The Interstate Highway System, since extended to 42,500 miles, is characterized by high design standards that produce high-speed, multi-lane, controlled-access thoroughfares with separate travel lanes in each direction and grade separations at all intersecting highways. The development of this type of highway has made highway planners increasingly aware of the social and economic impacts a modern highway can have on the communities through which it passes. That the Interstate System will link 90 percent of the cities in the United States with a population of 50,000 or more and that when completed it will carry 20 percent of the total motor vehicle traffic but comprise only 1 percent of the total highway mileage in the country have caused factors such as patterns of land use and commercial development adjacent to the highway system to become important considerations in the location and design of modern highways.

The 1956 Federal-Aid Highway Act prohibits commercial roadside development within the Interstate highway rights-of-way. Therefore, access points, or interchanges, become the focal points of the Interstate Highway System because they provide ingress and egress to the system, as well as access to commercial, industrial, and residential development. Because all of the Interstate highway traffic must be channeled through interchanges, the areas surrounding the interchanges are desirable locations for economic development. Another attractive characteristic of the interchanges is that the long-distance traveler does not have to travel far from the highway to obtain food, lodging, and gasoline. Also, many businesses and industries that do not necessarily attract customers from the highways do require frequent and direct access to the highways through the interchanges.

To maintain a satisfactory level of operation through the interchanges along the Interstate Highway System, or any controlled-access highway for that matter, careful

planning is necessary during the design stages of highway development. Unexpected or uncontrolled economic development can cause increases in traffic that will cause the interchange to reach design capacity prematurely and eventually to break down functionally, resulting in tremendous private and public economic losses.

A model needs to be developed that can predict the development of commercial establishments at an interchange based on the traffic and locational characteristics of the interchange. A study of interchange development on the Interstate Highway System in South Carolina was initiated with the objective of developing this type of predictive model.

The results of the study can be used in several ways. First, the model can be used to provide a basis for coordinated planning on the remainder of the Interstate System in South Carolina and in other states with similar demographic and economic characteristics. Second, the data can be used to predict the amount of economic development at existing interchanges along non-Interstate highways that have been constructed to Interstate standards. The model will also be useful in planning the interchanges proposed for non-Interstate highways that are to be upgraded to Interstate standards. Third, the results of the study will provide a method of planning for interchanges that have already been constructed but are not yet fully developed. Fourth, the results of this study can be used as an integral part of a comprehensive analysis of the economic feasibility of an interchange being planned for future construction. The last three applications are most valuable, for approximately 70 percent of the entire Interstate Highway System is already complete and open to traffic.

The study had three objectives. The first objective was to record the existing economic development at each interchange along the sections of the Interstate System in South Carolina that were open to traffic at the time the study was initiated. Future periodic checks of the interchanges can be made to provide an accurate record of the changes in development, thus providing information on development trends for each type of interchange. A second objective was to determine the interchange characteristics that influence economic development at interchanges and to quantify these characteristics so that each characteristic may be evaluated for every interchange under consideration. The third objective was to develop data that could be used to predict the amount of economic development at an interchange based on the characteristics of the interchange.

BRIEF LITERATURE REVIEW

Interchange development has concerned highway planners for many years. The initial studies involved Mass-128 around Boston (4, 5). A tremendous amount of unexpected industrial and commercial sites developed along the highway and caused early functional obsolescence of the facility.

Several highway departments began studying the effects of development on the interchange traffic and kept records of the economic development at the interchanges along Interstate highways (1, 2). The Alabama Highway Department used aerial photography annually to record development along the entire Interstate System in the state. The Michigan Department of State Highways (2) studied a 180-mile section of Interstate 94 in an attempt to determine the variables that affected economic development at the interchanges. Neither study reached any significant conclusions concerning the characteristics of interchange development, however.

Several agencies and individuals later attempted to develop models that could be used to predict interchange development. Fowler, Sanders, and Stocks (7) first attempted to predict interchange development based on the number of years the interchange had been opened to traffic and the distance to and population of the nearest urban area. Models were developed that would predict the number of gasoline pumps, the number of restaurant seats, and the number of motel rooms. None of the models proved to be very satisfactory, however.

Sauerlender, Donaldson, and Twark (8) conducted a similar study but, in addition, related interchange development to four other variables: type of interchange, ADT on Interstate highway, ADT on intersecting highway, and topography of the interchange area. No statistical analysis was conducted to test the significance of each variable,

but several important conclusions were reached. The most significant findings of this study were as follows:

1. Economic development was closely related to the average daily traffic on the intersecting highway,
2. Development was related to the topography, and
3. Development was related to the distance to the nearest urban center.

Twark (10) conducted a more extensive study to predict economic development at rural interchanges by using multiple regression techniques. He examined 105 interchanges along the Interstate Highway System in Pennsylvania. Three separate models were developed. The first model predicted the number of service stations, the number of motels, the number of restaurants, the number of non-highway-oriented businesses, and the average annual rate of growth in market value of real estate in the local community. In each case, the percentage of sample variation explained was very low. A second model was developed in an attempt to improve the proportion of sample variation explained by the first model. The second model predicted the number of gasoline pumps, the number of motel rooms, the number of restaurant seats, the number of non-highway-oriented businesses, and the average annual growth in the market value of local community real estate. Sample variation explained was improved in the restaurant and motel equations only, however. The third model was developed to predict highway-oriented development, non-highway-oriented development, and the average annual rate of growth in the market value of real estate in the local community. None of the relationships in the third model showed any improvement in percentage of sample variation explained over those in the first and second models.

Stein (9) attempted to define other variables that could be used to predict interchange development that had not been previously used. The most significant variable that he introduced was the use of travel time rather than the distance in miles to nearby urban areas as a measure of spatial separation.

Babcock and Khasnabis (3) analyzed the changes in land development that took place along 550 miles of controlled-access highways in North Carolina. The land areas were analyzed in terms of the rural, suburban, or urban interchange characteristics. Land development was broken down by whether it appeared to be attributable to the highway development. In rural areas, the predominant land developments were service stations and were so scattered that they could not be predicted. In suburban areas, service stations, motels, and industries were more equally distributed, were denser, and could be predicted reasonably. In urban areas, land developments could be predicted, but the factors required for the models were so numerous that statistical analysis of the factors was impossible.

A more comprehensive review of literature related to interchange development studies has been presented by Epps (6).

METHOD OF ANALYSIS

Extensive field analysis of the sections of the South Carolina Interstate Highway System that were open to traffic was conducted in an effort to determine the characteristics of interchange development. The study encompassed 131 interchanges along four Interstate highways. The solid lines in Figure 1 show the sections of the Interstate Highway System that were included in the study. Two of the highways, I-85 and I-26, are complete and open to traffic throughout the state. I-20 is now complete from the Georgia state line to the intersection with US-601 near Camden, whereas I-95 is open from the North Carolina line to the intersection with US-310 south of Sumter. Construction of I-77 has just begun. Approximately 385 miles of highway were included in the study; only the section of I-20 from the Georgia state line to the intersection with SC-6 west of Columbia was omitted.

Each of the 131 interchanges was studied thoroughly by means of a site investigation, detailed county highway maps, and traffic volume maps. During each site investigation, a diagram of the interchange was sketched to record the number of the intersecting highway, the type and configuration of the interchange, and the type and location of each

Figure 1. South Carolina Interstate Highway System.

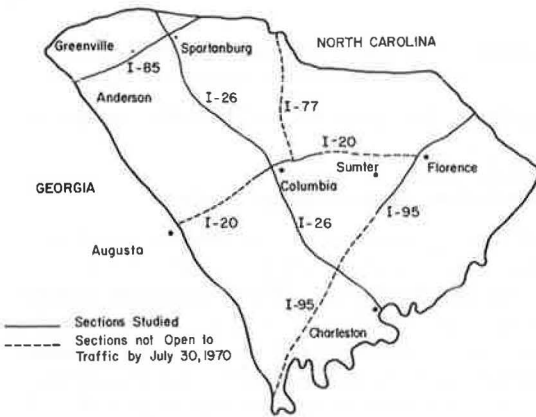


Figure 2. Completed interchange diagram.

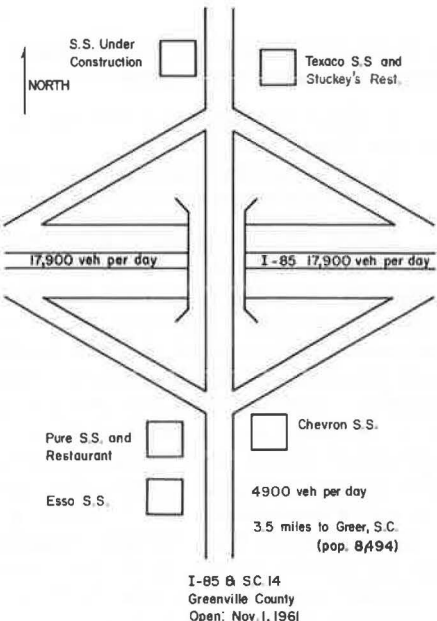


Figure 3. Amount of interchange development and ADT on Interstate highways in South Carolina.

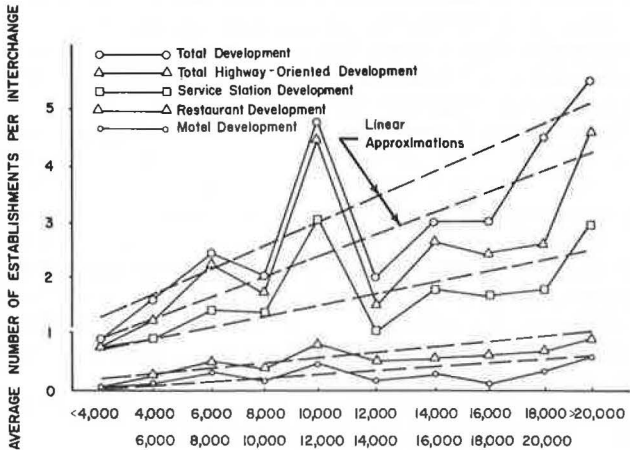
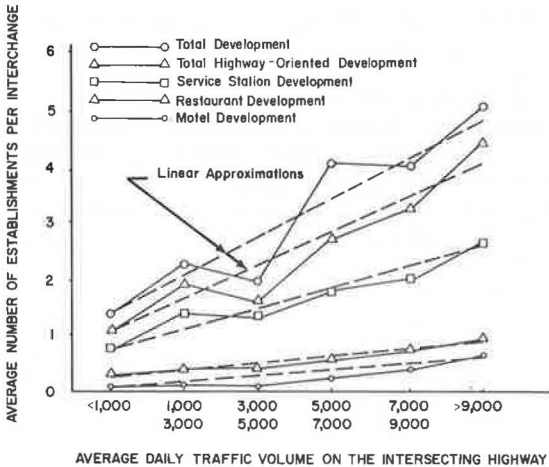


Figure 4. Amount of interchange development and ADT on intersecting highways in South Carolina.



unit of economic development in the interchange area. Other information on topography, residential development, and factors that might affect economic development were also noted on the interchange diagram. Information concerning the characteristics of the interchanges was compiled from county highway maps, the 1969 South Carolina Primary Highway Traffic Flow Map, county traffic volume maps, and other data supplied by the Traffic and Planning Division of the South Carolina Highway Department. The interchange characteristics recorded on the diagram consisted of the population of and the distance to communities near the interchange, ADT on the Interstate highway and the intersecting highway, the distances to adjacent interchanges in either direction along the Interstate highway, the distance to and population of the nearest major urban center by the shortest route, and the date the interchange was open to traffic. Figure 2 shows an example of a completed interchange diagram.

Several interchange characteristics were found to affect the amount of economic development attracted to the interchange: interchange type, volumes of traffic on the intersecting highways, distance to and size of the nearby communities, distance to the nearest large urban center, and average distance to adjacent interchanges. Of course, there are other important interchange characteristics that relate primarily to the economy of the area surrounding the interchange, but these factors are very difficult to measure.

All of the interchanges studied were classified as either complete or incomplete. A complete interchange is an interchange that allows a driver traveling in either direction on either of the intersecting highways to make any desired traffic movement and travel in any direction he desires, e.g., diamond, partial cloverleaf, full cloverleaf, trumpet, and split diamond interchanges. An incomplete interchange, e.g., a half diamond does not allow a driver to make certain traffic movements on either of the intersecting highways. An additional category used to classify complete interchanges further was a restricted interchange. A restricted interchange was defined as an interchange that allows a driver to make any desired traffic movement from either of the intersecting highways, but does not allow direct access to the adjacent land areas surrounding the interchange. An example is the intersection of two controlled-access highways. Six restricted interchanges were found on the sections of Interstate included in the study.

RESULTS OF THE STUDY

Interchange Type

Of the 131 interchanges studied, only 12 were categorized as incomplete or restricted. The incomplete or restricted interchanges only contributed four units of economic development, all of which consisted of non-highway-oriented development. Slightly less than 50 percent of the interchanges (65) were diamonds, whereas there were 40 partial cloverleaves (30 percent), 15 full cloverleaves (11 percent), two trumpets, one split diamond, three half diamonds, and five specialized or modified interchanges. There were 342 units of economic development located at the 119 complete interchanges composing almost 99 percent of the total economic development found on the 131 interchanges studied.

Interstate Highway Traffic Volume

Two important interchange characteristics are ADT on the Interstate highway and ADT on the intersecting highway. Figure 3 shows the relationship between ADT on the Interstate highway and average amount of economic development at the interchange. The solid lines represent the actual data from the 131 interchanges included in the study. The dotted lines represent linear approximations of the development patterns of each type of business establishment as a function of Interstate highway traffic volume. The linear approximations were used in an effort to examine the degree to which the amount of economic development varied linearly with the traffic volume on the Interstate highway.

As shown in Figure 3, ADT on the Interstate highway exhibited a very small effect on motel and restaurant development. Service station development, however, increased

significantly as ADT on the Interstate highway increased, but not in a linear manner. Interestingly, non-highway-oriented development, the difference between total development and total highway-oriented development, also increased as ADT on the Interstate highway increased, a rather unexpected finding.

Traffic Volume on Intersecting Highway

The average daily traffic volume on the intersecting highway had a significant effect on the development at the interchanges. Figure 4 shows that the intersecting highway traffic volume exhibited an almost linear influence on the amount of all types of interchange development. However, motel and restaurant development was only slightly affected by increases in ADT on the intersecting highway, whereas service station development showed a significant response to increasing traffic volume. Again, non-highway-oriented development increased slightly as ADT on the intersecting highway increased.

Community Factor

The other interchange characteristics investigated dealt with the location of the interchange in relation to nearby towns and communities, major urban centers, and adjacent interchanges. Each of these characteristics was also found to influence the amount of economic development at the interchange.

Communities located near the interchange offer a reasonable potential for business activity. The relative size of the community, measured by the population, provides an indication of the potential impact that the community can have on the economic activity at interchanges within or adjacent to the community. The economic activity is determined primarily by the volume of traffic generated by and attracted to the community. The distance from the community to the interchange has a modifying effect on the influence that the community will have on the business activity and volumes on non-Interstate highway traffic in the immediate vicinity of the interchange. For the proposed analysis, 10 miles was considered to be the maximum distance at which a local community would significantly influence interchange economic development. Based on the assumption of the 10-mile radius of influence, a variable that will hereafter be referred to as the community factor was developed. The community factor of each interchange was calculated by summing the gravity factors of each community within 10 miles of the interchange. The gravity factor of a community is designed to measure the influence the community would have on an interchange located a specified distance away. The gravity factor was calculated for each community by dividing the population of the community by the square of the distance from the community to the interchange under consideration. The distance was squared to reflect the effect that spatial separation has on trip distribution, as has been determined in urban transportation planning studies. The community factor for a single interchange is represented mathematically as

$$\text{Community factor} = \sum_{i=1}^n \frac{\text{population}_i}{\text{distance}_i^2}$$

where n = the number of communities within 10 miles of the interchange.

Figure 5 shows the relationship between community factor and interchange development. The effect of the community factor on total development, total highway-oriented development, and service station development was significant, but the relationships were clearly not linear. Motel and restaurant development was not significantly affected by the community factor, although the response of each factor was roughly linear in nature.

Distance to the Nearest Major Urban Center

Proximity to a large urban center with a population greater than 25,000 affects the amount as well as the types of economic development at an interchange. More motels and restaurants are developed at interchanges near urban areas than at interchanges farther from urban areas (Fig. 6). Also, non-highway-oriented businesses tend to compete more for land at interchanges near urban areas and make up a significant proportion of the total development. As the distance from the urban area increases, all types of development decrease.

At longer distances from the urban centers, service station development makes up a larger proportion of the highway-oriented development, and at distances over 40 miles it makes up almost 100 percent of the highway-oriented development as well as total development. The amount of motel and restaurant development decreases approximately linearly as the distance from the urban center increases. However, service station development, total highway-oriented development, and total development decrease rather erratically as the distance from the urban center increases.

Distance to Adjacent Interchanges

The distance to adjacent interchanges has been shown to be a significant factor in determining the development potential of an interchange. When interchanges are closely spaced, businesses tend to cluster about the interchanges. This clustering effect, however, is due to the higher probability of urban land use in the vicinity of closely spaced interchanges. Figure 7 shows the relationship between the amount of interchange development and the average distance to adjacent interchanges. This relationship is similar to that between interchange development and the distance to a major urban center (Fig. 6). However, the responses shown in Figure 7 are more linear in nature than those shown in Figure 6. Interchange spacing of less than $1\frac{1}{2}$ miles occurs more commonly in urban areas, whereas spacing of more than $6\frac{1}{2}$ miles is found primarily in rural areas. The amount of all types of development decreased as average interchange spacing increased. For interchange spacings greater than $6\frac{1}{2}$ miles, service stations constituted 100 percent of the total development, exactly the result for interchanges located more than 40 miles from a major urban area as noted in Figure 6.

PREDICTING INTERCHANGE DEVELOPMENT

The data shown in Figures 3 through 7 can be used to obtain approximate estimates of the amount and composition of the development that will locate at a proposed interchange. Based on the data collected in South Carolina, the following approach to estimating the expected development at interchanges is suggested.

1. Obtain accurate estimates of the traffic volumes on both intersecting highways, distances to and populations of nearby communities, distance to the nearest urban center with a population of at least 25,000, and distances to adjacent interchanges.
2. Using either the actual relationships between development and interchange characteristics shown in Figures 3 through 7 or the linear relationships shown by the dotted lines in these same figures, obtain an estimate of the average number of units of development for motels, restaurants, service stations, and total development for each of the five relationships.
3. Average the five estimates for each type of business establishment and round the values to the nearest whole unit of development to obtain estimates of the expected units of each type of development. Special care should be exercised in the rounding process to ensure that, if the units of development for some types of business are rounded up, other types of business should be rounded down.

This procedure results in an estimate of the number of motels, restaurants, service stations, and non-highway-oriented establishments expected to locate at each proposed interchange. It should be noted that the estimates obtained from this procedure may not be exact for a specific interchange being considered. However, on the average an interchange of the type being analyzed could be expected to attract the amount of develop-

Figure 5. Relationship between interchange development and community factor.

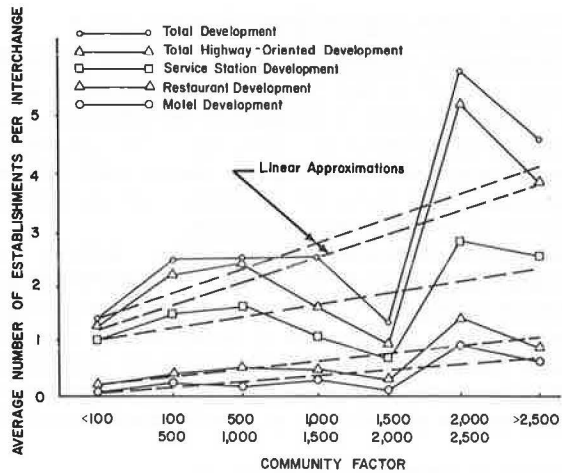


Figure 6. Relationship between interchange development and distance to nearest major urban center.

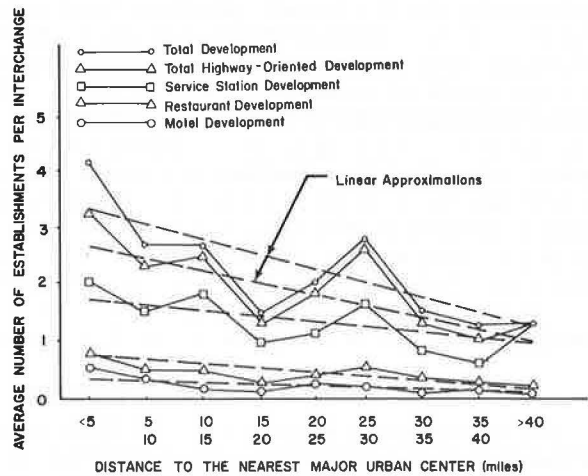
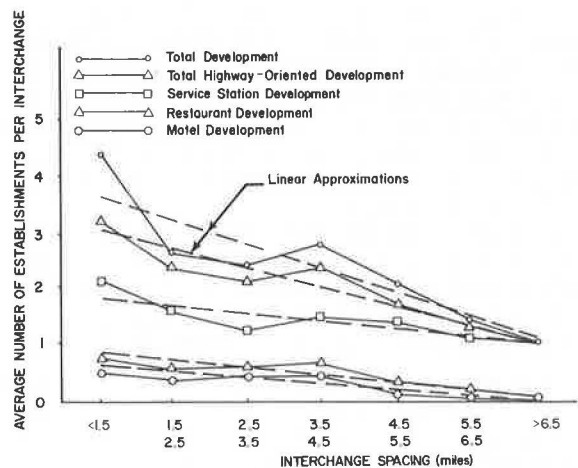


Figure 7. Relationship between interchange development and average distance to adjacent interchanges.



ment indicated by the estimate. The rough estimates of interchange development can be used in planning traffic control, traffic operations, and land use at proposed interchanges. The estimate of the expected development will vary slightly depending on whether actual or linear relationships between the amount of development and the five interchange characteristics are used. Also, the amount of variation between estimates obtained by the use of the two different relationships is higher for some types of businesses than for others.

It should also be emphasized that the relationships between the amount of development and the interchange characteristics are directly applicable only for conditions in South Carolina. For estimating interchange development in other states, the relationships should be derived from data collected in that particular state. However, it is believed that the linear relationships shown by the dotted lines in Figures 3, 4, 5, 6, and 7 are reasonably accurate for other states where the population distribution and economic characteristics are similar to those in South Carolina.

Statistical Analysis of Interchange Development Data

In an attempt to investigate in more detail the relationship between the amount of interchange development and the characteristics of the interchange, we conducted a limited statistical analysis of the data. The statistical analysis consisted of using multiple regression techniques to relate the amount of development at interchanges to a series of variables related to the traffic, demographic, and locational characteristics of the interchange. A primary aim of the statistical analysis was to improve the predictability of the amount of development at a proposed interchange.

A computer program known as the statistical analysis system (SAS), developed at North Carolina State University at Raleigh, was used in the statistical analysis. SAS is a multipurpose, versatile system that is applicable to many statistical data analysis problems. However, the version of the SAS program used in this study did not provide a stepwise regression capability to improve the derived predictive equations. The program was used to fit the input data to a model having specific dependent and independent variables. The system was used in this study in an attempt to develop multiple regression equations that would predict the average number of units of each type of economic development at a proposed interchange.

A regression equation was developed for each of the three highway-oriented types of businesses: service stations, restaurants, and motels. No attempt was made to develop an equation for non-highway-oriented businesses because of the poor results obtained by Twark (10). A fourth multiple regression equation was designed to predict the total number of development units expected at an interchange. Summing of the expected highway-oriented development units and subtracting the result from the expected total development would yield an estimate of the non-highway-oriented development at the interchange.

Initially, eight variables were used in the multiple regression equations generated by the SAS program: ADT on the Interstate highway, ADT on the intersecting highway, distance to nearest major urban center, interchange type classified as complete or incomplete (restricted), community factor, average distance to adjacent interchanges, amount of time the interchange has been opened to traffic, and population of nearest major urban center. After several computer trials, the variable concerning the time the interchange had been opened to traffic was eliminated from the analysis because it did not contribute to the reliability of the equations.

The traffic, locational, and demographic characteristics for each interchange were placed on a single punch card, and the data for the 131 interchanges were analyzed by the SAS subroutine on the IBM System 360/50 computer at Clemson University. Each regression equation was developed after several trials because the SAS program could not perform a stepwise multiple regression procedure. After each run of the program, the variables that were not significant at the 5 percent level were removed, and the program was rerun.

The multiple regression equation for the estimation of the total number of units of development at a proposed interchange proved to be the most reliable of the equations

that were developed. The significant variables used in the equation were ADT on the Interstate highway, interchange type, population of the nearest major urban center, and ADT on the intersecting highway. The multiple regression equation for total interchange development explained slightly more than 40 percent of the variation in the amount of development at the 131 interchanges. The coefficient of determination, R^2 , for the equation was 0.4042.

The variables used in the multiple regression equation for service station development were interchange type, ADT on the Interstate highway, population of the nearest major urban center, and ADT on the intersecting highway. The equation explained slightly more than 33 percent of the sample variation; $R^2 = 0.3319$.

The multiple regression equation for restaurant development explained only 23 percent of the sample variation with an R^2 of 0.2297. The significant variables of the equation were interchange type, population of the nearest major urban center, and ADT on the Interstate highway.

The multiple regression equation for motel development used the following significant variables: interchange type, ADT on the intersecting highway, ADT on the Interstate highway, and population of the nearest major urban center. The equation explained slightly more than 18 percent of the sample variation with an R^2 value of 0.1853.

The obvious nonlinear relationships between the independent variables and the dependent variable (Figs. 3, 4, 5, 6, and 7) caused the researchers to consider the possibilities of improving the linearity of the relationships by using several applicable transformations on the dependent and independent variables. In an attempt to improve the percentage of sample variation explained by the multiple regression equations, a square root transformation was applied to the dependent variable and a logarithmic transformation was applied to the independent variables. Neither of the transformations improved the percentage of variation explained. Logarithmic transformations on some of the independent variables resulted in even lower percentages. With these results, further attempts to describe the nonlinear characteristics of the relationships were abandoned.

The original purpose of the statistical analysis was to provide reliable multiple regression equations that could be used to predict the amount and type of economic development attracted to an interchange based on the traffic, locational, and demographic characteristics of the interchange. Because of the low percentages of sample variation explained by the multiple regression equations, it was concluded that the equations were not particularly useful for predicting interchange development. The relationships between the amount of interchange development and the characteristics of the interchange that were shown in Figures 3, 4, 5, 6, and 7 appear to be more useful for estimating the number of units of each type of business attracted to the proposed interchange. The relationships shown in the figures are particularly advantageous because they provide a visual representation of the variation in the amount of development as a function of the interchange characteristics. Until suitable multiple regression equations are developed to predict the interchange development, the procedure outlined previously is recommended. It was difficult to overcome the variability of the interchange development patterns by using multiple regression techniques.

The collection of the data needed to relate the amount of development to interchange characteristics is a time-consuming process. For the analysis of a single proposed interchange or even several proposed interchanges, the time required to gather sufficient information to develop the relationships could not be justified. However, most of the information must be gathered only once, and an organization that is confronted frequently with proposed access problems would profit greatly by investing the time necessary to gather information concerning interchange development patterns on sections of controlled-access highways. Periodic updating of the basic data would be required to ensure that current data are used in the analysis of proposed interchanges. The periodic updating of the data should not present a significant problem, however.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In the past, highway planners have had to rely primarily on intuition in planning for economic development around interchanges. Too often the development has been

severely underestimated and the interchange has reached its design capacity far before the design year. Perhaps some of the serious traffic operation problems that have developed at existing interchanges are an indication that little or no serious consideration was given to potential interchange development in the highway planning and design stages.

Several mathematical models have been developed that can be used to predict interchange development, but each model has presented major problems to those planners who attempted to use them. The initial models that were developed used variables that were easy to evaluate for each interchange, but the variables selected were not sufficiently descriptive to predict the amount of development at the interchange accurately. The later models predicted the amount of development satisfactorily, but several of the variables in the models were very difficult to evaluate for each separate interchange.

The primary intent of the present study, therefore, was to develop an approach that used variables that were not difficult to evaluate for each particular interchange and also provided an accurate estimate of the levels of economic development that could be expected at the interchange. Of primary importance was the requirement that the variables used in the approach be readily measurable for each interchange.

Five interchange characteristics were found to affect the amount of development found at an interchange: ADT on the Interstate highway, ADT on the intersecting highway, location and population of the communities within 10 miles of the interchange, distance to the nearest major urban area, and average distance to adjacent interchanges in either direction along the Interstate highway.

Each of these variables was examined in relation to the amount of economic development found at the 131 interchanges along the South Carolina Interstate Highway System. Because little development was found at interchanges that did not provide complete access to the motorist or did not allow the motorist to return to the highway in the direction desired, only those interchanges previously designated as complete and unrestricted would be expected to attract any appreciable amount of economic development. No analysis was made to determine the relative attractiveness of the various types of complete and unrestricted interchanges, however. An estimate of the level of development expected at a given interchange can be determined from the relationships between interchange development and the five interchange characteristics shown in Figures 3, 4, 5, 6, and 7. The major contribution of this study is considered to be the documentation of the relationship between the amount of interchange development and the interchange characteristics determined from an analysis of the Interstate System in South Carolina.

Multiple regression techniques were used in an attempt to predict the anticipated development at proposed interchanges by using the variables listed and the population of the nearest major urban center. However, low correlations were obtained between the various interchange characteristics and the amount and composition of commercial development located at the interchange. Therefore, it was concluded that the relationships between the five interchange characteristics and the amount of development at an interchange were more pertinent and useful than the multiple regression prediction equations.

The relationships shown in Figures 3, 4, 5, 6, and 7 cannot be used to predict the exact number of establishments that will locate at a proposed interchange. However, for a series of interchanges, the average business development predicted for the interchanges would reasonably approximate the actual development. Thus, the development predicted for a particular interchange from the relationships shown in Figures 3, 4, 5, 6, and 7 can be used as a reasonable estimate of the development that is likely to occur and can be used as a guide in traffic and land use planning at the interchange.

In the past, interchange planning has been conducted rather haphazardly and often with disastrous results. The data on interchange development presented herein can be used to provide both highway and land use planners with a reasonable estimate of the amount and type of commercial development expected to locate at a proposed interchange. With this information, planners can provide for the proper development of the interchange by designing the geometric configuration and traffic control provisions of the interchange and the location of the various commercial development units within the interchange area with the primary intent of minimizing the effect on the traffic flows through the interchange area.

The data on interchange development analyzed in this study have several important practical applications. First, the model can be used in the planning and design of the interchanges anticipated along the remainder of the Interstate Highway System to be constructed in South Carolina. Because more than 70 percent of the South Carolina Interstate Highway System is open to traffic at this time, this application is rather limited, however.

Second, the data can be used to estimate anticipated development at interchanges along non-Interstate highways that are being upgraded to Interstate highway standards. Because many states are attempting to develop a system of primary highways to provide safe and efficient travel by upgrading existing highways and constructing new primary highways, the data can be very helpful in the interchange planning and design considerations involved in this process.

Third, the data can be used in planning for interchanges that have already been constructed and are not yet fully developed. As nearby towns and cities grow and as traffic on the intersecting highways increases, new development can be anticipated at the best available locations within the interchange area. The new development can be predicted and the interchange area can be properly planned by using the data on interchange development characteristics.

A fourth application of the data would be as a part of a comprehensive economic feasibility analysis of a proposed interchange. The total costs associated with providing the interchange, including construction and accident costs, can be compared to the benefits received from the interchange, such as savings in travel time and income from commercial development at the interchange, to determine the economic feasibility of the interchange.

An important consideration in applying the data to different geographic areas should be emphasized. The data were obtained from the existing interchanges on Interstate highways in the state of South Carolina. The applicability of the data would necessarily then be limited to South Carolina or other states that have similar demographic and economic characteristics. These data are believed to be representative of conditions existing in the southeastern United States. However, to ensure reliable data, a state would be required to develop interchange development data that reflect the economic, demographic, and traffic characteristics of that particular state.

There are several aspects of the interchange development problem in which further research would minimize or alleviate some of the problems encountered during the course of this study. These recommendations are concerned primarily with the development of additional data that could be incorporated into mathematical models for use in predicting the amount of economic development that will be attracted to a proposed interchange.

The initial recommendation concerns the development of several additional measurable variables that reflect the effects of the communities surrounding a proposed interchange. These variables should represent such community growth trends as changes in population, per capita income, and average real estate values. These additional variables would then be combined with the traffic and locational variables and used as basic input data in developing suitable multiple regression equations. Such growth-descriptive variables are very difficult to quantify, and gathering such information for the large number of interchanges that would have to be examined to provide statistically reliable data could prove to be a difficult and expensive task.

Another recommendation for future research would be refinement of the multiple regression equations for predicting interchange development. The multiple regression equations based on the traffic and locational data of existing interchanges are static in nature. The mathematical models only predict the final total amount and the general types of development that might locate at a particular interchange site. As the Interstate System nears completion, comprehensive data can be gathered on the dynamic development patterns of the various types of business establishments. The necessary information must be gathered over a significant period of time after the entire system has been opened to traffic with the intention of developing dynamic mathematical models that would predict not only the amount of development that would occur but also the sequence in which these establishments would locate at the interchanges. Aerial photo-

graphs taken annually of completed sections of Interstate highway in several states such as the program in Alabama (1) would provide the information necessary to derive multiple regression equations that describe the dynamic nature of interchange economic development. The data on the typical sequence in which interchange development occurs would also form a basis for classifying the degree of maturity of the development pattern at existing interchanges. This information could be very useful in traffic and land use planning for existing interchanges.

Another recommendation relates to a logical substitute for one of the variables used in the analysis presented in this report. The substitution of travel time for distance (mileage) to the communities or major urban centers would more reasonably reflect the alignment, pavement conditions, and traffic congestion on the existing highway. Trip distribution and assignment research in urban areas has shown conclusively that travel time is a more sensitive variable than travel distance in measuring the effects of spatial separation on the characteristics of travel. The use of travel times would necessitate a slightly more extensive data gathering procedure inasmuch as the major routes to the communities surrounding each proposed interchange would have to be traveled to obtain a reasonable estimate of the average travel time. Alternatively, realistic estimates of average travel speeds could be used to compute the travel times. The travel time in minutes could then be used in place of the distance factor to determine the effect of each surrounding community and the nearest urban center on interchange development.

Another suggestion for future research is collecting information on the development patterns of the various types of business establishments located at interchanges on controlled-access highways in other states. Relationships between the amount of development and the various interchange characteristics similar to the relationships developed in this investigation for South Carolina can be developed in other states. If data on the relationship between interchange development and interchange characteristics were available for several states, a comparison of the relationships between states that have either similar or different economic, geographic, and demographic characteristics could be made. An evaluation of the differences in interchange development patterns between states might also lead to a more complete understanding of the nature of interchange development. Data on the nature of the variation in interchange development patterns with economic, geographic, and demographic conditions would provide a basis for making decisions on the applicability of data collected in one state to analysis of interchange development in other states. Combining interchange development data from several states would also provide a larger data base for developing multiple regression equations relating the amount of development at an interchange to interchange characteristics.

REFERENCES

1. Photographic Comparison of Land Use Areas Adjacent to Interchange Limits of the Interstate System. Alabama Highway Department, HRP Repts. 8, 18, 23, 30, 36, 46, and 52, 1964-1970.
2. Ashley, R. H., and Berard, W. F. Interchange Development Along 180 Miles of I-94. Highway Research Record 96, 1965, pp. 46-58.
3. Babcock, W. F., and Khasnabis, S. Land Use Changes and Traffic Generation on Controlled Access Highways in North Carolina. North Carolina State University, Highway Research Program, Project ERSD-110-70-4, 1971.
4. Ball, C., and Teitz, M. Expressways and Industrial Location. Traffic Quarterly, Vol. 12, No. 4, 1958, pp. 589-601.
5. Bone, A. J., and Wohl, M. Massachusetts Route 128 Impact Study. HRB Bull. 227, 1959, pp. 21-49.
6. Epps, J. W. Economic Consideration for the Provision of Access to Rural Access-Controlled Highways. Department of Civil Engineering, Clemson University, PhD dissertation, 1971.
7. Fowler, R. D., Sanders, J., and Stocks, A. H. A Pilot Study of Highway-Oriented Business Development at Nonurban Interstate Interchange Areas. Center for Appalachian Studies and Development, West Virginia University, 1965.

8. Sauerlender, O. H., Donaldson, R. B., Jr., and Twark, R. D. Factors That Influence Economic Development at Nonurban Interchange Locations. Institute for Research on Land and Water Resources, Pennsylvania State University, Highway Impact Research Program, Research Rept. 9, 1966.
 9. Stein, M. M. Highway Interchange Area Development—Some Recent Findings. Public Roads, Vol. 35, No. 11, 1969, pp. 241-250.
 10. Twark, R. D. Model for Economic Development at Rural Interchanges on Pennsylvania Interstate Highways. Department of Business Logistics, Pennsylvania State University, PhD dissertation, 1967.
-