

Traffic Interactance Between Cities

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The majority of research work in traffic-demand evaluation and projection in the United States naturally and properly has been based on a given large city or a single metropolitan complex. The unique feature of the study covered by this paper is that it evaluates the traffic "interactance" or exchange between five independent cities and towns, remote from each other, but in the same vicinity.

A group of independent cities in the central Piedmont section of North Carolina are expanding and growing toward each other, tending to form a metropolitan complex. Their mutual economic and sociological affinity is great and is increasing. These cities are Greensboro, Winston-Salem, High Point, Thomasville and Lexington, varying in population from 125,000 down to 16,500 (est. 1958). Their nature is primarily industrial and distribution. Combined, they seem to be forming a new interrelated but multi-centered community.

In cooperation with the Urban Studies Program (Institute of Research, University of North Carolina), an area origin-destination study was made to reveal the traffic "interactance" between these cities. A reliable expression of the gravity model was developed involving only population and distance, and this formula was applied to all city pairs in the state for long-range traffic estimation purposes. Coordinate studies by the USP include other aspects, including land use, urban development, economic, governmental, and sociological trends and relationships.

● THE traffic study was accomplished by means of a special type of origin-destination traffic survey and analysis. Some 35 roadside interview stations were selected to intercept all movements into, out of, and between the five cities (at the 35 stations). Station locations were purposely chosen at expected "traffic valley" points between the centers, to avoid the mass of short "commuter" trips, these not being of interest in the stated purpose of the study. A total of 118,603 roadside interviews were made, this being a 98 percent sample.

Special techniques were required in the analysis to avoid duplication of trip data brought about by interviews of equivalent trips at different points on different interview dates. These exhaustive and intricate adjustments removed the equivalent of about one-third of the total trips, and reduced the adjusted net trip summary to 98,277 total daily trips.

Although the five cities varied widely in size, with populations of 16,500 up to 125,000, there was a very close relationship in their traffic interchange in proportion to combined population and in inverse relation to distance. This fact is developed more fully in subsequent discussions.

Perhaps the major result of the traffic study was the development of an expression of the "gravity" formula indicating the values for traffic interaction between city pairs in terms of population and distance. The report on the Origin-Destination Traffic

Survey at Five-City Crescent Area (N. C. State Highway Commission and U. S. Bureau of Public Roads, November 1959) discussed both the strength and the weakness of such a formula approach.

After much trial and mathematical exploration, Eq. 1 was derived as the best expression to fit the basic data, this being a quadratic type of equation:

$$T = 0.04m^2 + 4.9m + 160 \quad (1)$$

in which

T = number of 24-hr (September-October 1958) weekday trips starting in City A and ending in City B, plus vice-versa; excluding any partial or through trips; and

m = square root of the product of the population of City A and City B, divided by the square of the travel distance between chosen centroids in Cities A and B. To clarify:

$$m = \frac{\sqrt{\text{pop. A} \times \text{pop. B}}}{(\text{distance A to B})^2} \quad (2)$$

Eq. 2 has been developed and used for many years and is commonly referred to as an expression of the "gravity model." It was discussed and used by Willa Mylroie in HRB Bulletin 119, and in "Highway Traffic Estimation," by Schmidt and Campbell, published by the Eno Foundation for Traffic Control, 1956. For a given situation, the value "m" in Eq. 2 becomes a constant for "T" in Eq. 1.

Eq. 1 represents a quadratic adaptation of this relationship to more nearly fit the refined intercity data from the Five-City Crescent Origin-Destination Traffic Survey. It is likely that other adaptations might fit other conditions in other localities equally well.

Having been derived as the relationship giving the best "fit" to the O-D data for the optimum number of city pairs, Eq. 1 was applied first to these pairs, with results given in Table 1.

TABLE 1

City Pairs	No. Trips		Difference
	O-D Data	Formula	
Greensboro - Winston-Salem	3,037	2,825	-212
Greensboro - High Point	5,257	5,317	60
Greensboro - Thomasville	659	710	51
Greensboro - Lexington	401	390	-11
Winston-Salem - High Point	2,040	2,375	335
Winston-Salem - Thomasville	751	998	247
Winston-Salem - Lexington	1,293	1,142	-151
High Point - Thomasville	6,138	6,676	538
High Point - Lexington	830	912	82
Thomasville - Lexington	1,316	1,253	-63
Totals	21,722	22,598	
Totals of differences, arithmetic	1,750		
Gross arithmetic differences	8.1%		
Total of differences, algebraic	876		
Gross algebraic difference	4.0%		
Average of individual percentage errors	10.2%		

It will be observed that one of the largest percentage differences is for the Winston-Salem - High Point combination, with 335 fewer actual O-D trips than the formula would indicate. These cities are in different counties. High Point's "tradi-

tional" affiliation has been with Greensboro, its county seat and main line neighbor, rather than Winston-Salem which is farther away, and largely self-contained. Winston-Salem's major working force is in the manufacturing of cigarettes and other tobacco products for world-wide distribution. High Point's major industry is the manufacture of furniture. It may be that the difference in skills and material serves to further depress the traffic interaction which would otherwise be expected. This theory is supported also in the Winston-Salem - Thomasville pair. Similar reasoning might be applied to other variations.

It was found that the quadratic form of expression was advisable, as contrasted with the linear, to damp or minimize the effect of these variations.

FURTHER TESTS OF FORMULA

Following this test of the formula, and desiring further verification, Eq. 1 was applied to data on trips between the five cities and more remote counties outside the five-city area. These included comparisons with trip data having termini in Wake, Alamance, Durham, Rowan, Mecklenburg, and Iredell Counties. Each of these counties contains a sizable city near its center, with the city dominating the traffic pattern for the whole county, and representing an acceptable centroid for the purpose of population and distance determination. It was found that the formula provided equally satisfactory results when compared with trips having one terminus in the five cities and the other terminus in these counties as listed above. This further verified the value of the formula as a tool for prediction of traffic interaction.

The formula was put to still a third test. Data obtained from the 1959 Concord, N. C., Origin and Destination Traffic Study, involving trips between many North Carolina cities and counties were compared with the interaction indicated by the formula. In cases where there were as many as about 175 trips between places, the formula provided values with differences of less than 20 percent as compared to origin-destination values. The accuracy was best where the distances between points being compared were less than about 50 miles. With distances of over 100 miles, the formula could not be compared, due to the small number of long trips. Population data for 1959 was of necessity estimated, but seems to be reliable, based on 1960 census data since obtained.

In general, the tests on the formula showed that the level of confidence in its use is better than 80 percent for any pair of cities in North Carolina which are reasonably near each other, under normal seasonal conditions. This relationship may hold in other states.

There is some indication that the existence of a sizable third town C, between two major towns A and B, may decrease the amount of interaction between A and B below the value which would be indicated by the formula.

Limits

It should again be emphasized that the formula is not intended to develop total traffic to be counted or expected at any point, unless it is applied in increments to all overlapping pairs of trip loci which may be involved.

Adaptation of Formula

The significance of the survey lies mainly in the possible use of the formula in trip prediction for long-range planning for highway expressway and arterial street design. If land-use predictions may be made in terms of future residences, work sites, shopping centers, etc., even in rural areas involving clusters of independent cities and towns, the formula or some form of it, could be used with reasonable confidence in forecasting the traffic interaction demand between such areas and between cells within these areas.

Such an adaptation has been made for statewide long-range highway planning in North Carolina. Using a digital computer to handle the enormous bulk of the arithmetic involved in applying the formula, together with manual adjustments and adaptations of the formula values for every pair of places in and near the state, traffic

volume projections to 1980 were obtained on every corridor-segment of the entire state highway system.

Using this and other data, internal state systems have been developed in terms of relative importance as a guide in the establishment of design standards and construction programming for the next 15 years. A complete statewide needs study to the year 1975, based on these data, has recently been published and adopted by the North Carolina State Highway Commission.

Other corollary reports, including much of the traffic data developed in this study, are to be published by the Urban Studies Program relating to land use, and to economic and sociological interaction in a metropolitan complex believed now in process of formation.