Transportation and Land Use Connection Study

DRAFT

Phase 1 Report

FY 2007

Roanoke
Valley Area
Metropolitan
Planning
Organization

Executive Summary

In response to recent policy developments, the RVAMPO pursued a study of the connection between land use/development and transportation. The Unified Planning Work Program called for a project that would examine the historic relationship between land use and transportation in the Roanoke Valley and in surrounding rural areas.

Because of the growth along the US 221 corridor in southwest Roanoke County, that corridor was chosen to be examined in more detail. Staff examined development occurring after 1980 within the corridor. The Institute of Transportation Engineers (ITE) *Trip Generation* manual was utilized to estimate the transportation impact of new development. The ITE manual estimates were compared to actual observed traffic counts recorded over the same period.

Estimates obtained through utilizing the ITE manual were significantly higher than traffic increases observed on arterials across the study area. Possible explanations for the discrepancy were explored including the 'double-counting' of trips internal to the study area and other possible sources of error in the methodology used to estimate additional trips using the ITE manual.

Travel behavior data from the Federal Highway Administration was also explored to shed light on how travel behavior may influence traffic and possible ways land use might impact travel behavior.

The following recommendations are provided in the study:

- Encourage an appropriate mix of development and development of village centers to capture traffic within the same 'zone' and to avoid impacts across the larger arterial network.

- Building setback requirements, site ingress and egress, and access management concerns must always be approached with consideration for future capacity needs on transportation facilities.

- Travel behavior and long-range land use planning decisions together have a tremendous impact upon the ultimate influence of development upon transportation infrastructure in a region and should be considered in 'transportation scenario' planning.

- The Virginia Department of Transportation Annual Average Daily Traffic Count Program should be expanded, increasing the sample size of counts used in producing count estimates for facilities and thereby increasing accuracy of the AADT estimates.

Background and Introduction

A number of developments in the realm of transportation policy have called for greater attention to the link between transportation and land use. State and local policymakers have both called for a greater emphasis on looking at the impacts of development on transportation and to consider the linkages between land development and use and the impacts on transportation networks. The Roanoke Valley Area Metropolitan Planning Organization included a Transportation and Land Use Study in its Unified Planning Work Program for Fiscal Year 2007. The Rural Transportation Work Program also called for similar work in the rural portion of the Roanoke Valley – Alleghany Regional Commission Service Area.

The Transportation and Land Use Connection Study, as conceptualized in the Urban Work Program and Rural Work Program, specifies three specific analytical steps. The project description calls for, first, establishing the overall historic transportation/land use pattern by producing a number of maps and diagrams showing land use and transportation network changes over time. Secondly, the project description suggests that staff will relate the overall land use pattern to existing transportation plans produced for the region. The third step involves examining predicted trip generation rates from the Institute of Transportation Engineers *Trip Generation* manual versus traffic rates observed in real-world count exercises or annual traffic count data.

Methodology

Staff devised a three-part methodology corresponding to the three analytical elements proposed in the Unified Planning Work Program.

1. Establish the Historic Transportation/Land Use Pattern

In examining the historic pattern of transportation and land use in the Roanoke Valley region, staff utilized a Geographic Information Systems software suite to run queries on parcel layers collected from the region's local governments. These parcel layers, which contain a variety of attributes including parcel size, land use or zoning, and a number of structure characteristics for parcels where structures have been constructed. In determining historic trends, data on the year structures were built were used to map various time series. Staff also researched the approximate date of construction for the region's major arterials and highways. Maps showing development and growth over time were overlaid with a colored representation of the regional arterial network including information on when each arterial was constructed.

Staff also utilized parcel centroids in a similar exercise after stakeholder input suggested that using entire parcels clouded the analysis, especially in the more rural portions under analysis.

2. Relate the Transportation/Land Use Pattern to Existing Plans

In relating the existing land use pattern to existing transportation plans, staff utilized parcel data used in the initial step. Using fields on the land use, staff assigned each parcel to one of four general land use categories, which included Single Family Residential, Multifamily Residential, Commercial/Industrial, and Government/Institutional.

The long-range plan Constrained List of Projects was overlaid for display. As expected, the majority of projects were located along a mix of uses. The generalized land use layer developed will be maintained in subsequent years for similar planning exercises and for use in regional transportation plans.

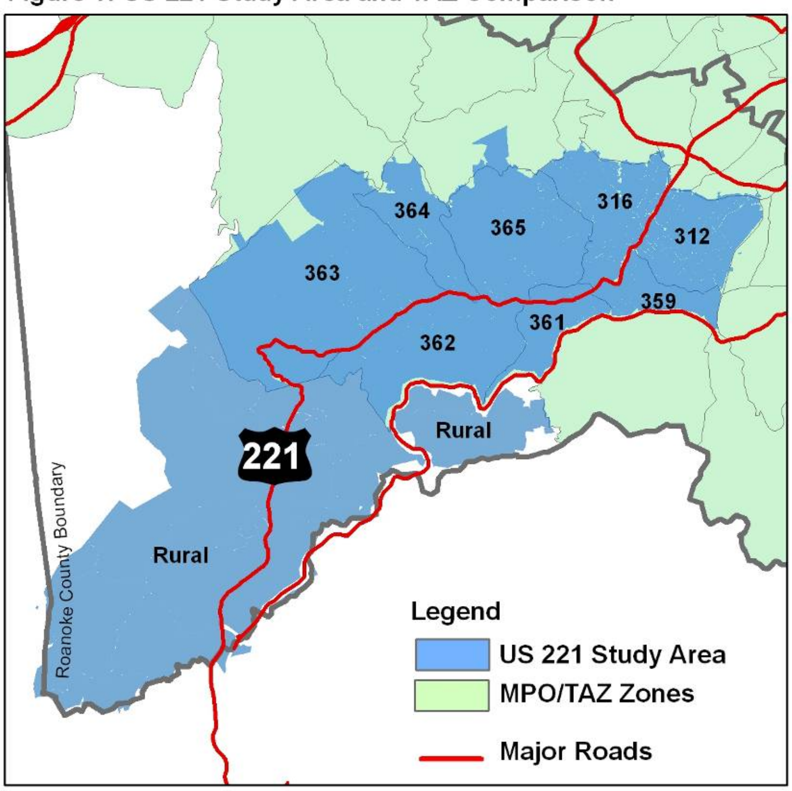
3. Evaluation of Future Impacts of Patterns

The final step of the project involved comparing traffic impact projections from the Institute of Transportation Engineers Trip Generation Manual to observed counts. It was determined that the selection of a portion of the study area was in order to facilitate the study of historic relationship between development and traffic in the Valley and to compare ITE projected trip generation to actual traffic counts collected by the Virginia Department of Transportation over time.

The Roanoke Valley Area Metropolitan Planning Organization's Transportation Technical Committee suggested staff examine the US 221 corridor and examine developmental trends for the previous 20 years, at least.

Staff started by selecting a study area, composed of parcels, following the boundaries of Traffic Analysis Zones (TAZs) used in transportation modeling and planning applications. The figure below illustrates which TAZs were selected for inclusion in the study area. The study area extends into a rural portion of Roanoke County. Parcels were selected along either side of US 221 in the rural portion for inclusion in the study area.

Figure 1: US 221 Study Area and TAZ Comparison



TAZ boundaries are based on US Census geography and did not follow parcel lines in some areas. The portion of the project study area within the MPO study area followed TAZ boundaries as closely as possible.

TAZs were used so that data produced by the transportation demand model for the region could be used to estimate the number of trips internal to the study area and other factors that might impact projected counts.

Staff queried parcels using Geographic Information Systems with structures built after 1980. These parcels were then classified according to their use. Staff utilized the estimated weekday generation rates and trip generation rates for Saturday and Sunday in determining estimated trip generation for every parcel on which a structure was built after 1980.

Residential trip generation rates were available on a per unit basis and were computed as follows:

Annual Trip Generation = (Weekday Rate * 261)+(Saturday Rate *52)+(Sunday Rate * 52)

Commercial trip generation rates were available per 1,000 square feet and were computed as follows:

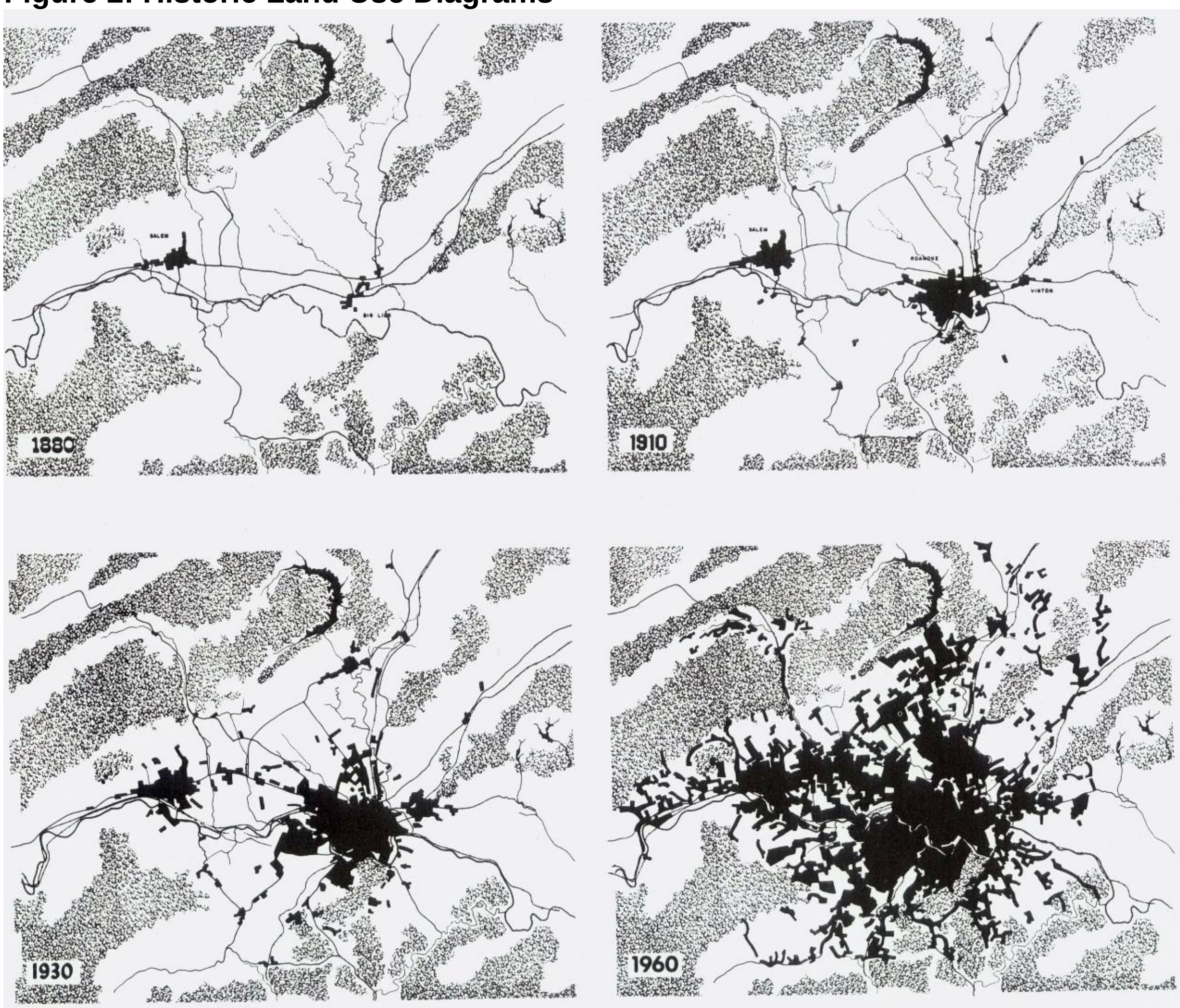
Annual Trip Generation = [(Weekday Rate*(Sq. Ft./1000))*261]+[(Saturday Rate*(Sq. Ft./1000)) *52]+[(Sunday Rate*(Sq.Ft./1000))*52]

Estimated annual trip generation was computed for parcels constructed after 1980 in this fashion. Staff then studied Average Annual Daily Traffic Count Data for arterials in the study area for comparison of the projected rate increase and the actual increase in traffic in the study area.

Historic Transportation/Land Use Development Pattern

The historic pattern of growth and development has been of perennial interest to regional planning agencies serving the region including the Roanoke Valley Regional Planning Commission (predecessor of the Roanoke Valley-Alleghany Regional Commission) and the Roanoke Valley – Alleghany Regional Commission (formerly known as the Fifth Planning District Commission). Numerous studies can be found in the planning archives discussing the historic pattern of development and attempting to predict future land use patterns. The following figures were scanned from *The Land Use Plan – 1965* produced by the Roanoke Valley Regional Planning Commission in 1969 and illustrate various developmental 'snapshots' prior to 1960.

Figure 2: Historic Land Use Diagrams



This material illustrates quite well that development prior to 1960 was concentrated heavily in the urban core of the region, although notable development was beginning to occur along certain rural corridors. It is worth noting that these diagrams suggest that, by 1960, the largest proportion of land within the Cities of Roanoke and Salem were developed.

None of the previously conducted studies and plans related to land use development discussed the historic pattern of land use development compared to major arterial improvements or construction.

Staff produced a series of historic land development maps overlaid on representations of historic arterial networks in hopes that examining historic land development in conjunction with information regarding when certain known arterial improvements were made would shed light on the impact of major transportation system changes on land development in the Roanoke Valley.

Both parcel centroids and parcel shading techniques were used to produce maps. The use of parcel centroids (or utilizing single dots to represent the central point of a land parcel) proved to yield a superior visual representation of land development. Parcels with structures constructed prior to 1965 were represented by red centroids. Those with structures built between 1965 and 1979 were represented by violet centroids, and parcels with structures built after 1980 were represented by blue centroids.

The arterial network that existed prior to 1966 was colored red. Roads constructed in 1966-67 are represented by violet lines. Arterials constructed in 1969-71 are represented by green lines, and finally the US 220 Southern Expressway, constructed in 1981, is represented by a dark blue line.

Figure 3: Historic Parcel and Arterial Development

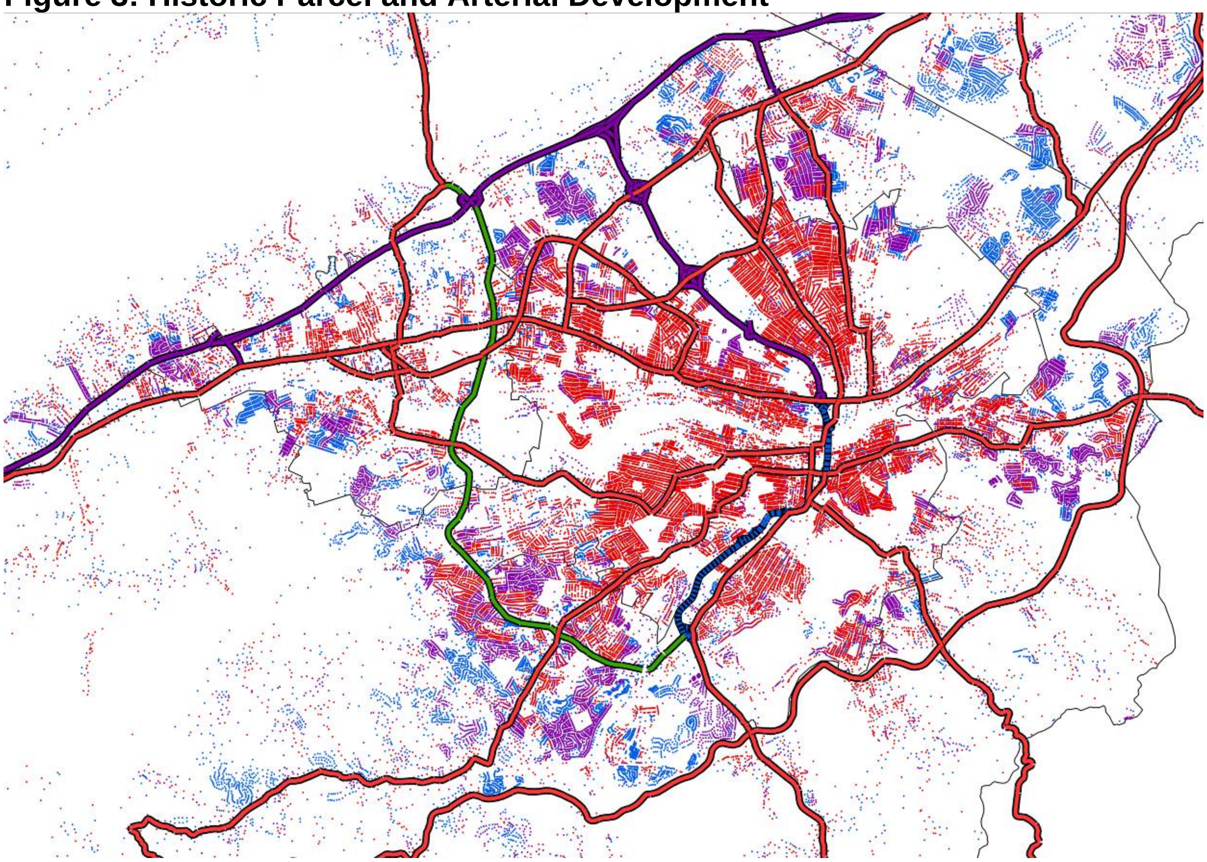


Figure 3 shows that development prior to the development of the Interstate Highway System serving the region was heavily focused in the City of Roanoke. In the mid to late 1960's and 1970's, large numbers of parcels were developed in suburban Roanoke County. The map shows that areas along the present-day SR 419 experienced a great deal of development in this period, although a significant proportion of parcels in close proximity to SR 419 were developed prior to its widening to a 4-Lane facility.

After 1980, the majority of development appears to have occurred in several suburban and rural areas in the overall study area. The Bonsack area in northeast Roanoke County along US 460, the US 221 corridor in southwest Roanoke County, and southern Botetourt County seem to have exhibited the highest levels of growth in this era.

Insufficient data exists to determine the true nature of the impact of arterial construction upon land development patterns historically. A number of other factors undoubtedly came into play including housing market trends and forces, lack of developable land in the urban core, changing land use policies and zoning in influencing development. Figure 3 serves to illustrate quite well the general relationship between arterial improvement/construction and land development.

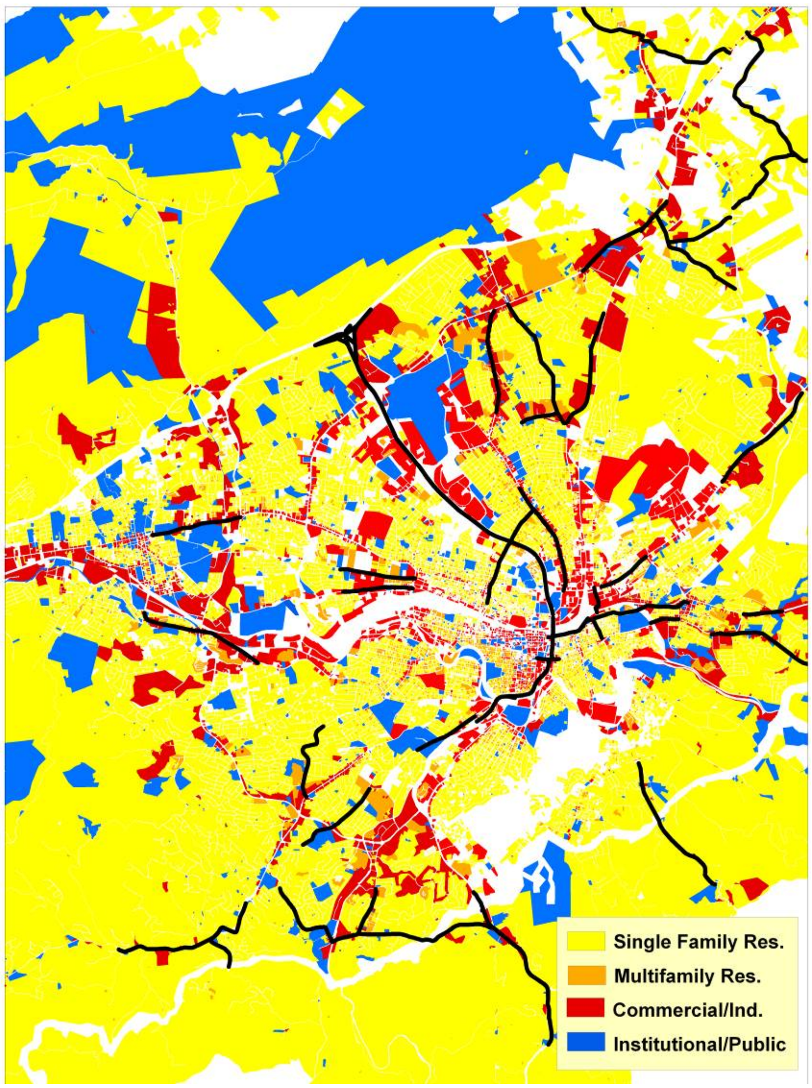
Additional representations of historic land use change including maps utilizing parcel shading methods can be found in the Appendix.

Land Use Patterns and Existing Transportation Plans

Staff took parcel data collected for the first phase and reduced the land use categories to a common, generic scheme of four general land uses including commercial/industrial, single family residential, multifamily residential and institutional/governmental uses.

Figure 4 below is the resulting regional land use map with the 2025 Constrained Long Range Transportation Plan's Constrained List overlaid.

Figure 4: Regional Land Use with 2025 CLRTP



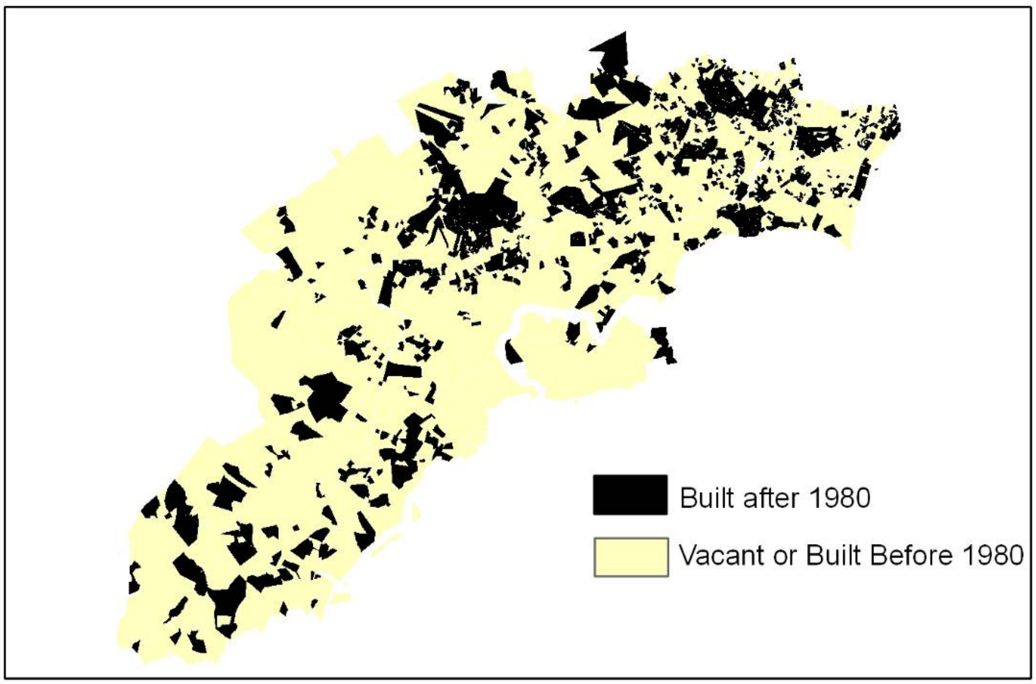
As specified in the Unified Planning Work Program, this layer will be archived for future analysis and for later phases of the land use/transportation connections study effort.

Evaluation of Future Impact of Patterns

As explained in the methodology section, staff examined in more detail historical development trends along the US 221 corridor. Specifically, the study area focuses on the US 221 corridor beginning at the intersection of US 221 and Colonial/Penn Forest Boulevard and ending at the Roanoke County Line consists of TAZs 312, 316, 359, 361, 362, 363, 364, and 365.

Staff queried all parcels with structures built after 1980 for further analysis. Figure 5 below illustrates the number of parcels involved in the analysis. Approximately 41% of the parcels in the study area were developed after 1980 (2,851 parcels of a total 6,951 parcels were developed after 1980). It is also worthwhile to note that nearly 80% of the parcels in the study area have been developed, as only 1,449 of the nearly 7,000 parcels have no structures.

Figure 5: Parcels in Study Area with Structures Built After 1980



Roanoke County parcels are classified according to a specific use model. Staff utilized the Roanoke County Use Model Codes and General Land Use Classifications within the parcel data to assign each parcel an appropriate trip generation rate. The Institute of Transportation Engineers *Trip Generation Manual, 7th Edition* was utilized in determining appropriate trip generation rates based on use.

Residential rates were calculated on a per unit basis. Trip generation rates were calculated based off weekday rates in addition to rates computed for Saturdays and Sundays. Commercial rates were calculated in a similar fashion, except the ITE manual based rates for most commercial establishments on a per 1,000 sq. ft. basis. The basis for institutional rates varied depending upon the use.

The following equations were used in calculating the annual increase in trips represented by the development in the study area:

Annual Trip Generation = (Weekday Rate * 261)+(Saturday Rate *52)+(Sunday Rate * 52)

and

Annual Trip Generation = [(Weekday Rate*(Sq. Ft./1000))*261]+[(Saturday Rate*(Sq. Ft./1000)) *52]+[(Sunday Rate*(Sq.Ft./1000))*52]

The following is a summary of the initial results:

- Single Family Residential: 2,495 units were constructed between 1980 and 2007 in the study area, representing an increase of 8,462,414.86 trips in 2007 when compared to 1980.
- Multifamily Residential: 279 units were constructed between 1980 and 2007 in the study area, representing an increase of 577,122.4 more trips in 2007 when compared to 1980.
- Commercial/Industrial/and Institutional: 77 commercial/industrial/and institutional parcels were developed between 1980 and 2007 in the study area, representing an increase of 1,304,781 trips in 2007 when compared to 1980.

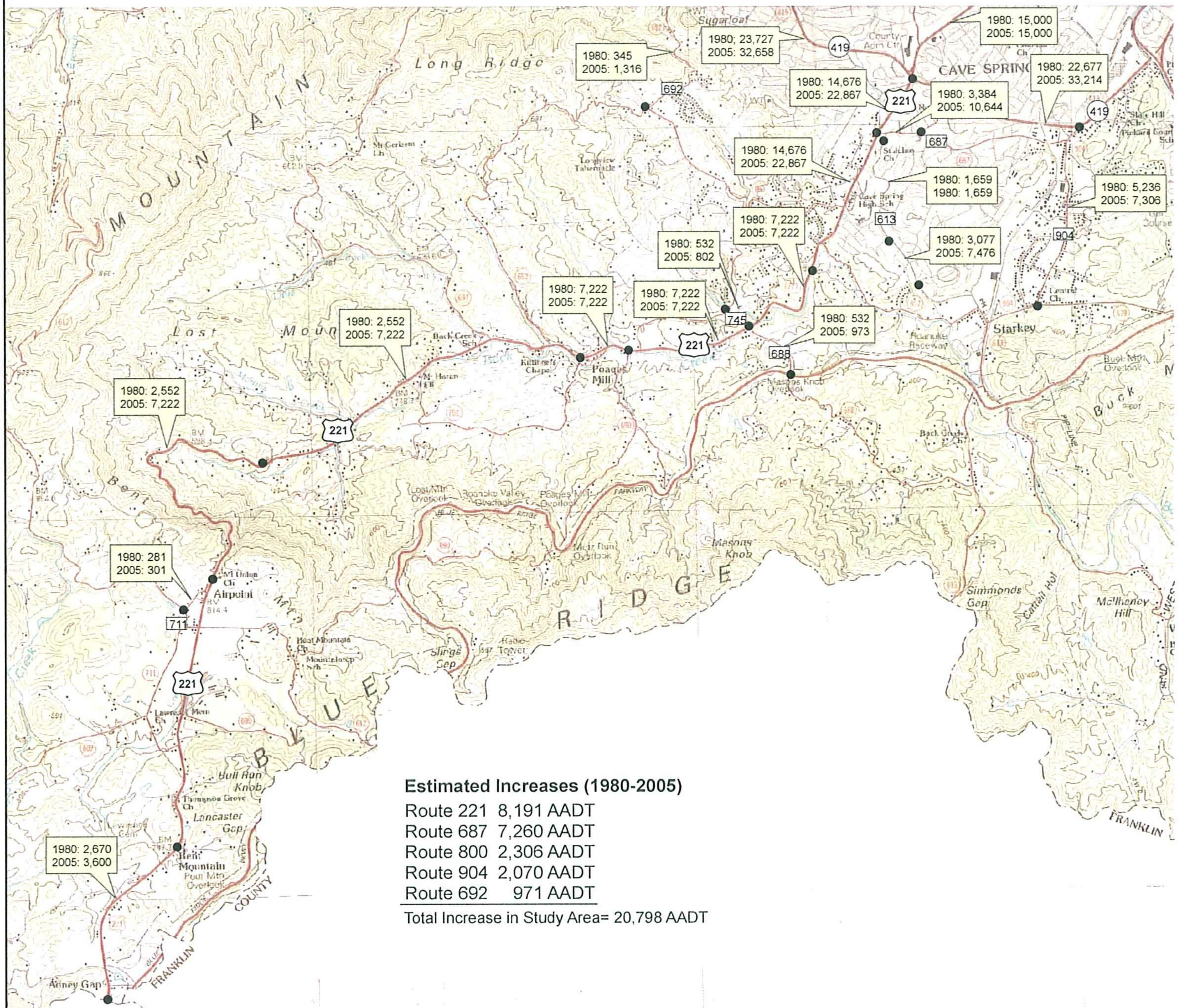
Based on these initial results according to the ITE manual, the study area should have experienced an additional 10,344,318 trips in 2007 than in 1980 (based solely on development activities and not considering behavioral changes and increasing per capita vehicle-miles traveled). This should equate roughly to an increase in Annual Average Daily Traffic of 28,340 vehicles per day on the arterial network in the immediate study area.

Observed Traffic Volumes

The following map shows historical traffic volumes for 1980 and 2005 for the study area. Based on the numbers, it is estimated that the region’s traffic increased by 20,798 vehicles per day during that period. This was calculated by totaling the traffic on the main roads that residents and customers use to leave and enter the study area (see table below map on the following page).

Staff determined that certain figures produced by the Four Step Transportation Model might assist in understanding the difference in traffic observed versus expected (as determined by utilizing the ITE manual). It was determined that determining the number of internal trips within the study area is important in determining how many trips may be underrepresented in the actual AADT counts.

Route 221 Corridor
1980-2005 Traffic Volumes



Estimated Increases (1980-2005)

Route 221	8,191 AADT
Route 687	7,260 AADT
Route 800	2,306 AADT
Route 904	2,070 AADT
Route 692	971 AADT

Total Increase in Study Area= 20,798 AADT

Four Step Transportation Model

The basic modeling process is to develop a set of mathematical equations that relate trip characteristics (productions and attractions) to socio-economic and land use parameters. The model is obtained through a process of synthesizing trip ends and assigning these trips to the existing highway network using the traditional four step transportation planning process (Trip Generation, Trip Distribution, Mode Split and Assignment).

Trip ends are predicted for differing trip types or purposes. For the trip generation process, the trip purposes for the Roanoke study fall into four categories. Three of these trip purposes begin and end within the study area. The first is home-based-work (HBW), where one trip end is at home and the other at work. The second is home-based-other (HBO), which includes trips that either begin or end at home but do not involve trip ends to or from work. These trips include shopping, recreational, school, etc. The third trip purpose is non-home-based (NHB), where neither trip end is at home. The fourth purpose has one trip end inside the study area and the other outside the study area. These are called internal-external trips (IX). The next step in the model development is the trip distribution process. This is where the production and attraction end of each trip is linked. This results in a zone-to-zone table or matrix of the number of trips for each purpose. The matrices are added together with the X-X trip table for input into the assignment module.

The final step in the modeling process is traffic assignment where each synthesized zone-to-zone trip is assigned to the roadway network using the shortest path, in travel time, between two zones. The synthesized trips are then compared for accuracy to the observed counts as they occur on the roadway network. Parameters in the computer model are then adjusted until the assigned volumes most closely match the observed traffic counts. Future travel can then be predicted based on trips generated from forecasts of the existing land use and socio-economic data. The future trips are then assigned to the existing highway network (plus any committed improvements) to identify any network deficiencies. Alternative networks can be developed and tested to resolve any such deficiencies. This process results in a list of recommended transportation projects that will meet the future travel demands of the area.

As with trip generation and distribution, the assignment output for the region should be checked for reasonableness, ensuring that observed conditions are closely replicated by the assignment output. The validation tests for highway assignment are presented at three levels: 1) system-wide, 2) corridor, and 3) link specific. This study was not an attempt to validate the four step model.

It should be noted that, by 2025, the travel demand model projects that a similar increase could take place on the road network serving the study area. By that time, several segments of Route 221 and Colonial Avenue will have difficulty handling the traffic load.

Four Step Model and Route 221 Study Area

Table 1 lists the model traffic analysis zones included in the study area. Please note that these zone numbers (used by the Four-Step Transportation Model) are different than the numbers used by the US Census Bureau.

Table 1: Model TAZ Identifiers

Model Traffic Analysis Zones	
147	198
151	199
194	200
196	(external) 237
197	

Table 2 displays the attractions and generators for the above the study area. These are estimated to be a total of home based work, home based other, and non-home based trips. Trips in the table are defined as one leg of a journey (i.e. from home to the store). As expected through the model design, internal generators and attractions within the study area are equal (4,336). Because of a higher proportion of residential land use, the generators from the study area are higher than the attractions to the study area. By using data in the trip distribution matrix, it could be estimated that about 15% of trips are internal to the study area.

Table 2: Study Area Generators and Attractions

Study Area Generators and Attractions
19,229 attractions to the study area
40,124 generators from the study area
59,353 trips in and out of study area
4,336 attractions from study area to study area
4,336 generators from study area to study area
8,672 (14.6%) of total trips are internal

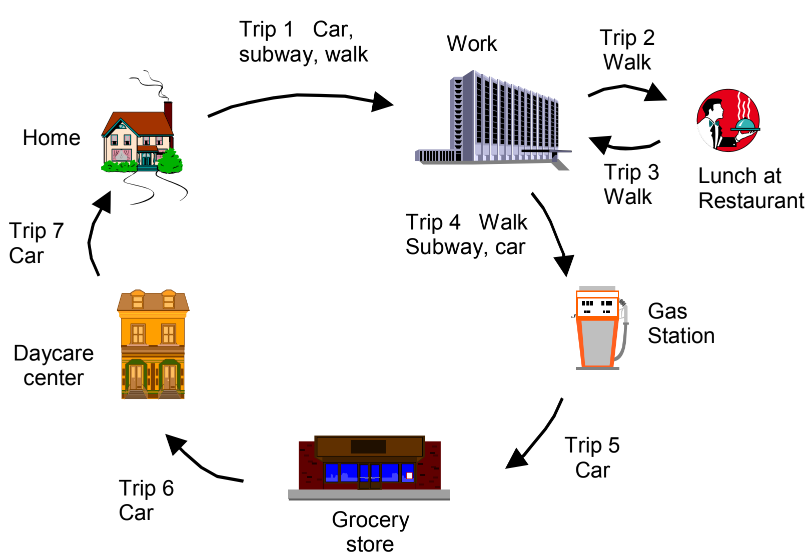
Analysis of Observed Traffic Volumes and Model Trip Matrix

Using observed traffic volumes, it is estimated that traffic increased in the region by 20,798 vehicles between 1980 and 2005. Furthermore, it is estimated that 8,672 trips are internal to the study area. The internal trip number seems reasonable in that traffic on Route 419 only increased by 11,000 vehicles between 1980 and 2005. It is assumed that most of the traffic in the study area would utilize Route 419 or US221 north of 419, to leave and enter the region. Stated another way, of the 20,798 vehicles "generated" by the study area, only about 11,000 have a destination or origin outside the area.

In seeking possible explanations for the discrepancy in the estimated versus actual increase in traffic, staff performed research into general travel behavior nationally to aid in formulating possible explanations.

Figure 6 is a basic diagram of a potential daily travel scenario for an average American. This diagram aids in the understanding of the sheer number of 'trips' made by Americans every day. Only a small proportion of the trips are directly related to going between work and home.

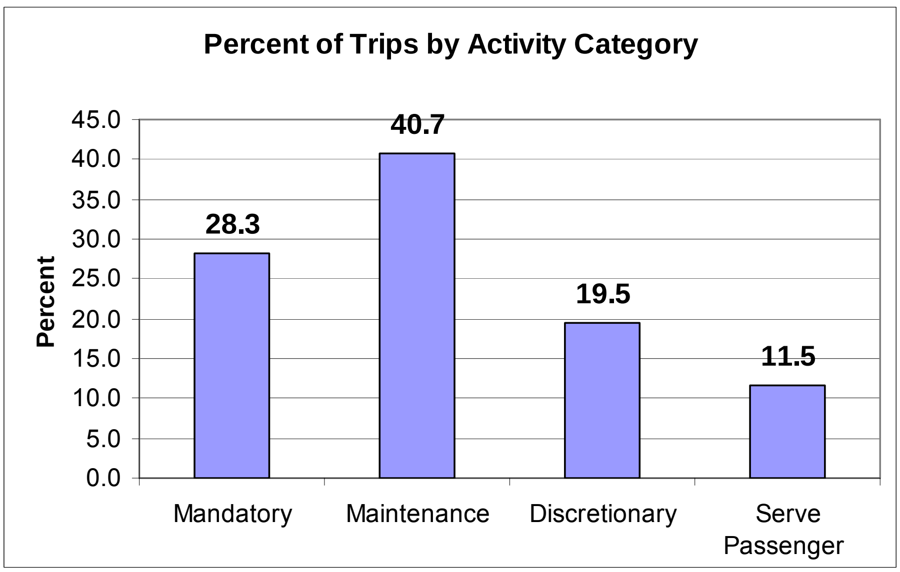
Figure 6: Daily Travel Scenario



Types of Trips

The National Household Travel Survey, conducted by the Federal Highway Administration (FHWA), captures household travel characteristics. The following chart divides travel into three groups: mandatory trips like going to work, maintenance trips like buying groceries, and discretionary trips such as going to a movie or a Sunday drive. Peak traffic often relates to mandatory work trips, thus transportation planning often focuses on commuters and home based work travel. However, it is important to note that almost 41% of trips are for maintenance activities. To carry the line of thinking further, about 75% of trips are not related to workplace commuting. FHWA found that non-workers typically spend as much time traveling as did workers. Between 1995 and 2001, people reporting spending more time in discretionary travel.

Figure 7: Trips by Activity

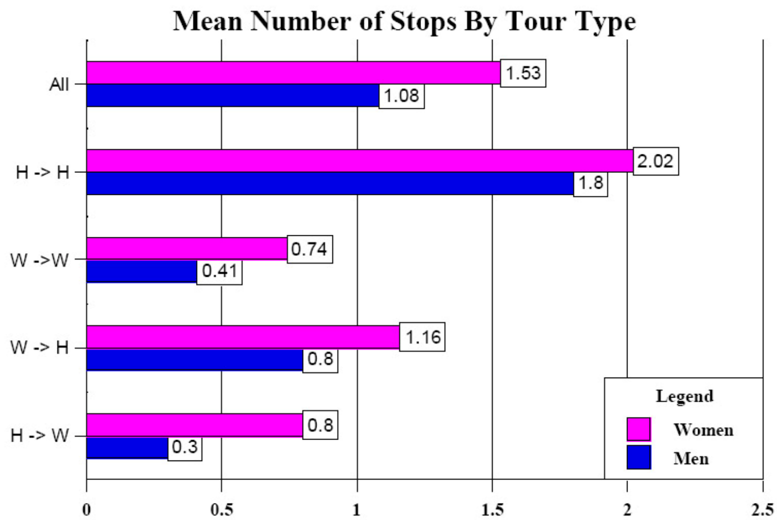


Source: FHWA, 2001.

Stops by Trip Type

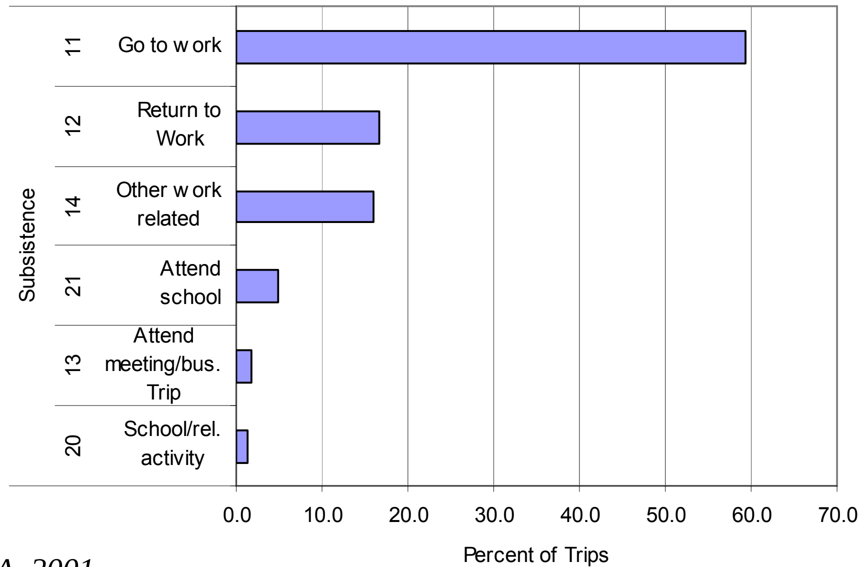
Figure 8 below shows that more trip-chaining occurs with groups of trips starting at the home and ending at the home.

Figure 8: Stops by Trip Type



Source: FHWA, 2001.

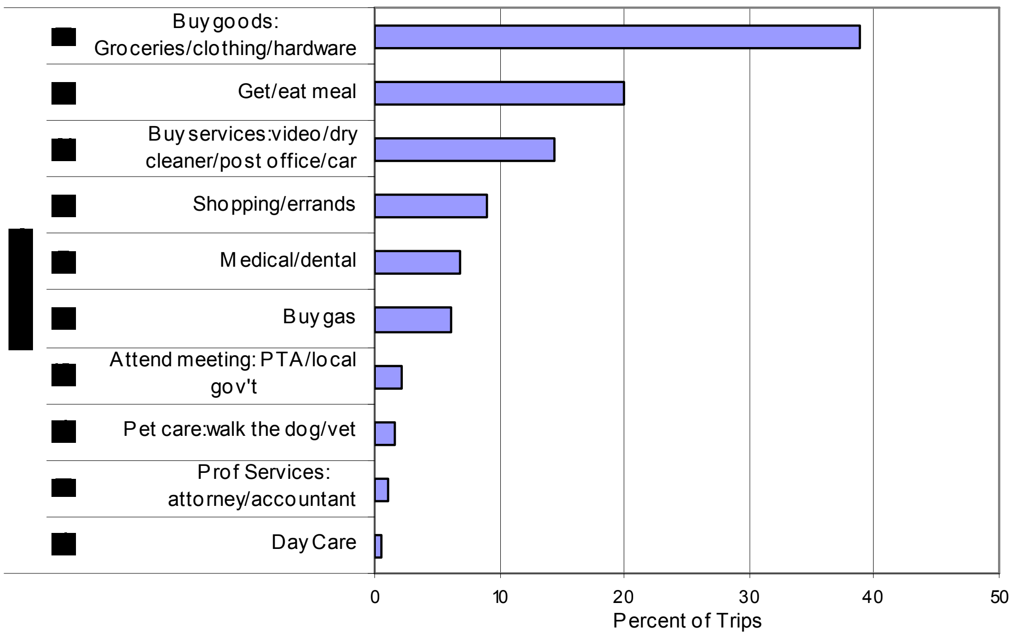
Percent of Trips as Mandatory Activity



Source: FHWA, 2001.

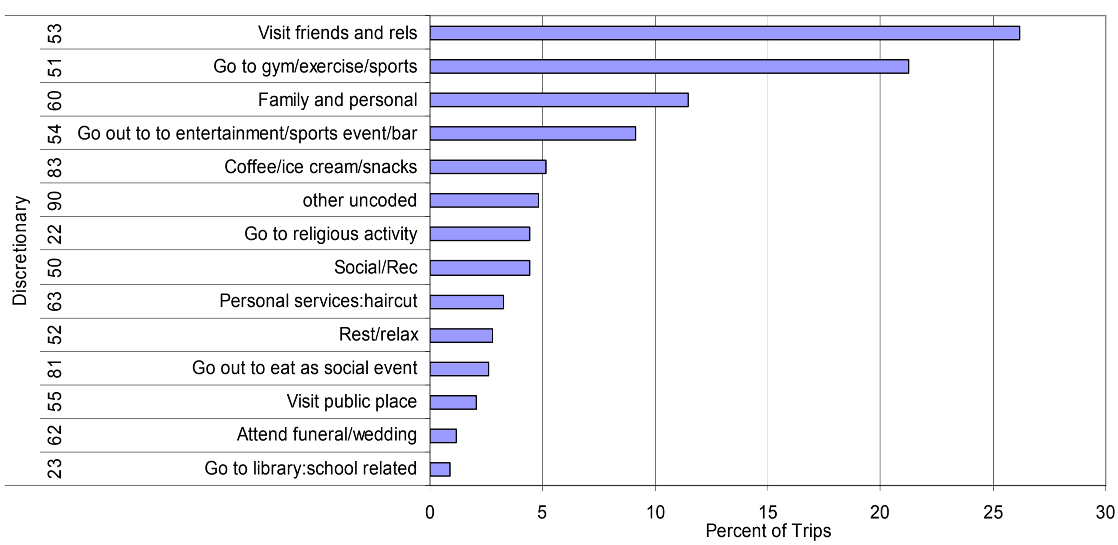
About 91% of mandatory trips (25% of all trips) are work related. Of the maintenance related activities, 39% are related to buying goods such as groceries. About 20% of maintenance trips are people getting a meal or eating at a restaurant. Finally, the largest group of discretionary trips is people visiting friends or relatives, which account for 26% of discretionary trips

Percent of Trips as Maintenance Activity



Source: FHWA, 2001.

Percent of Trips as Discretionary Activity



Source: FHWA, 2001.

Further Analysis and Comparison of Expected Versus Actual Traffic Increase

The question of how ITE estimated trip generation compares to actual observed increases in traffic remains largely unanswered. The fact that 14.6% of trips are internal to the study area suggests that 14.6% of the trips are perhaps double-counted, or even perhaps counted as many as three times, using the ITE methodology.

It is important to remember that the ITE methodology counts trips at each impacted site. Every trip with a trip end at any given parcel is counted as a trip. It is conceivable and almost certain that a number of trips within the study area are chained together and are counted multiple times using the ITE methodology.

For instance, if Jim, a hypothetical citizen living within the study area, left home to drop off his child at Hidden Valley High School, then went to the supermarket also in the study area to purchase groceries before returning home, the ITE methodology would count this sequence as four trips, while Jim could have traveled on US 221 only twice (going to the supermarket and returning, for instance). Stated differently, the traffic counter being used to determine AADT would have registered two vehicles on US 221, but Jim actually took four trips.

It is therefore a reasonable assumption that at least 14.6% of the trips are ‘double-counted’ and perhaps a smaller percentage is ‘triple-counted’ using the ITE methodology (or more accurately, 14.6% of trips are likely underrepresented in the AADT counts). Therefore it is reasonable to assume that at least 4,137 trips and perhaps as many as 6,000 trips as computed using the ITE methodology are trip-chained among several sites within the study area.

It should be stated that the ITE methodology is also subject to sampling error in the methodologies used to compute the trip generation of specific sites. It should be noted that performing an analysis for such a broad study area necessitated the use of the weekday and weekend generation rates for most uses. These rates are perhaps the most subject to sampling error as they are the most generalized of trip generation rates.

It is therefore possible that the majority of the discrepancy between the ITE manual projected increase in trips and the observed increase in traffic counts can be largely explained by various sources of error in the ITE methodology.

Conclusions

There can be no question that there is an obvious connection between land use and transportation. It is known intuitively that developing land will increase demand for transportation services. There should be no need to 'prove' the existence of such a connection. This study sought to better understand the connection in the Roanoke Valley and in some of the surrounding rural areas. Uncovering trends that could be used to project future impacts of development was also a major study goal.

This effort shows us perhaps that the relationship between land use and transportation is never quite as clear cut as one would like to assume. Merely knowing that development has occurred is not enough to ascertain what the expected transportation impact will be. In terms of determining traffic impacts, the nature of development, the influence of the public sector through effective planning, and travel behavior are all as important as the fact that development has occurred.

The ITE methodology demonstrates, on one hand, the traffic increase that could have been borne out of the development activity surrounding the US 221 corridor should a different set of circumstances have existed. For instance, if the mix of development along US 221 had become even more prominently residential, the proportion of internal trips would have likely decreased over time and traffic on arterials across the regional network might have experienced a greater increase.

One of the most interesting findings is, as noted earlier, that even though the study area generated 20,798 trips only 11,000 of those trips have a destination outside the area. Could this be a result of the specific mix of development in the study area? Another important and valid question might seek to understand the transportation impact of applying the village center concept in planning for areas similar to the US 221 Corridor Study Area. These initial results seem to support the notion that the encouragement of village centers, which increase intrazonal traffic and reduce interzonal traffic along the arterial network, is a goal that not only develops communities and a sense of place but helps combat congestion.

Planners must always remember that site design should not only take the present into consideration but should consider the need for additional capacity in the future. Building setback requirements, site ingress and egress, and access management concerns must always be approached with consideration for future needs.

The Roanoke Valley Area Metropolitan Planning Organization has just embarked on a study process involving the development of various scenarios that might impact transportation through changes in modal choice, trip distribution, trip frequency, and other similar factors. This effort should reaffirm the importance of the scenario planning effort. Travel behavior and long-range land use planning decisions together can have a tremendous impact upon the ultimate impact of development upon transportation infrastructure in a region and should be considered in 'transportation scenario' planning.

The ultimate goal of the RVAMPO is to develop the scenario planning effort into a way to provide inputs to a locally-maintained transportation demand model. Impacts of potential scenarios can be translated into population and employment activity across Traffic Analysis Zones (the two main inputs of the modeling process) and used to determine potential outcomes in terms of future traffic volume.

In addition, staff observed potential deficiencies in AADT Traffic Count data published by the Virginia Department of Transportation. There were supposed AADT volumes on certain segments of US 221 in the study area that were unchanged between 1980 and 2005, for instance. This seems highly suspect and there is little information on the methodology of the program. The program methodology should be published in more detail in the actual AADT publication. The program should also be expanded so that better data can be collected increasing the accuracy of AADT estimates.

The following is a summary of recommendations made in this conclusions section:

- Encourage an appropriate mix of development and development of village centers to capture traffic within the same ‘zone’ and to avoid impacts across the larger arterial network.

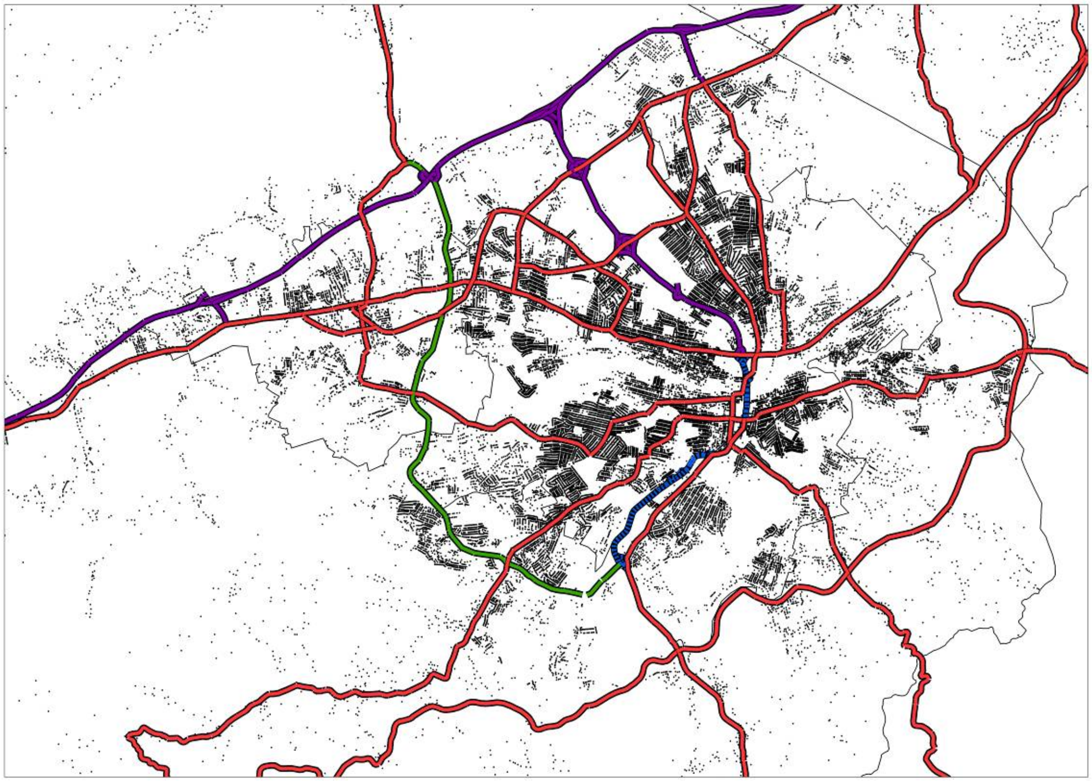
- Building setback requirements, site ingress and egress, and access management concerns must always be approached with consideration for future needs.

- Travel behavior and long-range land use planning decisions together can have a tremendous impact upon the ultimate impact of development upon transportation infrastructure in a region and should be considered in ‘transportation scenario’ planning.

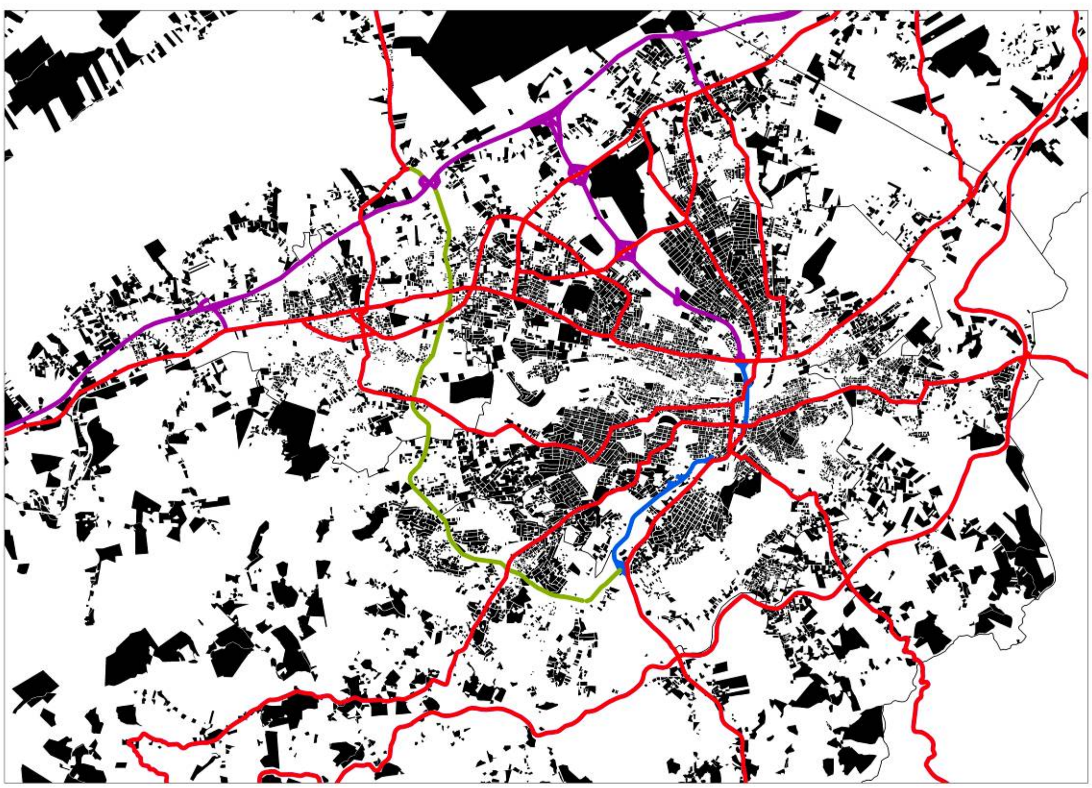
- The Virginia Department of Transportation Annual Average Daily Traffic Count Program should be expanded to increase accuracy of AADT estimates.

APPENDIX

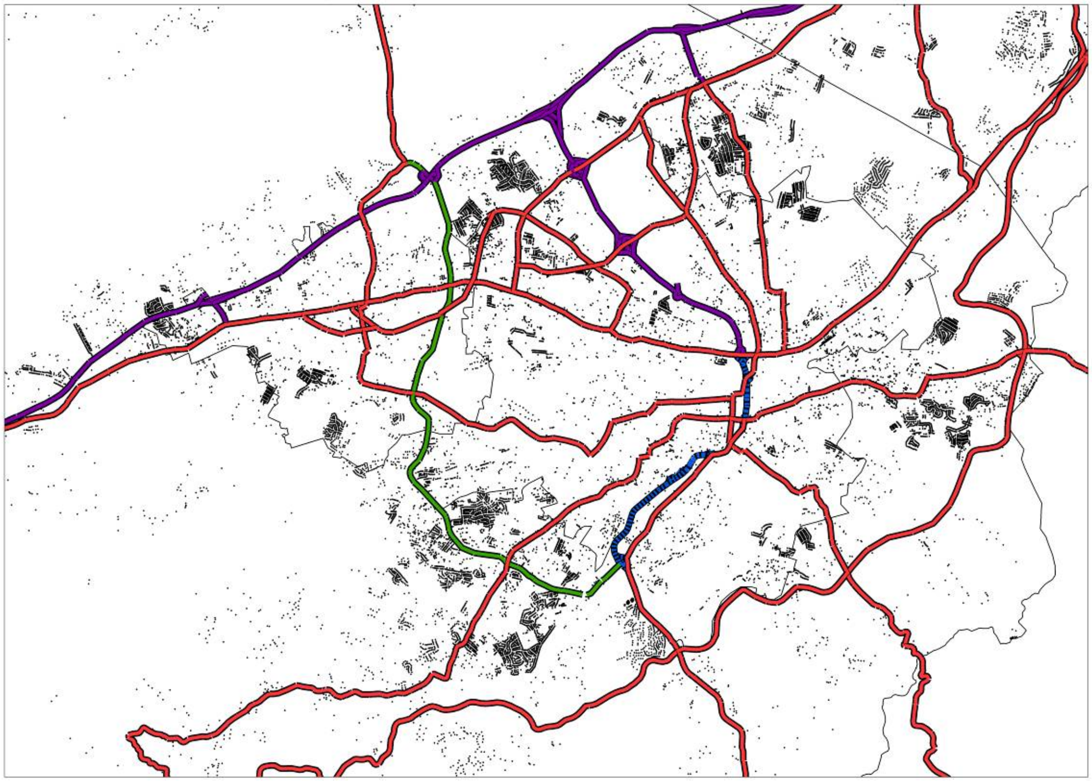
Development Before 1964 – Parcel Centroids



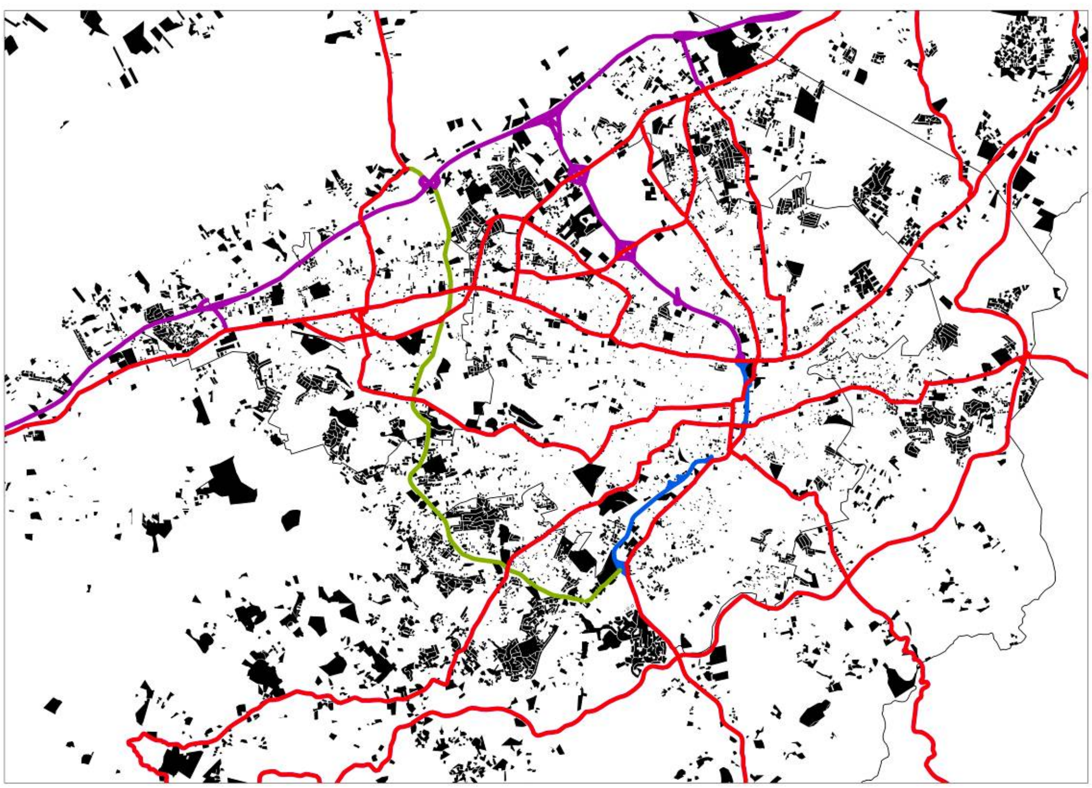
Development Before 1964 – Parcel Shading



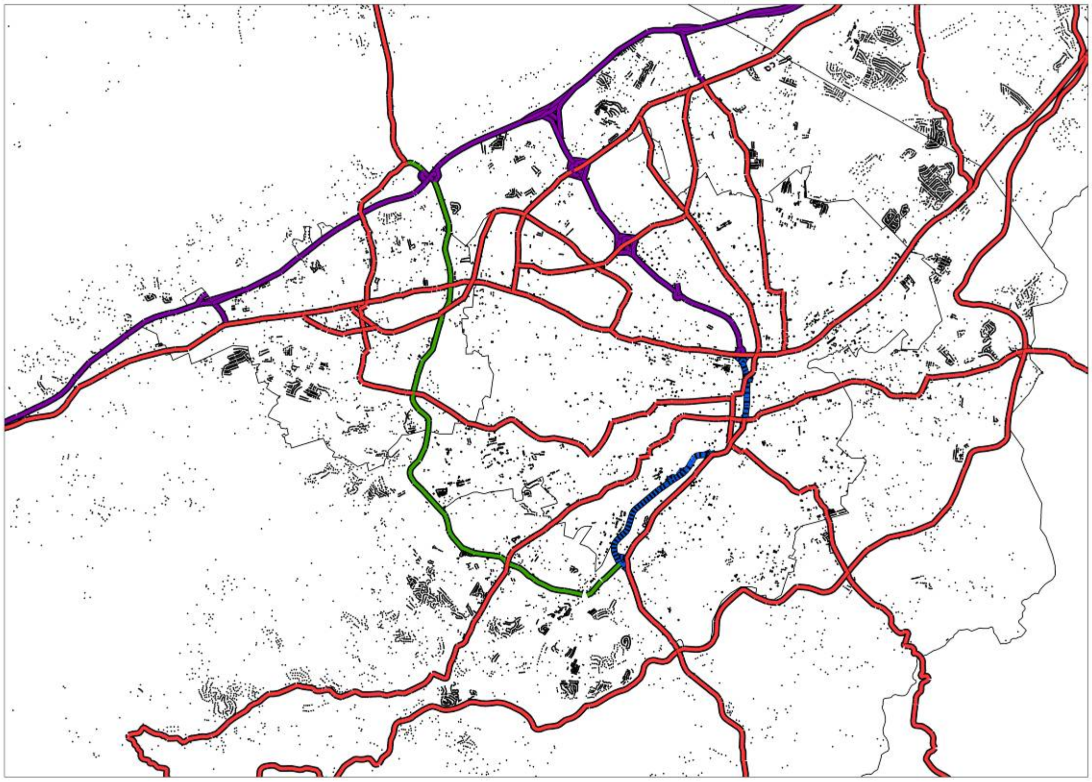
Development Between 1965 and 1979 – Parcel Centroids



Development Between 1965 and 1979 – Parcel Shading



Development After 1980 – Parcel Centroids



Development After 1980 – Parcel Shading