Final Report VTRC 09-R2

Virginia Transportation Research Council

research report

Improving Socioeconomic Land Use Forecasting for Medium-Sized Metropolitan Planning Organizations in Virginia

http:/www.virginiadot.org/vtrc/main/online_reports/pdf/09-r2.pdf

DANIELLE R. McCRAY
Graduate Research Assistant

JOHN S. MILLER
Associate Principal Research Scientist

LESTER A. HOEL
Faculty Research Engineer
and
L. A. Lacy Distinguished Professor of Engineering
Department of Civil & Environmental Engineering
University of Virginia

Virginia Transportation Research Council, 530 Edgemont Road,
Charlottesville, VA 22903-2454, www.vtrc.net, (434) 293-1900

Standard Title Page - Report on Federally Funded Project

1. Report No.: FHWA/VTRC 09-R2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Improving Socioeconomic Forecasting for Medium-Sized Metropolitan Planning Organizations in Virginia		5. Report Date: September 2008
		6. Performing Organization Code
7. Author(s): Danielle R. McCray, John S. Miller, and Lester A. Hoel		8. Performing Organization Report No.: VTRC 09-R2
9. Performing Organization and Address: Virginia Transportation Research Council 530 Edgemont Road Charlottesville, VA 22903		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.: 84995
12. Sponsoring Agencies' Name and Address: Virginia Department of Transportation 1401 E. Broad Street Richmond, VA 23219	Federal Highway Administration 400 North 8th Street, Room 750 Richmond, VA 23219-4825	13. Type of Report and Period Covered: Final
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract:

Socioeconomic forecasts are the foundation for long range travel demand modeling, projecting variables such as population, households, employment, and vehicle ownership. In Virginia, metropolitan planning organizations (MPOs) develop socioeconomic forecasts for a given horizon year at a traffic analysis zone level., and the Virginia Department of Transportation (VDOT) uses these forecasts as input to the four-step travel demand model system. This report identifies the socioeconomic forecasting practices currently used by four medium-sized Virginia MPOs, computes the accuracy of socioeconomic forecasts generated by one such MPO, and recommends practices for improving such forecasts.

This research found that medium-sized Virginia MPOs are using similar techniques to forecast socioeconomic variables. These techniques are to (1) identify jurisdictional population control totals based on U.S. Census and Virginia Employment Commission data; (2) disaggregate population projections to the zonal level based on comprehensive plans, local knowledge, and historic trends; (3) apply historic ratios of households to population and autos to population to forecast households and autos; (4) use historic trends and local expertise to determine future employment; and (5) revise zone projections through coordination with local jurisdictions.

Using a forecast that was developed for the Lynchburg region in 1981 with a horizon year of 2000, the *study area percent error* was computed as the difference between the forecasted and observed values for the entire study area. While the study area percent error for number of vehicles and employment was less than 10%, the study area percent errors for population and households were 48% and 14%, respectively. Two adjacent zones accounted for approximately 80% of the population error and 90% of the household error, and the error resulted because anticipated development therein did not materialize. The *zone percent error* is the average difference between forecasted and observed values for each zone. Population, households, and vehicles had similar zone percent errors of 61%, 65%, and 54% respectively, while the employment zone percent error was 154%.

Four recommendations for improving forecasts are given. First, localities should provide updates to MPO or PDC staff as changes in land development occur, and such staff should perform socioeconomic forecasts more frequently than the current practice of every five years. Second, MPOs should consider providing two sets of socioeconomic variables for the travel demand model: (1) the baseline forecast (which is the MPO's best estimate) and (2) the baseline forecast modified by some percentage that accounts for the possibility of forecast error. Third, best forecasting practices should be shared among MPOs through a user's group, a workshop, or some other forum where MPO and PDC staff will be in attendance. Fourth, VDOT should communicate these recommendations to MPO staff who are responsible for completing socioeconomic forecasts.

17 Key Words: travel forecasting, population forecasting, travel demand modeling, forecast accuracy, regional planning	18. Distribution Statement: No restrictions. This document is available to the public through NTIS, Springfield, VA 22161.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 78	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

FINAL REPORT

IMPROVING SOCIOECONOMIC LAND USE FORECASTING FOR MEDIUM-SIZED METROPOLITAN ORGANIZATIONS IN VIRGINIA

Danielle R. McCray
Graduate Research Assistant

John S. Miller
Associate Principal Research Scientist

Lester A. Hoel
Faculty Research Engineer
and
L.A. Lacy Distinguished Professor of Engineering
Department of Civil & Environmental Engineering
University of Virginia

Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

September 2008
VTRC 09-R2

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Virginia Department of Transportation, the Commonwealth Transportation Board, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. Any inclusion of manufacturer names, trade names, or trademarks is for identification purposes only and is not to be considered an endorsement.

ACRONYMS

DPB	Department of Planning and Budget
CTPP	Census Transportation Planning Package
GIS	Geographic information systems
LRTP	Long-range transportation plan
MPO	Metropolitan planning organization
NHTS	National Household Travel Survey
PDC	Planning district commission
RVARC	Roanoke Valley-Alleghany Regional Commission
TAZ	Traffic analysis zone
VDOT	Virginia Department of Transportation
VEC	Virginia Employment Commission

EXECUTIVE SUMMARY

Socioeconomic forecasts are the foundation of long-range travel demand modeling, projecting variables such as population, households, employment, and vehicle ownership. Estimates are completed for a given horizon year at a TAZ level. These forecasts are used as input to the four-step travel demand model system. In Virginia, socioeconomic forecasts are completed by metropolitan planning organizations (MPOs). The state is responsible for executing the travel demand model.

This study addressed two issues. First, the process for socioeconomic forecasting for medium-sized areas is unclear, and the particular steps taken by Virginia MPOs to forecast future socioeconomic values are not well defined. Second, the accuracy of forecast values from prior studies is not known. If these forecasts are not accurate, the results of the travel demand model based on these forecasts may not be accurate.

This study identified the socioeconomic forecasting practices currently used by four medium-sized Virginia MPOs, computed the accuracy of the socioeconomic forecasts generated by one such MPO where data were available for such a retrospective evaluation, and recommended practices for improving such forecasts. Although the scope of this research was limited to medium-sized metropolitan areas with population between 60,000 and 250,000, the recommended practices may merit consideration for MPOs of all sizes.

This research found that medium-sized Virginia MPOs are using similar techniques to forecast socioeconomic variables. These techniques are to (1) identify jurisdictional population control totals based on U.S. Census and Virginia Employment Commission data; (2) disaggregate population projections to the zonal level based on comprehensive plans, local knowledge, and historic trends; (3) apply historic ratios of households to population and autos to population to forecast households and autos; (4) use historic trends and local expertise to determine future employment; and (5) revise zone projections through coordination with local jurisdictions. Of the four metropolitan areas studied, only one MPO completed the most recent socioeconomic forecast with internal staff and the other three MPOs employed a consultant who coordinated with localities to identify anticipated growth. Several interviewees suggested that because land development decisions are made incrementally, whereas updates to models are made infrequently, growth is not always anticipated in the model.

This research also found that forecast and actual values differ. Using a forecast that was developed for the Lynchburg region in 1980 with a horizon year of 2000, the *study area percent error* was computed as the difference between the forecast and actual values for the entire study area. Although the study area percent error for number of vehicles and employment was less than 10%, the study area percent errors for population and households were 48% and 14%, respectively. Two adjacent zones accounted for approximately 80% of the population error and 90% of the household error, and the error resulted because anticipated development therein did not materialize. The *zone percent error* is the average difference between forecast and actual values for each zone. Population, households, and vehicles had similar zone percent errors of 61%, 65%, and 54% respectively, although the employment zone percent error was 154%.

The report recommends four steps for improving socioeconomic forecasts. First, localities should provide updates to MPO or PDC staff as changes in land development occur, and such staff should perform socioeconomic forecasts more frequently than the current practice of every 5 years. Second, best forecasting practices should be shared among MPOs through a user's group, a workshop, or some other forum where MPO and PDC staff will be in attendance. Third, MPOs should consider providing two sets of socioeconomic variables for the travel demand model: (1) the baseline forecast (which is the MPO's best estimate) and (2) the baseline forecast modified by some percentage that accounts for the possibility of forecast error. (The percentages may be taken from Table 8 in this report or they may be based on local expertise.) Fourth, VDOT should communicate these recommendations to MPO staff who are responsible for completing socioeconomic forecasts. One possibility for implementing this fourth recommendation is through the VDOT district planner.

FINAL REPORT

IMPROVING SOCIOECONOMIC FORECASTING FOR MEDIUM-SIZED METROPOLITAN PLANNING ORGANIZATIONS IN VIRGINIA

Danielle R. McCray
Graduate Research Assistant

John S. Miller
Associate Principal Research Scientist

Lester A. Hoel
Faculty Research Engineer
and
L.A. Lacy Distinguished Professor of Engineering
Department of Civil & Environmental Engineering
University of Virginia

INTRODUCTION

The relationship between socioeconomic forecasting and travel demand modeling is a fundamental component of transportation planning. Socioeconomic variables, such as population, households, employment, and vehicle ownership, are forecast for a given horizon year at the traffic analysis zone (TAZ) level. A TAZ typically contains no more than 1,000 people and is the unit of geography most commonly used in conventional transportation planning. Socioeconomic forecasts are used as input to the four-step (i.e., trip generation, trip distribution, mode choice, and traffic assignment) travel demand model that predicts future use of transportation infrastructure.

In Virginia, the Virginia Department of Transportation's (VDOT) Transportation and Mobility Planning Division is responsible for travel demand modeling for 11 of Virginia's 14 metropolitan planning organizations (MPOs); individual MPOs are responsible for the socioeconomic forecasts that serve as inputs to these models. Since VDOT's regional travel demand model is dependent on the MPO's regional socioeconomic forecasts, coordination between these two agencies and comprehension of the forecasting processes are essential for reliable model results. As each MPO has considerable autonomy with respect to how it develops its forecast, VDOT has suggested that similarities or differences in MPO forecasting methods be documented (Agnello, P., personal communication, November 3, 2006).

With more than 50 years of planning experience among transportation planning professionals, it is now feasible to examine the reliability of techniques for projecting socioeconomic variables, e.g., the extent to which the employment forecast made in 1980 for the year 2000 represents the actual employment in 2000. Given that such a 20-year forecast may be affected by rezonings, market forces, and other developments beyond the control of the demographer, it is reasonable to evaluate the accuracy of socioeconomic forecasts for MPOs as suggested by VDOT staff (Caldwell, L., personal communication, February 1, 2007).

Although forecast accuracy is a national concern for a wide variety of data types and models, it is of particular interest for medium-sized MPOs (those with a population under 250,000) for two reasons. First, unlike larger MPOs, medium-sized MPOs may have a very small staff—perhaps only one person—who generates these forecasts. Thus, successful practices in such situations merit documentation and dissemination. Second, as these areas are not fully developed, there may be greater flexibility to consider different transportation and land development scenarios than is the case in more densely populated areas where development necessarily constrains the scenarios that may be considered.

PROBLEM STATEMENT

Since socioeconomic forecasting processes used by medium-sized MPOs are not fully understood, two potential problems affect state and local planning staff. First, the lack of documentation regarding how MPOs develop these forecasts limits the opportunity for MPOs to share ways of improving their forecasts. Second, because the accuracy of forecasts is not known, it is not possible to report the extent to which socioeconomic forecast error influences travel demand model results based on such forecasts.

PURPOSE AND SCOPE

The purpose of this study was threefold: to identify the socioeconomic forecasting practices used by medium-sized MPOs in Virginia, to document the accuracy of previous socioeconomic forecasts by such MPOs by means of a case study approach, and to identify practices for improving the accuracy of such forecasts.

The study was limited to medium-sized metropolitan areas in Virginia with a population between 60,000 and 250,000. The reason for limiting the study scope was that the project steering committee was interested in the planning practices used among medium-sized metropolitan areas, which tend to have smaller numbers of staff who can perform socioeconomic forecasts. Larger urbanized regions of the state, which have comparably greater resources for forecasting, were thus excluded from the study.

METHODOLOGY

Four tasks were performed to achieve the study objectives:

1. Select MPOs from medium-sized metropolitan areas in Virginia to participate in the study.

2. Conduct, verify, and synthesize interviews of staff from the selected MPOs to identify their current socioeconomic forecasting procedures, and conduct a literature review to provide context regarding the comments made during the interviews.

3. Compare forecast and actual socioeconomic variables for a selected MPO in a case study.

4. Identify practices for improving the accuracy of socioeconomic forecasts by medium-sized MPOs in Virginia.

Select Medium-Sized Metropolitan Planning Organizations to Participate in Study

Of the 14 MPOs in Virginia (U.S. DOT, 2007), 4 MPOs were selected for this study. The 4 MPOs were selected based on (1) the fact that they were not in the large urbanized areas of Virginia (e.g., Hampton Roads, Northern Virginia, and Richmond) but rather were medium-sized MPOs consistent with the scope of the research effort); (2) direction from the steering committee, and (3) the knowledge of the steering committee members and researchers of the MPOs studied. These MPOs were as follows:

1. *Central Virginia MPO, established in 1979.* The membership of this MPO includes the City of Lynchburg, Amherst County, Bedford County, Campbell County, and the Town of Amherst.

2. *Harrisonburg-Rockingham MPO, established in 2003.* The membership of this MPO includes the City of Harrisonburg and that part of Rockingham County surrounding the city, to include the incorporated towns of Bridgewater, Dayton, and Mount Crawford.

3. *Roanoke Valley Area MPO, established in 1974.* The membership of this MPO includes the cities of Roanoke and Salem, the Town of Vinton, and the urbanized portions of the counties of Bedford, Botetourt, and Roanoke.

4. *Winchester-Frederick MPO, established in 2003.* The membership of this MPO includes the City of Winchester, the Town of Stephens City, and the urbanized portions of Frederick County.

Conduct, Verify, and Synthesize Interviews of MPO Staff

Staff from the four MPOs were interviewed. In many cases, the planning district commission (PDC) provides personnel for the MPO. Therefore, some interviewees were affiliated with both the PDC and the MPO. The authors initially contacted either the MPO’s executive director or the MPO's transportation planner (as identified on the FHWA's Transportation Planning Capacity Building Program website (U.S. DOT, 2007) to complete interviews for each MPO. That individual either participated in the interview or identified another person with the appropriate background knowledge to answer the questions. At the time of the interviews, the Harrisonburg-Rockingham MPO did not have a transportation planner and representatives from local governments were asked to participate in the interview. In addition to MPO or local government staff as noted here, VDOT district planning offices were also invited to participate in the interviews. Table 1 shows the MPO, PDC, local government, and VDOT personnel present for each interview.

During each interview, participants were asked questions in three categories:

1. *Technical:* the details and steps involved with completing a forecast.
2. *Administrative:* the resources required to perform the forecasts.
3. *Assessment:* an evaluation of the forecasting process and suggested improvements.

The questions were tailored to the specific experiences and circumstances of the agency. When an interviewee had additional knowledge or experience pertinent to forecasting but beyond the scope of the initial question, additional questions were asked.

The following questions were used as a basis for the interviews and were asked of each interviewee:

Technical

- Explain the process currently used by the MPO/ PDC to forecast future land use.
- What input variables are required to produce the land use forecast?

Table 1. Interview Schedule

MPO	Name/Title	Organization(s) Represented	Interview Date
Roanoke Valley Area	Mark McCaskill Matt Miller[a]	Roanoke Valley-Alleghany Regional Commission	April 19, 2007
Central Virginia	Bob White	Virginia's Region 2000 Local Government Council	May 23, 2007
	Rick Youngblood[a]	Virginia Department of Transportation (Lynchburg District)	
Harrison-Rockingham	Andrew Williams[b]	Harrisonburg-Rockingham Metropolitan Planning Organization and the Central Shenandoah Planning District Commission	June 15, 2007
Winchester-Frederick[c]	John Bishop, Planning Director	Frederick County Local Government	July 11, 2007
	Tim Youmans, Planning Director	City of Winchester Local Government	
	Bob Ball, Staunton District Transportation Planner	Virginia Department of Transportation (Staunton District)	

[a]Interview was conducted at the office of the interviewees.
[b]Written response to the interview questionnaire was completed by the interviewee.
[c]Interview was conducted via telephone conference.

- What output variables does the land use forecast generate?
- What data sources are used to generate these land use forecasts?
- How does the MPO determine the size of TAZs and what is the average TAZ size in square miles?
- What is the total area of the MPO region?

Administrative

- Describe the professional background of the individual(s) responsible for developing land use forecasts and the number of staff members assigned.
- How does the MPO/PDC coordinate land use forecasts with local jurisdictions?
- How frequently are the land use forecasts prepared?
- How much time and effort does it take to prepare an updated land use forecast?

Assessment

- Describe the quality of data available to the MPO to prepare a land use forecast.
- What improvements in data quality are needed?
- Are there limitations that could be overcome to produce land use forecasts?
- If these limitations could be overcome, how would this influence your land use forecasts?
- What changes would you like to see to the existing land use forecasting process?
- How does the regional land use forecast influence local planning decisions?
- How does the regional land use forecast influence how the MPO prioritizes projects over which it has control?
- How does the regional land use forecast influence the development of the long-range transportation plan (LRTP)?
- How does the regional land use forecast influence what projects are funded by the state?

Responses were summarized to document the procedures used to forecast socioeconomic variables, and Appendix A shows an example forecasting procedure. A draft summary of the interview was sent to all those present to ensure accuracy in reporting what had been said.

A detailed literature review was conducted in order to prepare for the interviews and to appreciate the context of the interview responses. The literature reviewed covered the topic of socioeconomic forecasting at the regional level and was obtained by using the Transportation Research Information Service (TRIS). Some of the literature documented the accuracy of forecasts (e.g., Eustace et al., 2005), and some provided best practices for forecasting (e.g., Institute of Transportation Engineers, 1992).

Compare Forecast and Actual Socioeconomic Variables for the Lynchburg Metropolitan Region: A Case Study

Four regions were candidates for the case study to compare forecast and actual socioeconomic variables: Harrisonburg, Lynchburg, Roanoke, and Winchester. For each region, relevant documents were obtained, such as LRTPs, technical appendices to these plans, and publications that contained socioeconomic data. Some documents were available only at the offices of the MPO staff who were interviewed, whereas other documents were available through the VDOT Research Library. A review of the publications showed that a retrospective case study was not feasible for all regions, as detailed in Appendix B.

The Lynchburg metropolitan region (hereinafter called "Lynchburg region") was selected for the case study. This region, and thus the case study area, now includes all of the City of Lynchburg and the urbanized areas of Amherst, Bedford, and Campbell counties. (The urbanized portions of these counties have higher density than the non-urbanized portions of these counties.) The researchers selected the Lynchburg region as the site for the case study for two reasons: (1) a complete dataset was available; and (2) the horizon year of 2000 had already transpired. An additional consideration was that one of the researchers and one steering committee member had a strong local knowledge of the region, which proved helpful during the case study analysis.

Five steps comprised the case study:

1. *Document year 2000 forecast zonal socioeconomic values for population, households, employment, and vehicle ownership.* The *Lynchburg Area Transportation Study: Year 2000 Transportation Plan* (Virginia Department of Highways & Transportation [VDH&T], 1980) was used to identify year 2000 forecasts.

2. *Document year 2000 actual zonal socioeconomic values for the same variables listed in Step 1.* The *Lynchburg MPO 2000 Model Development Technical Report* (Michael Baker Jr., Inc., 2005) includes 2000 base year land use data validated with U.S. Census data, Virginia Employment Commission (VEC) data, Bureau of Economic Analysis data, comprehensive plans, aerial photography, and local input. The 2000 base year data from that report were used to identify year 2000 actual socioeconomic values.

3. *Aggregate the TAZs used in Step 1 and the TAZs used in Step 2 as necessary to develop comparable TAZs.* Although the TAZs from Step 1 and Step 2 both represented the Lynchburg region, the individual TAZ boundaries were not identical. For example, a section of land that was one TAZ in 1980 (Step 1) might have been two TAZs in 2000 (Step 2). Accordingly, geographic information systems (GIS) software was used to create case study TAZs that were directly comparable. Details of the computational steps required to relate these zones are provided in Appendix C, and the relationships themselves are provided in Appendix D.

4. *Compute the absolute error and percent error of each socioeconomic variable identified in Step1 by case study TAZs.* For a given zone i, the *absolute error* shows the magnitude of the error (Eq. 1) and the *percent error* shows the absolute error divided by the actual value (Eq. 2).

$$\text{Absolute Error}_i = \left|\text{Forecast}_i - \text{Actual}_i\right| \qquad \text{[Eq. 1]}$$

$$\text{Percent Error}_i = \left(\frac{\left|\text{Actual}_i - \text{Forecast}_i\right|}{\text{Actual}_i}\right) * (100) \qquad \text{[Eq. 2]}$$

The absolute error and the percent error for each zone are provided in Appendix E.

5. *Analyze and interpret the findings.* The largest contributors to these errors were identified.

Identify Practices for Improving Accuracy of Socioeconomic Forecasts

Initial practices for improving the accuracy of socioeconomic forecasts by medium-sized MPOs were identified through the interviews, the literature review, and the case study. Then, three of these practices were discussed at length with the project steering committee during the period January through May of 2008. The discussions focused on how best to implement these practices given three distinct stakeholders in Virginia who are either customers or generators of these socioeconomic forecasts: VDOT's Central Office, which executes the travel demand model (based on these forecasts); the VDOT district planner, who may work closely with the MPO; and the MPO, which performs the socioeconomic forecasts.

RESULTS AND DISCUSSION

Synthesis of MPO Interviews

Interview findings supplemented by findings from the literature review are discussed here with respect to three themes: socioeconomic projections (TAZ structure, data sources, and forecasting procedures); administrative techniques (resources required for forecasting and coordination with local jurisdictions); and assessment of socioeconomic forecasts (successes, challenges, and the influence of forecasts on decisions). Individual responses are detailed in Table 2, and highlights from the interviews are noted here.

Socioeconomic Projections

Traffic Analysis Zone Structure

Regional urban travel demand models are based on forecasts of social and economic activity. The region is subdivided into TAZs. For each TAZ, population, employment, households, and auto ownership are forecast for the horizon year, typically 20 years out. The results are documented in the region's LRTP. The zone forecasts are used by VDOT planners as inputs into the regional travel demand model.

Table 2. Review of Four Medium-Sized Metropolitan Planning Organizations (MPOs) in Virginia[a]

Name[b,c]	Harrisonburg-Rockingham MPO	Winchester-Frederick MPO	Central Virginia MPO	Roanoke Valley Area MPO
General Information				
Designation year[d]	2003	2003	1979	1974
Area (mi^2)[d]	106	103	248	216
Population (2000)[d]	61,319	61,697	121,646	215,033
Population density[e]	579	599	491	996
Geographic area	City of Harrisonburg and part of Rockingham County	Frederick County, City of Winchester, and Town of Stephens City	City of Lynchburg and parts of Amherst, Bedford, and Campbell counties	Cities of Roanoke and Salem; Town of Vinton; and urbanized portions of Bedford, Botetourt, and Roanoke counties
Socioeconomic Projections				
Traffic analysis zones (TAZs)	Zonal structure determined by population density.	Zonal structure based on 2000 U.S. Census geography. Adjustments made such as increasing number of TAZs in metropolitan area and changing population density in Frederick County.	Zonal structure has relatively large TAZs because development patterns are unique. TAZs are weighted differently depending on population density.	Zonal structure based on areas with similar travel characteristics. MPO responsible for TAZ structure, VDOT further subdivides TAZs to address model needs. MPO boundaries may change and influence TAZs on outskirts of region.
Data sources	Comprehensive plans and zoning ordinances; VEC projection data not used extensively in most recent projection, as data trend tends not to be accurate due to James Madison University.	VEC (population), U.S. Census, Weldon Cooper Center, MPO Economic Division, and Northern Shenandoah Valley Regional Commission.	VEC (population), local planners, Region 2000 staff, Weldon Cooper Center, and travel surveys completed by VDOT.	VEC, land use plans, future development details, local knowledge, and U.S. Census.
Forecasting procedures	Zonal population and employment forecasts derived exclusively from comprehensive plan, zoning ordinances, and local knowledge. Most recent forecast completed by consultant.	Zonal population forecasts derived from Weldon Cooper Center annual population data and local knowledge. Zonal employment forecasts derived from unmodified VEC jurisdictional totals and local knowledge. Most recent forecast completed by consultant.	Zonal population forecasts derived from Weldon Cooper Center annual population data and local knowledge. Zonal employment forecasts derived from unmodified VEC jurisdictional totals and local knowledge. Most recent forecast completed by consultant.	Zonal population forecasts derived from U.S. Census decennial population data and linear regression technique to allocate population increase. Zonal employment forecasts derived from modified VEC jurisdictional totals and linear regression technique used to allocate employment increase.

Name[b,c]	Harrisonburg-Rockingham MPO	Winchester-Frederick MPO	Central Virginia MPO	Roanoke Valley Area MPO
Administrative Techniques				
Resources required for forecasting	MPO Technical Advisory Committee and subcommittee; both are responsible for "ground truthing" work of consultant. Two to three local government employees are also resources.	Interviewees suggested that consultant responsible for forecast would be better able to address resources required to complete forecast.	VDOT (provides funding for model development), MPO (provides funding for overall planning process), Region 2000 (develops population forecasts through statistical research), consultant ("streamlines MPO regional model" and works with local planners), MPO staff (lead training for local planners) and Technical Committee (assisted with development of LRTP).	One PDC/MPO staff member responsible for overseeing projections for past 14 years (background includes geography, census experience, and mapping).
Time and effort required for forecasting	3 months to update forecast.	Unknown, as consultant was responsible for completing forecast.	Unknown. However, technical committee with support from Region 2000 trained for 1 year to prepare LRTP.	1 week required for staff to update forecast; input from localities requires up to 4 months.
Coordination with local jurisdictions	Coordination occurs among local government staff who serve on subcommittee to work with consultants to develop forecasts.	Coordination occurs among local jurisdictions and regional agencies such as MPO Economic Division, MPO Technical Advisory Committee, and Northern Shenandoah Valley Regional Commission.	Coordination occurs between local officials and the MPO/ Region 2000 through collaborative discussion activity; effort was significant success.	Coordination occurs between local jurisdictions and MPO/PDC during forecasting process (when localities provide input) and after process (when localities indicate whether they agree or disagree with forecast).
Update	Every 5 years	Every 5 years	Every 5 years	Every 5 years
Assessment of Socioeconomic Forecasts				
Successes and challenges	Data readily available from localities and member communities. Difficult to identify areas of improvement as this was first forecast completed for MPO.	Forecasting process does not capture ongoing nature of development changes; represents snapshot in time. Consistent process for updating socioeconomic data on more frequent basis suggested.	Zonal predictions less accurate than forecasts for entire region. Significant problem is inconsistent process for updating TAZs details based on land development decisions made at local level. More frequent updates of socioeconomic data would allow for decision makers to capitalize on funding opportunities.	Improvements needed in consulting with VDOT (to determine standards and preferred formats of TAZ data) and in calibrating TAZ projections with VEC and U.S. Census control totals.

Name[b,c]	Harrisonburg-Rockingham MPO	Winchester-Frederick MPO	Central Virginia MPO	Roanoke Valley Area MPO
Influence on decision making	Socioeconomic forecasts have little influence on local planning decisions; help determine where growth trends will most likely continue and type of road facility that may be needed in future; influence travel patterns and prioritize which projects should receive critical funding based on planning assumptions in rapidly growing areas; may expedite planning process but do not influence obtaining construction dollars.	Socioeconomic forecasts have strong link with LRTP; however, first forecast has not influenced decision making significantly.	Socioeconomic forecasts may affect phase of funding localities pursue based on anticipated developments.	Socioeconomic forecasts may have some influence on decisions at local/regional level, but they are not driving forces. Instead, funds and resources are basis for decisions.

VEC = Virginia Employment Commission, VDOT = Virginia Department of Transportation; PDC = planning district commission; LRTP = long-range transportation plan.

[a]A sample of Virginia's MPOs with population between 60,000 and 250,000; not including the three large urban areas of Northern Virginia, Hampton Roads, and Richmond.

[b]Association of Metropolitan Planning Organizations. MPO Directory Listing. Washington, DC, undated. http://www.ampo.org/directory/index.php. Accessed November 15, 2006.

[c]Virginia Department of Transportation. *Transportation Enhancement Programs: Metropolitan Planning Organizations.* Richmond, 2006. http://www.virginiadot.org/projects/resources/Resources_TAB.pdf . Accessed November 15, 2006.

[d]U.S. Department of Transportation, Transportation Planning Capacity Building–Metropolitan Planning Organization (MPO) Database. Federal Highway Administration/Federal Transit Administration, 2007. http://www.planning.dot.gov/Summary.asp?ID=370. Accessed March 2007.

[e]Calculated based on area and population data.

PDCs and MPOs use data from the most recent U.S. Census to identify TAZ boundaries. The Census Transportation Planning Package (CTPP) is a customized dataset derived from the decennial census that includes specific datasets related to transportation (U.S. Department of Transportation, 2006). Most recently, TAZ-UP software, created by the Federal Highway Administration, was used by MPOs and state departments of transportation to define TAZs for the 2000 CTPP.

The Census 2000 TAZ-UP Program (TRB Subcommittee on Census Data for Transportation Planning, 2008) was used by the Roanoke Valley Area and the Winchester-Frederick MPOs for their most recent forecasts. Interviewees from the Winchester area reported that as a result of changes to the TAZ-UP software that will be implemented with the next decennial census, TAZ sizes may increase in 2010 (Youmans, T., personal communication, July 13, 2007).

Interviewees suggested that the size of TAZs varied throughout a given region as a result of population distribution. As expected, TAZ size increases outward from the central business district to the suburbs. There is some variation among regions: TAZ sizes in the Lynchburg region are relatively larger than those of other comparable regions because of unique growth trends in the area (Youngblood, R., personal communication, May 23, 2007). The Lynchburg region's population density is relatively lower than that of comparable regions of similar size, which suggest larger TAZs.

Data Sources

Multiple data sources are used to gather information regarding the projected composition of a metropolitan region. Federal and state agencies estimate current or past data and projections of future data at the state and jurisdictional levels. The decennial census, completed by the U.S. Census Bureau, provides details for data trends that are used to update current socioeconomic data for a metropolitan area's zonal system.

VEC is the state agency responsible for developing population projections. The *Code of Virginia*, § 60.2-113 (Virginia General Assembly, 2007), states the following:

> The Commission shall take all necessary steps through its appropriate divisions and with the advice of such advisory boards and committees as it may have to: . . .
>
> 5. Prepare official short and long-range population projections for the Commonwealth for use by the General Assembly and state agencies with programs which involve or necessitate population projections; . . . .

VEC publishes data in various formats and offers labor market analysis tools to examine data by occupation, labor force, education, and demographics at the state, jurisdictional, metropolitan statistical area, and planning district levels. Those aggregated VEC projections are often used as control totals when metropolitan regions subdivide the geography into smaller geographical units. In addition, the demographic and workforce services of the Weldon Cooper Center for Public Service at the University of Virginia compile data from the U.S. Census Bureau and VEC.

Local and state data sources were used for socioeconomic projections. Agencies such as the U.S. Census Bureau, Weldon Cooper Center for Public Service, and VEC develop population control totals for jurisdictions. Then land use plans, future development plans, and expertise from local officials are used to identify growth areas within these jurisdictions (and such growth areas may help develop forecasts for individual TAZs).

Forecasting Procedures

According to Hanson and Giuliano (2004), errors in demographic inputs to travel models are unavoidable, and therefore MPOs are required to update their transportation plans every 3 years. As a consequence, MPOs that conform with air quality standards are required by federal legislation to update transportation plans at least every 5 years and nonattainment regions are required to update plans on a more frequent basis.

With the exception of the Roanoke Valley-Alleghany Regional Commission (RVARC), consultants were used to develop socioeconomic projections. Institutional knowledge and documentation of forecasting methodologies are sometimes lost when a private consultant firm is responsible for the forecast. RVARC was the only regional representative to provide a detailed description of its forecasting process. The procedure used by RVARC in 2001 to forecast socioeconomic variables for year 2025 using 2000 base year data was as follows:

1. Update 2000 base year data for population, housing units, households, passenger vehicles available, and employment variables using the U.S. Census Bureau's decennial census and the CTPP.

2. Project 2025 year data (2025) using updated base year data, historical trends, and state projections or control totals.

3. Verify growth allocation through an official review process with local planners and the MPO.

Appendix A provides a simplified example of each step in the process that illustrates the actual calculations.

Administrative Techniques

Resources Required for Forecasting

A significant effort is required to complete a forecast. An experienced MPO interviewee noted that the actual forecast may be completed within 1 to 2 weeks using internal staff; however, the review and approval by local governments can take several months (Miller, M., personal communication , April 19, 2007). Those regions that employed a consultant to complete the forecast could not state the amount of time required to complete the socioeconomic forecast. Socioeconomic forecasts are updated every 5 years as required by federal law.

Limited resources available at the MPO level influence how forecasts are prepared. A medium-sized MPO or PDC typically has one planner responsible for completing socioeconomic forecasts. Interviewees identified technical committees and subcommittees as fundamental resources for local knowledge; they often assist with the allocation of growth throughout the metropolitan region.

In one instance it was suggested that the required data were not clear. One MPO had produced a forecast for each zone for different types of employment. However, the travel demand model in that instance required only the total employment for each zone. Thus, only the individual types of employment could be summed to yield the total employment required by the model (Miller, M., personal communication, April 19, 2007), providing an example of how more information concerning data requirements might be beneficial. Despite this example, however, discussions with the project steering committee showed that VDOT modelers prefer MPOs to provide more detail, rather than less detail, for the various socioeconomic forecasts.

Coordination with Local Jurisdictions

In each of the four MPO interviews, interviewees mentioned coordination with localities. Local planners with knowledge of the region are often asked to review the zonal projections for their respective jurisdiction. Interviewees indicated that it may be difficult to identify a specific representative of each locality who is willing to work on the forecast updates. Coordination activities included correspondence with localities in the Roanoke region or in-person discussions with local planners in the Lynchburg region.

As the composition of metropolitan areas varies, responses from localities also vary. In the most recent forecast for the Roanoke region, local planners took months to respond and the few responses received concerned desired adjustments to employment forecasts reflecting negative trends in their respective jurisdiction or questionable map boundary adjustments. In the Lynchburg region, each local jurisdiction worked closely with the MPO and the consultant responsible for the travel demand model to project anticipated distribution of growth among the different TAZs.

Assessment of Socioeconomic Forecasts

Successes and Challenges

Interviewees from the Central Virginia MPO and Roanoke Valley-Alleghany Regional Commission suggested that they were pleased with their most recent socioeconomic forecasts. The forecasts for the entire region tended to be closer to actual observations than forecasts for individual zones. Newer MPOs (i.e., Winchester-Frederick and Harrisonburg-Rockingham) indicated that they had difficulty identifying areas of improvements as forecasts for only one LRTP had been completed since the establishment of both MPOs in 2003.

Interviewees from the Winchester-Frederick MPO noted they would like to reduce the time spent on data cleansing as this time is increased when there is a disagreement between consultants and the MPO. (In general—and not specific to the Winchester-Frederick MPO—

data cleansing refers to removing individual errors from a given dataset. An example of data cleansing in preparing a socioeconomic forecast might be to increase the number of homes in a given zone such that this number matches the number of houses shown on a property tax map of the area.] For this same MPO, large TAZs hindered the network analysis because some of these TAZs had multiple major corridors (which can adversely affect the traffic assignment portion of the travel demand model [Martin and McGuckin, 1998]). However, the TAZ-UP Program may address TAZ size in the future as MPOs will have more guidance with establishing TAZ boundaries.

In two interviews, the "biggest problem" with respect to socioeconomic information in travel demand models was that "there is not a consistent process for updating TAZs based on land development decisions made at the local level." (Miller, M., personal communication, April 19, 2007; Youngblood, R., personal communication, May 23, 2007) This led to a discussion of how land development decisions, e.g., a county decides to rezone a 10-acre parcel from agricultural to high-density residential zoning, could be systematically updated. A mechanism should be in place that does the following:

- identifies the TAZ containing this parcel
- reduces by 10 the agricultural acres in this TAZ in the travel demand model
- increases by 10 the residential acres in this TAZ in the travel demand model
- provides a year at which the residential units will be constructed
- modifies the trip generation rate accordingly for this TAZ for the year provided (and for future years).

The interview comments and the literature were consistent. Effective socioeconomic forecasting practices in the literature are summarized in Appendix F. These include estimating economic development (Institute of Traffic Engineers, 1992), considering the extent to which previous trends will likely be good predictors of future trends (Meyer and Miller, 2001), and verifying socioeconomic inputs (Wegmann and Everett, 2008). Despite the existence of such practices, however, the literature documents that it is difficult to develop projections for smaller geographical areas [such as a TAZ] (Murdock et al., 1991) and that errors in demographic inputs to travel models are unavoidable (Hanson and Giuliano, 2004). Thus, a "best practice" appears to be to take steps to ensure forecast data are of high quality (such as the update mechanism that interviewees suggested) but to recognize that there will be some error in any forecast.

Influence of Socioeconomic Forecasts on Decision Making

Interviewees indicated that forecasts may expedite the planning process but do not have a significant impact in obtaining funding for construction projects. Although forecasts help identify growth trends and, by extension, the type of roadway facility that will be needed, the availability of funding determines whether a facility can be built.

Forecasts may, however, affect the phase of funding that localities pursue. For example, if a forecast indicates significant development within the next 8 to 10 years, officials may pursue funding for a feasibility study and preliminary engineering to improve existing infrastructure to support the anticipated growth. Thus, if that development is not reflected in the forecast, the region may miss an opportunity to apply for the limited funding that is available for such improvements.

Accuracy of Socioeconomic Forecasts for Lynchburg Region: Case Study

The forecast and actual socioeconomic variables for the Lynchburg region were compared for the period 1980 through 2000 as a case study. Datasets generated two decades apart were compared, and the differences between forecast and actual values were analyzed. Any reasons for any differences between forecast and actual values were used to suggest improved procedures to develop forecasts.

Comparison Between Forecast and Actual Socioeconomic Variables

The *Lynchburg Area Transportation Study: Year 2000 Transportation Plan (*VDH&T, 1980) was used to obtain the variables used and the number of TAZs in 1980 to produce the year 2000 forecast. The *2030 Lynchburg Area Transportation Study* (Michael Baker Jr., Inc., 2005) was used to obtain the actual variables and number of TAZs in the year 2000. Table 3 lists the variables used and the number of TAZs in 1980 to produce the year 2000 forecast and the actual values for the year 2000. In 1980, there were only 85 TAZs compared with 282 TAZs in 2000. In 1980, the variable *total population* was used, whereas in 2000, the population variables *total population, households,* and *group quarters were used.* With these exceptions, all other

Table 3. Socioeconomic Variables for Comparison

Year 2000 Forecast (Created in 1980)[a]	Year 2000 Actual (Created in 2000)[b]	Case Study (Created in 2008)
Total population[c]	Total population, households, group quarters[d]	Total population[c]
Occupied dwelling units	Households	Households
Autos	Vehicles	Vehicles
Total employment	Total employment	Total employment
Retail employment	Retail employment	Retail employment
Non-retail employment[e]	Non-retail employment	Non-retail employment
Students by zone of attendance[f]	-----	-----
85 TAZs	282 TAZs	68 TAZs[g]

[a]Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan,* Richmond, 1980.
[b]Michael Baker Jr., Inc., *2030 Lynchburg Area Transportation Study,* Virginia Department of Transportation, Richmond, 2005.
[c]Total population includes households and group quarters parameters; however, the subcategory values were not explicitly identified or documented.
[d]According to the U.S Census Bureau (U.S. Census Bureau, 2007), *group quarters* is a place where people live or stay that is normally owned or managed by an entity or organization providing housing and/or services for the residents. Typically, people living in group quarters are not related. Group quarters include such places as college residence halls, residential treatment centers, skilled nursing facilities, group homes, military barracks, correctional facilities, workers' dormitories, and facilities for people who are homeless.
[e]Value determined as the difference between total employment and retail employment.
[f]Parameter not analyzed in case study.
[g]Zones for the 1980 and 2000 datasets were aggregated to produce a new set of 68 TAZs that would be used to compare data from both time periods.

variables were similar in the base and forecast years. The third column is a list of variables used for the case study analysis.

The term *autos* is used in the context of the earlier study (VDH&T, 1983), whereas the term *vehicles* is used in the later study (Michael Baker, Inc., 2005). The researchers did not find a formal definition of these terms, and in fact in the later study (Michael Baker Inc., 2005), the phrases *auto ownership* and *vehicle ownership* are used interchangeably. In the researchers' judgment, and consistent with travel demand forecasting practice (Garber and Hoel, 2009), *autos* or *vehicles* denotes motorized passenger vehicles that may be used for personal travel such as motorcycles, two- or four-door auto sedans, light-duty pickup trucks, and other sport utility vehicles.

Since the forecast dataset generated in 1980 and the actual dataset generated in 2000 had different zone sizes, adjustments were necessary to make correct comparisons. For example, the area represented by TAZ 1 in 1980 might not have corresponded to the same area identified as TAZ 1 in 2000. Accordingly, zones were aggregated to produce a new set of 68 TAZs that could be compared for both time periods. Figure 1 illustrates the process. In this example, TAZ 28 (from the 1980 study) is compared to the aggregation of TAZs 76, 77, and 82 (from the 2000 study). Appendix D provides an equivalency table showing the relationship between TAZs from 1980 and 2000. Figure 1 illustrates the transformation for Case Study TAZ 22.

Comparison of Forecast and Actual Values

Table 4 summarizes the comparison between actual and forecast variables for the entire region and for individual TAZs. The total population forecast for all 68 TAZs (179,309) differed from the actual 2000 population (121,078) by 58,231 (or 48% of the actual value). The population forecast for TAZ 22 (Figure 1) was 2,600, and the actual 2000 population was 2,201. Thus, the absolute error for that TAZ 22 was 2,600 – 2,201 = 399 and the percent error was 399/2,201 = 18%. For all 68 case study TAZs, the mean absolute error for population was 1,177 and the mean percent error was 61.

For the entire study area (68 TAZs*)*, the forecast variables of population, households, and retail employment exceeded actual values, whereas the forecast variables of total employment, non-retail employment, and vehicles were less than the actual values. Forecast values for vehicles and employment were less than 10% in error, whereas the errors for population and households were 48% and 14%, respectively. The large difference between the forecast population and the actual population (58,231) suggests that the Lynchburg region did not grow to the extent that was originally anticipated. Households were also over projected; however, the absolute and percent errors were much lower than the population error.

The TAZ forecast errors were larger than the study area errors. For population, households, vehicles, and employment, these errors were 61%, 65%, 54%, and 154%, respectively. Forecast errors of retail employment for the entire study were only 1.2%, whereas the TAZ error was 180%. One plausible explanation for the discrepancy between a very low study area error and a very high zone error is the small values for retail employment (11,800 divided by 68 zones), as changes in a relatively small number may yield large percent errors.

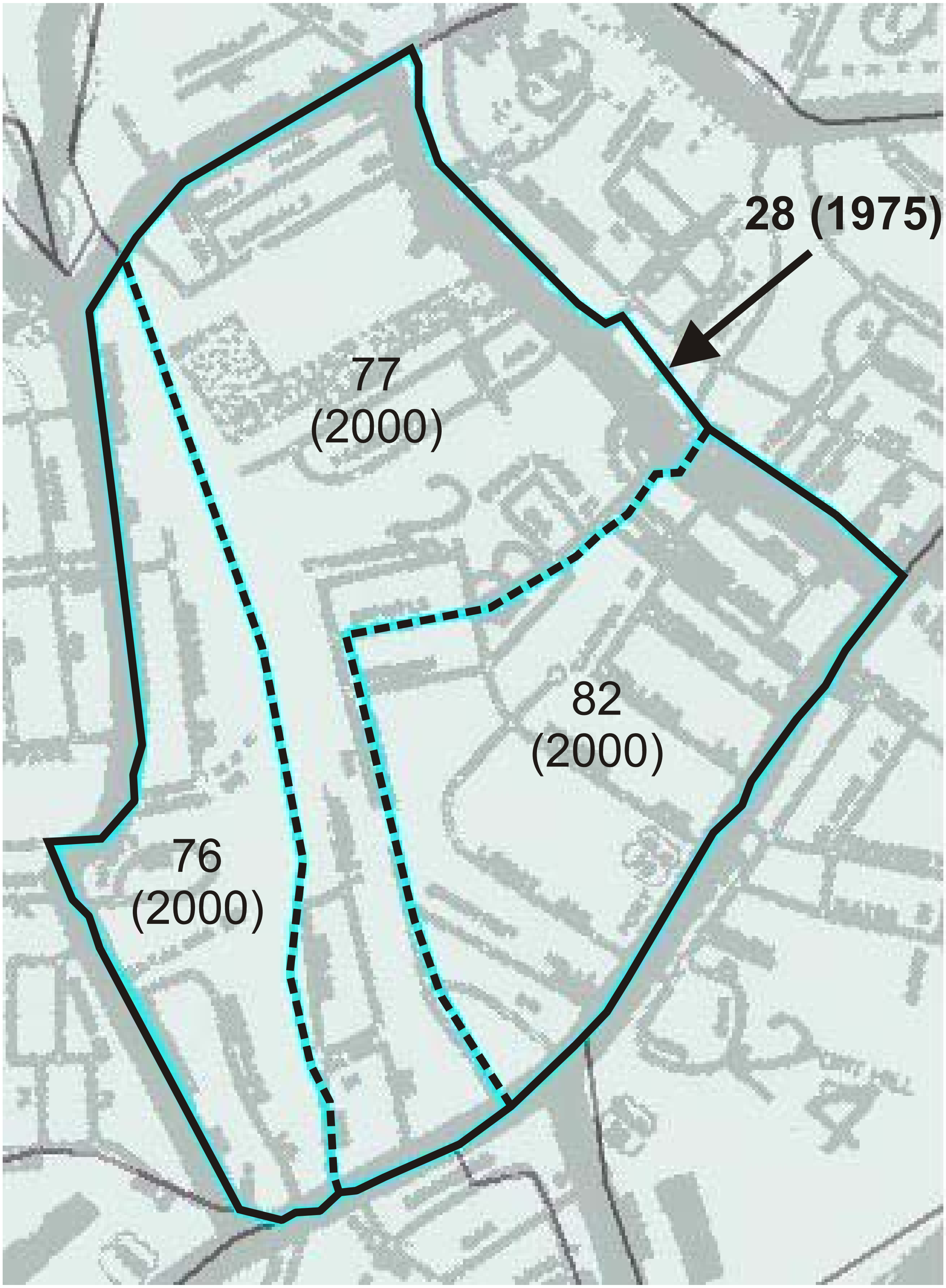

Figure 1. Aggregation of 2000 TAZs to Be Comparable to 1980 TAZs

Table 4. Comparison of Actual and Forecast Variables for Entire Lynchburg Region and Individual TAZs

Variable	Forecast[a]	Actual[b]	Study Area		Zone Average	
			AE[c]	PE[d]	MAE[e]	MPE[f]
Population	179,309	121,078	58,231	48.1%	1,177	61.0%[g]
Households	54,317	47,510	6,807	14.3%	265	65.3%[g]
Total employment	68,606	74,154	5,548	7.5%	716	154%
Retail employment	11,799	11,660	139	1.2%	137	179.8%[h]
Non-retail employment[i]	56,807	62,494	5,687	9.1%	1,126	388.2%
Vehicles	78,716	87,319	8,603	9.9%	649	53.8%[g]

AE = absolute error; PE = percent error; MAE = mean absolute error; MPE = mean percent error.
[a]Sum of all TAZ forecast values.
[b]Sum of all TAZ actual values.
[c]Calculated absolute error.
[d]Calculated percent error.
[e]Sum of individual absolute error for each TAZ divided by 68.
[f]Sum of individual percent error for each TAZ divided by 68 or number of zones with a percent error.
[g] For population, households, and vehicles, Zone 5 had no actual values, which yields dividing by zero in Eq. 2. Thus, the percent average was computed with the remaining 66 – 1 = 65 zones.
[h]For retail employment, 14 zones had no actual retail employment, which yields dividing by zero in Eq. 2. Thus, the percent average was computed with the remaining 66 – 14 = 52 zones.
[i]Variable not forecast in 1980 plan; instead, it was calculated as the difference between total and retail employment.

Reasons for Difference Between Forecast and Actual Values

Two factors contributed to the difference between forecast and actual values: (1) the expected large development did not materialize, and (2) the control totals for surrounding counties did not match actual values. For this study area, the impact of the former was much greater than the impact of the latter.

Major Source of Error: Expected Large Development Did Not Materialize in Two Zones

Further data analysis provided a possible explanation for the large magnitude of error for some variables compared in the case study. Figure 2 is a scatter plot of population residuals for each case study TAZ. Zones 17 and 52 are outliers with a large over projection of population that deviated from population errors for all other zones (all of which were between -2,509 and 2,195 population).

The combined over projection of population for TAZs 17 and 52 accounts for approximately 80% of the population forecast error for the entire study area. Together, the two zones accounted for 53,000 in forecast population; however, only 6,707 in population actually resided there in year 2000: approximately 46,600 in population less than anticipated.

These two adjacent TAZs (19.5 square miles) are situated in Campbell County and the City of Lynchburg and are partially enclosed by three primary corridors: U.S. 29, U.S. 460, and U.S. 501. Although each TAZ is located in two jurisdictions, only 7% of the combined area is located in the City of Lynchburg, with the remaining land mass in Campbell County, thus accounting for the larger over projection of population in Campbell County. TAZs 17 and 52 represent two discrete zones from the 1980 dataset; therefore, it is highly unlikely that aggregation of the base zonal structure contributed to this error.

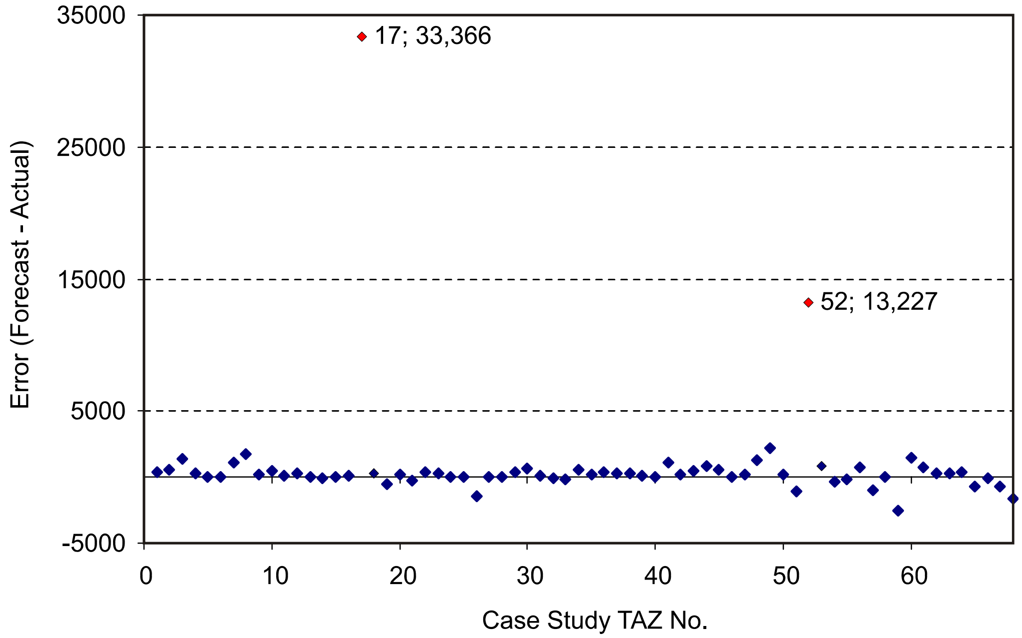

Figure 2. Population Residuals for Case Study TAZs

Figure 3 shows that the same case study zones (17 and 52) also contributed to the large error for households forecast for year 2000. It can be seen that TAZ 52 had a larger error than TAZ 17, accounting for approximately 4,600 households expected by year 2000 that did not materialize.

Table 5 shows the study area error and average zone error for each variable when zones 17 and 52 were eliminated from the dataset. The results were a lower population study area error of 10% and a lower household study area error of approximately 1%. These two zones accounted for approximately 80% of the population error and 90% of the household error.

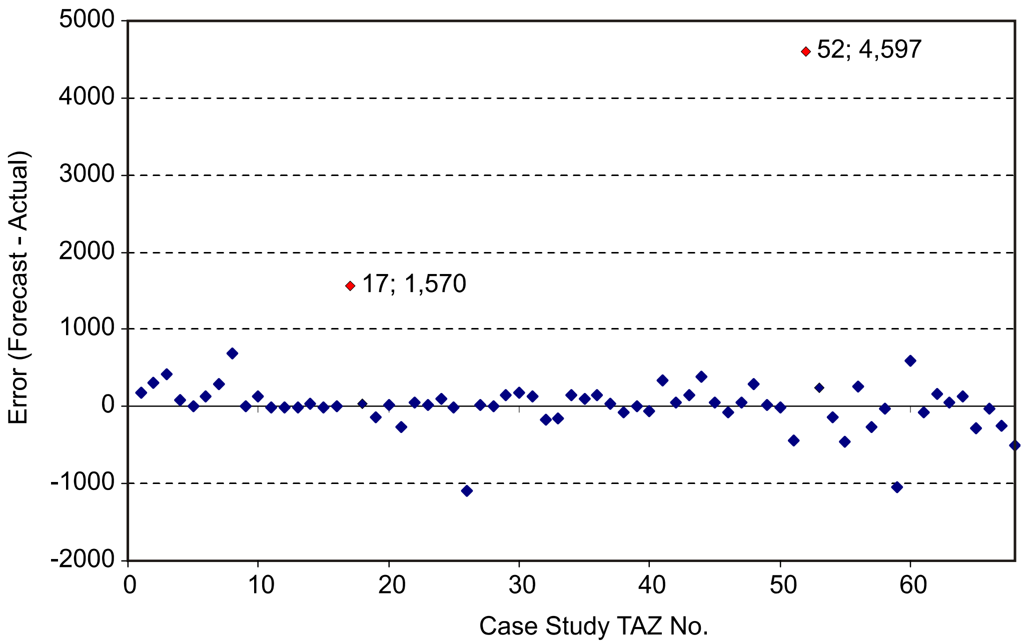

Figure 3. Household Residuals for Case Study TAZs

Table 5. Summary of Results by Variable without TAZs 17 and 52

	Forecast[a]	Actual[b]	Study Area		Zone Average	
			AE[c]	PE[d]	MAE[e]	MPE[f]
Population	126,009	114,371	11,638	10.1%	492	39.0%[g]
Households	46,577	45,937	640	1.3%	176	47.7%[g]
Total employment	63,485	72,395	8,910	12.3%	667	135.6%
Retail employment	11,632	11,323	309	2.7%	139	184.9%[h]
Non-retail employment[i]	51,853	61,471	9,618	15.6%	1096	359.1%
Vehicles	58,723	82,024	23,301	28.4%	446	44.9%[g]

[a]Sum of all TAZ forecast values.
[b]Sum of all TAZ actual values.
[c]Calculated absolute error.
[d]Calculated percent error.
[e]Sum of individual absolute error for each TAZ divided by 66.
[f]Sum of individual percent error for each TAZ divided by 66 or number of zones with a percent error.
[g] For population, households, and vehicles, Zone 5 had no actual values, which yields dividing by zero in Eq. 2. Thus, the percent average was computed with the remaining 66 – 1 = 65 zones.
[h]For retail employment, 14 zones had no actual retail employment, which yields dividing by zero in Eq. 2. Thus, the percent average was computed with the remaining 66 – 14 = 52 zones.
[i]Variable not forecast in 1980 plan; instead, it was calculated as the difference between total and retail employment.

Although study area population and household errors decreased, errors for employment and vehicle ownership increased. This suggests that employment and vehicle ownership errors were distributed evenly among zones other than 17 and 52.

Table 6 shows the forecast and actual population to household ratios for the study area and zones 17 and 52. The ratio for TAZ 52, which was 13.2 persons per household, was higher than the forecast average ratio of 3.3 persons per household or the statewide 2000 average of approximately 2.8 persons per household shown in Figure 4. Had TAZs 17 and 52 not been part of the study, the ratio would have been 2.7 persons per household, which is relatively close to the statewide average for 2000.

Although Table 3 indicated that *group quarters* was not explicitly considered in the 1980 report (VDH&T, 1980), it is possible that group quarters were expected to accommodate the over

Table 6. Population: Forecast and Actual Household Ratios

Area	Forecast 2000[a]			Actual 2000[b]		
	Population	HHS	Population: HHS Ratio	Population	HHS	Population: HHS Ratio
TAZ 17	36,100	2,740	13.2	2,734	1,170	2.3
TAZ 52	17,200	5,000	3.4	3,973	403	9.9
Total study area	179,309	54,317	3.3	121,058	47,503	2.5
Total study area (without TAZs 17 and 52)	126,009	46,577	2.7	114,351	45,930	2.4

HHS = Households.
[a]Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan*, Richmond, 1980.
[b]Michael Baker Jr., Inc., *2030 Lynchburg Area Transportation Study*, Virginia Department of Transportation, Richmond, 2005.

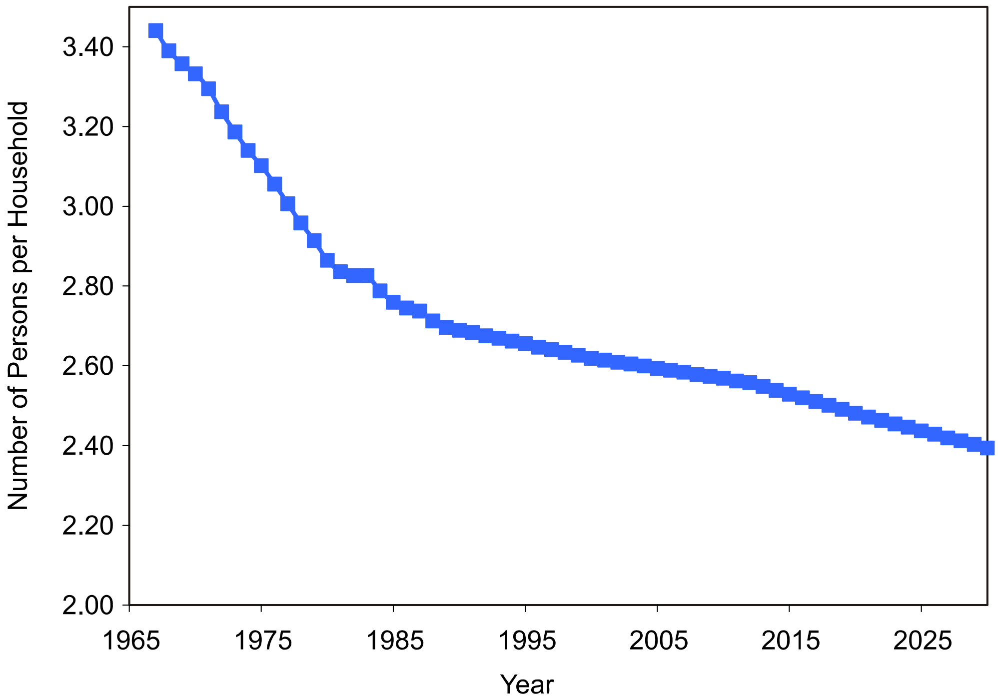

Figure 4. Trends in Persons per Household in Virginia, 1967-2030. The figure was drawn from data presented by NPA Data Services, Inc., in *Stateside Service CD*, Arlington, VA, 2003.

forecast population in TAZ 17. This inference, that group quarters were expected to accommodate some of the over projected population, suggests this unique factor was not common throughout the study area and influenced the projection of population and households for Case Study TAZs 17 and 52. The 1980 plan specifically identified Liberty Baptist College (present day Liberty University) as one of the major planned developments considered in the 2000 forecast. Liberty University is located in the area identified as TAZs 17 and 52. In addition, the university is specifically identified in the 1980 plan as a special generator of population increase:

> The estimated Study Area population of 112,000 in 1978 is forecast to increase to 179,000 by the year 2000, a 60% increase. This 2.7% increase per year growth rate far exceeds the 1.2% per year growth rate for the State. This is directly attributed to the projected increase in population as a result of the Liberty Baptist College planned expansions (VDH&T, 1980).

During the early 1980s, a golf course and retirement community of more than 1,000 homes were planned for the same area of the region (Youngblood, R., personal communication, February 25, 2008). Although the 1980 study does not explicitly document plans for a golf course/retirement community, it is possible that the planned community had the potential to have a greater influence on household forecast, particularly for Zone 52, which had a relatively lower forecast person to household ratio.

The planned expansion development of the university clarifies the large population to household ratio for TAZs 17 and 52. College dormitories are group quarters, which were not identified in the 1980 report. These findings suggest that the anticipated expansion of Liberty University led to the over projection of population for year 2000. The omission of group quarters in the forecast also explains why the household error was larger for TAZ 52 than for TAZ 17 (Figure 3) and the population error was smaller for TAZ 52 than for TAZ 17 (Figure 2).

Minor Source of Error: Control Totals for Surrounding Counties Did Not Match Actual Values

U.S. Census data from the Weldon Cooper Center for Public Service (2008) were used to compare the accuracy of control totals for this study area. The City of Lynchburg is the only jurisdiction located completely within the study area. For Amherst, Bedford, and Campbell counties, only the urbanized portions (areas of higher density compared to the other portions of the county) were included in the case study area. Because U.S. Census data encompass an entire jurisdiction and not just the urbanized portion, a direct comparison between the U.S. Census data and the case study data is feasible only for the City of Lynchburg.

Table 7 shows how the actual U.S. Census population, the forecast Department of Planning and Budget (DPB) population, and the forecast case study population changed between 1980 and 2000. (At present, control totals are generated by VEC, but in 1983, at the time the *Lynchburg Area Transportation Study: Year 2000 Transportation Plan Technical Report* [VDH&T, 1983] was published, it appears that control totals were generated by DPB.) The report noted:

> Jurisdictional population control totals were formulated after an analysis of population projections by the Commonwealth of Virginia's Department of Planning and Budget (DPB), a review of historic population growth trends for the jurisdictions, reviews of local comprehensive plans, and with the knowledge of major developments (e.g., Liberty Baptist College) gained through the process of reviewing their master plans and/or development impact studies (VDH&T, 1983).

Table 7. Jurisdiction Population Data for Lynchburg Region

Jurisdiction	U.S. Census Data[a]			DPB	Case Study Data[c]		
	1980	1990	2000	2000 Forecast[b]	1980 Base[d]	2000 Forecast[e]	2000 Actual[f]
City of Lynchburg	66,743	66,049	65,269	71,900	68,377	74,491	62,585
Amherst County	29,122	28,578	31,894	33,700	17,281	28,766	24,758
Bedford County	34,927	45,656	60,371	41,100	4,049	6,600	10,417
Campbell County	45,424	47,572	51,078	54,500	14,427	69,451	23,318

DPB = Commonwealth of Virginia Department of Planning and Budget.
[a]U.S. Census data account for the entire area of each jurisdiction. Data from Weldon Cooper Center for Public Service, *Demographics and Workforce*, Charlottesville, VA. www.coopercenter.org/demographics. Accessed March 2007.
[b]Commonwealth of Virginia, Department of Planning and Budget, *Planning Projections: Virginia Counties and Cities:1980-2000*, Richmond, June 1977.
[c]The case study area includes all of the City of Lynchburg and urbanized portions of Amherst, Bedford, and Campbell counties. Census data for Amherst, Bedford, and Campbell County includes more than the case study area population.
[d]Data from Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan*, Richmond, 1980.
[e]Data from Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan*, Richmond, 1980.
[f]Data from Michael Baker Jr., Inc., *2030 Lynchburg Area Transportation Study*, Virginia Department of Transportation, Richmond, 2005.

For Lynchburg, the U.S. Census data showed that population *decreased slightly* between 1980 and 2000 whereas the case study showed that a 9% *increase* in population between 1980 and 2000 was forecast. The case study forecast was larger than the DPB forecast because jurisdictions were allowed to adjust VEC control totals by 10% (Caldwell, L., personal communication, February 25, 2008) and it seems reasonable to assume that this provision would have been applicable to a DPB control total.

For Amherst, Bedford, and Campbell counties, Table 7 shows actual population increases (from the U.S. Census) and projected population increases (from the DPB and the case study). Numerically, the overprojection of 4,008 population for the urbanized portion of Amherst County (where 28,766 population were forecast but the actual population was only 24,758) tended to compensate for the under projection of 3,817 population for the urbanized portion of Bedford County (where 6,600 population were forecast but the actual population was 10,417). The largest discrepancy occurred with Campbell County, where the 2000 forecast exceeded the 2000 actual population by 46,133 people. The difference for Campbell County may be attributed to the influence of planned developments on the forecast. The 1980 plan (VDH&T, 1980) anticipated larger growth for Amherst, Bedford, and Campbell counties as "rapid population growths were occurring in the suburban areas with little growth or actual declines in the central city."

Jurisdiction control totals also affected other forecasts. For example, although the actual number of jobs was greater than the forecast values for each jurisdiction, the combined total employment percent error for Amherst and Bedford was greater than 40%. This contributed to a larger employment error by zone, although, as shown in Table 4, the study area employment error remained relatively small at 7.5%.

Identified Practices for Improving the Accuracy of Forecasts by Medium-Sized MPOs in Virginia

The following 10 effective practices were identified during the course of this research; some were provided by interviewees and others were based on practices identified in the literature review or during the case study. They are not necessarily comprehensive. The details, including the origins, of these practices are provided in Appendix F.

1. Update regional forecasts more frequently than every 5 years. Such updates may be initiated by MPOs (through conducting more periodic updates) or localities (by communicating updates to the MPO as soon as anticipated changes in local land use, such as rezonings, are evident).

2. Recognize that despite a region's best efforts, forecasts will have some error. Thus, consider developing two sets of forecasts: (1) the best estimate, and (2) this estimate modified by a high or a low percentage.

3. After the travel demand model has been executed with the two sets of forecasts developed in Practice 2, assess how the resultant recommendations might be affected.

4. Consider whether the various types of forecast errors that are possible, such as discrepant population forecasts or trip generation forecasts, are likely to *compound* or *cancel*.

5. If performing a trend analysis, consider the extent to which previous trends will likely be good indicators of future trends.

6. Consider the extent to which economic development (or other exogenous factors) may influence forecasts.

7. Use a judicious mix of analytical procedures and local knowledge, the latter of which is critical for shorter-term forecasts.

8. When presenting possible forecasts to a steering committee, ask the members to comment not just on the forecast (such as the employment in 2030 for a given subset of exurban zones) but also on the inherent assumptions (such as the extent to which the exurban area will remain an attractive employment location relative to other zones within the region).

9. Use the American Community Survey as appropriate to update certain trends, such as number of vehicles per household.

10. Discuss with the district planner or persons executing the travel demand model the types of data that are required for the model for the particular region.

Practices 1, 2, and 10 were also discussed with the project steering committee with regard to how they could be implemented in Virginia. That conversation reinforced four main observations pertaining to the feasibility of implementing these practices in Virginia.

First, for all three practices, the division of responsibilities is that the travel demand model is operated by VDOT whereas the socioeconomic forecasts are performed by MPOs. Accordingly, although VDOT may support these practices, it is the MPOs' decision as to whether these practices should be adopted. The committee suggested that one way to encourage such an adoption is to have a forum where MPOs could share lessons learned regarding socioeconomic forecasts. (The details of this suggestion are provided in Recommendation 2 of this report.)

Second, there is no single best answer regarding how often forecasts should be updated as noted in Practice 1. Although very frequent updates (e.g., annually) might be desirable in terms of data accuracy, the conversation with the steering committee indicated that for some MPOs with very small staff, annual updates might be infeasible. In such a situation, it was hypothesized that an MPO might simply ignore the recommendation. Accordingly, it was recognized that updates should be more frequent than the minimum of every 5 years, but it was suggested that an exact frequency (e.g., every year, 2 years, etc.) not be given. The details of this suggestion are shown as Recommendation 1 of this report.

Third, it was noted that MPOs may have local knowledge that gives them a better estimate of forecast accuracy than that noted herein, especially if larger MPOs were to consider these recommendations. Thus regarding Practice 2, it was suggested that MPOs could use, at their preference, either the estimates of accuracy based on this case study or estimates of accuracy based on the MPO's own research. The details of this suggestion are shown as Recommendation 3 of this report.

Fourth, the discussions with the steering committee better articulated the role of the VDOT district planner who, like MPO staff, has local knowledge of the area being studied and is in a position to assess the data requirements of the travel demand model. Accordingly, Practice 10 is the subject Recommendation 4 of this report.

SUMMARY

As stated in the "Purpose and Scope" section, the purpose of this study was threefold: (1) to identify the socioeconomic forecasting practices used by medium-sized MPOs in Virginia, (2) to document the accuracy of previous socioeconomic forecasts by such MPOs by means of a case study approach, and (3) to identify practices for improving the accuracy of such forecasts.

Socioeconomic Forecasting Practices Used by Medium-Sized MPOs in Virginia

The method medium-sized MPOs in Virginia use for forecasting socioeconomic variables may be summarized as follows:

- Create jurisdictional population control totals based on VEC population projections, historic population trends for each jurisdiction, local comprehensive plans, and master plans for major developments.

- Modify control totals based on local comprehensive plans, master plans, and population trends. In Virginia, jurisdictions may override population control totals by 10%.

- Disaggregate jurisdictional population projections to traffic zones based on knowledge of planned developments, land use plans, and comprehensive plans.

- Use historic ratios of dwelling units to population and auto to population to derive forecast dwelling units and autos.

- Use historic trends to forecast employment and school enrollment for each zone.

Accuracy of Previous Socioeconomic Forecasts by Medium-Sized MPOs in Virginia

The Lynchburg metropolitan region was used in a case study to determine the accuracy of previous socioeconomic forecasts by medium-sized MPOs in Virginia.

There were three major findings:

1. *The study area percent error and the average zone percent error of five socioeconomic variables were found to be as follows.*

- *Population:* study area percent error of 48.1% (58,231 population), average zone percent error of 61% (1,177 population).
- *Households:* study area percent error of 14.3% (6,807 households), average zone percent error of 65% (265 households).
- *Retail employment:* study area percent error of 1.2% (139 jobs), average zone percent error of 180% (137 jobs).
- *Non-retail employment:* study area percent error of 9.1% (5,687 jobs), average zone percent error of 388% (1,126 jobs).
- *Vehicle ownership:* study area percent error of 9.9% (8,603 vehicles), average zone percent error of 54% (649 vehicles).

2. *Eighty percent of the study area population error resulted from two contiguous zones, where a large expected development did not occur.* Case study zones 17 and 52, geographically bound by U.S. Routes 460, 29, and 501, accounted for the largest portion of the study area population error. Proposed development expansions of Liberty University and the new development of a golf course with retirement home facilities did not occur within the horizon time period of the forecast. The absolute population error of these two zones (46,593 population) accounted for 80% of the absolute population error (58,231 population) for the entire study area. The remaining 20% of study population error was distributed among all remaining zones.

In addition, combined case study zones 17 and 52 accounted for a large portion of study area error for all other variables:

- *Households:* error of 6,167 households compared to study area error of 6,807 households
- *Vehicle ownership:* error of 14,698 vehicles compared to study area error of 8,603 vehicles
- *Non-retail employment:* error of 3,930 jobs compared to study area error of 5,687 jobs
- *Retail employment:* error of 170 jobs compared to study area error of 139 jobs.

3. *Zone residuals, the difference between actual and desired zone values, tended to cancel out such that the overall study area error was much smaller than the sum of the absolute*

errors by zones. After the two zones that anticipated significantly large development were excluded, the average zone error for population was 39% and the study area population error was only 10%. As area size increased, the accuracy of the forecast improved with positive and negative zone residuals cancelling such that the study area error was reduced.

Identified Practices for Improving Accuracy of Forecasts by Medium-Sized MPOs in Virginia

As stated previously, 10 practices were identified for improving the accuracy of forecasts. They are provided in Appendix F. Although VDOT can support implementation of some of these practices (such as executing the travel demand model with two sets of inputs if requested), the final decision for several of these practices (such as providing two sets of inputs) rests with the MPO.

CONCLUSIONS

- *Medium-sized MPOs in Virginia use similar methods to forecast socioeconomic variables.* For example, MPOs modify use local and master plans, population trends, and VEC information to forecast future population in a given traffic analysis zone.

- *For MPOs using the methodology outlined in this report, the case study suggested relatively high average zone percent errors. For example, assuming no unforeseen large-scale change in land development, such errors for population and employment were 39% and 136%.*

- *For MPOs using the methodology outlined in this report, the case study suggested comparatively smaller study area percent errors. For example, assuming no unforeseen large-scale change in land development, such errors for population and employment were 10% and 12%.*

- *More frequent updates are the single most effective recommendation for improving the accuracy of socioeconomic forecasts given the methodology in use at present,* For example the case study demonstrates that knowledge development would not materialize as anticipated in two of the study's 68 zones reduces the study area population error from 48% to 10%.

- *Forecast errors are unavoidable and thus should be recognized when applying the travel demand model*. The above conclusion addresses one way to reduce these errors, but several of the ten best practices noted in Appendix F concern assessing how potential discrepancies affect the results of the travel demand model.

RECOMMENDATIONS

1. *The locality should communicate changes in anticipated local land development on a more frequent basis to the MPO and PDC staff that are developing socioeconomic forecasts*. In some cases, socioeconomic forecasts are updated only once every 5 years. In the future, socioeconomic forecasts should be performed more frequently. As the Lynchburg case study suggested, incorporating anticipated land development changes as soon as they are known may eliminate 80% of the error in population forecasts. This recommendation may be implemented by the MPO (by performing the updates more frequently) but also to some extent by localities (by providing the updated information more frequently). This recommendation corresponds to Practice 1 in Appendix F.

2. *MPOs should consider holding, attending, or supporting forums that allow the dissemination of effective socioeconomic forecast practices.* Such forums might include:

   - annual meetings held by the Virginia Association of Planning District Commissions

   - a users' group to enable MPOs to share ideas concerning socioeconomic forecasts

   - a 1-day workshop hosted by the Virginia Local Technical Assistance Program (VLTAP) to provide training regarding socioeconomic forecasts

   - a meeting organized by VEC to seek comments from MPOs regarding control totals (if Recommendation 1 is implemented, the MPOs may be in a position to provide feedback to VEC based on local changes in land use).

   The 10 effective forecast practices provided in Appendix F might serve as a starting point for such a forum. In the absence of such a forum, this recommendation could be implemented by MPOs using the best practices noted therein.

3. *MPOs should consider providing two socioeconomic forecasts for the travel demand model: (1) the baseline forecast, which is the MPO's best estimate, and (2) the baseline forecast modified by a high or low value based on either local expertise or the default adjustments provided in Table 8.*

   As noted in the "Conclusions" section, for MPOs using the methodology outlined in this report, the case study suggested that zone population errors might be as high as 39% assuming no unforeseen large-scale change in land development. Thus, a travel demand model that uses a high and a low population value would enable decision makers to understand the extent to which population errors affect the travel demand forecast. High and low values vary by study area, forecasting method, and socioeconomic variable. Thus, these high and low values may be based on local knowledge or on the information provided in Table 8, which shows the percent errors from the case study examined in this report.

   This recommendation may be implemented several different ways depending on the concerns of the particular MPO. As suggested in Table 9, adjustments may be based on either local knowledge or the values given in Table 8. The high and low values may be based on an entire region or just a portion of the region that is expecting an exceptional change in growth. This recommendation corresponds to Practice 2 in Appendix F.

Table 8. Default Adjustments to Socioeconomic Forecasts[a]

Scenario	Population	Households	Total Employment	Retail Employment	Non-Retail Employment	Vehicles
Entire study area	+/- 10%	+/- 1%	+/- 12%	+/- 3%	+/- 16%	+/- 28%
Individual zone	+/- 39%	+/- 48%	+/- 136%	+/- 185%	+/- 359%[b]	+/- 45%

[a]These default adjustments are the percent errors based on the case study in this report. They may be modified based on local knowledge.
[b]This large value appears to have resulted because retail employment was a small portion of total employment and may be modified based on local knowledge.

Table 9. Implementation Options for Recommendation 3

Scenario	What MPO Requests
MPO forecasts region's population to be 100,000 in 20 years but is concerned that study area population may be underestimated. Previous forecasts have shown that population was underestimated by 5%.	Run travel demand model twice: once with population of 100,000 and once with regional population of 105,000.
MPO forecasts region's population to be 100,000 in 20 years but is concerned that population may be underestimated. No knowledge of historical forecast accuracy is available.	Run travel demand model twice: once with population of 100,000 and once with regional population of 110,000, based on study area adjustment shown in Table 8.
MPO forecasts region's population to be 100,000 in 20 years but is concerned that population growth may occur in western part of region as opposed to eastern part. No knowledge of historical forecast accuracy is available.	Run travel demand model twice: once with population of 100,000 as forecast by MPO. Then, decrease zone population in eastern zones by 39% and increase zone population in western zones by 39%, based on zone population adjustment shown in Table 8.
MPO is concerned about forecast in 3 zones where new industrial park is expected to increase employment. Although new employment for these 3 zones is 25,000, MPO views this forecast as highly variable.	Run travel demand model twice: once with employment of 3 zones as 0 and once with employment of 3 zones increased by 136% as shown by zone employment adjustment in Table 8.
New MPO forecasts region's population to be 100,000 but would like to investigate fully impact of uncertainty in population and auto ownership. MPO believes employment projections are credible, however.	Run travel demand model 3 times: 1. with baseline values provided by MPO 2. with reducing zone population and vehicles by 39% and 45%, respectively, as shown in Table 8 3. with increasing zone population and vehicles by 39% and 45%, respectively, as shown in Table 8.

4. *VDOT should provide a forum regarding guidance and/or best practice guidelines for MPOs completing socioeconomic forecasts.* The district planner is a place within VDOT for disseminating such information. The guidance should include directions for conducting the scenario analysis as discussed in Recommendation 3. This corresponds to Practice 10 in Appendix F.

COST AND BENEFITS ASSESSMENT

Each of the four recommendations identified for this project has a benefit/cost tradeoff. Although each requires effort that will benefit the overall transportation planning process, there is relatively low risk associated with implementation as the recommendations will likely improve coordination and effectiveness of socioeconomic forecasting for MPOs.

Recommendation 1. The *cost* is the additional person-hours required to update all socioeconomic variables in all zones and thus will vary as a function of the land development. The following may be considered an example: A county approves eight new developments per year and performs these updates annually. Assuming between 4 and 8 hours are required to update population, households, employment, and vehicles based on each development, between 40 and 80 total hours will be required. The *benefit* is more accurate socioeconomic data for the travel demand model. Both local jurisdictions and MPOs will be beneficiaries as updated socioeconomic data are essential when major transportation decisions are made at the local and regional levels. (Although it is theoretically possible that making updates too frequently could compound existing errors, this risk appears to be lower than the current risk of not providing updates frequently enough, given that the current updates are, in some cases, every 5 years.)

Recommendation 2. The *cost* is (1) the hours spent by MPOs who undertake the training and (2) the hours required to organize the training session. Although an MPO attending the training may need only 8 to 16 person-hours, the cost of preparing the training is highly variable and cannot be estimated reliably. The benefits are, in concert with Recommendation 1, more accurate socioeconomic data for the travel demand model. Improved accuracy of input data will improve the accuracy of model results such as forecast vehicle miles traveled for particular corridors.

Recommendation 3. The *costs* are (1) the hours spent by the MPO identifying the maximum expected error for the new scenario and (2) the person-hours spent by VDOT Transportation and Mobility Planning Division staff responsible for the travel demand models. Both costs are highly variable because of (1) the number of scenarios considered for each sensitivity analysis and (2) the availability of historic information regarding forecast accuracy. The *benefit* is multiple travel demand forecast scenarios for a metropolitan area with a range of possible development patterns that may occur. Such efforts will provide additional projected growth details for transportation decision makers when deciding on the scheduling and funding of specific projects.

Recommendation 4. The cost is highly variable. It may be as small as a communication between the VDOT district planner and an MPO representative or it may be a longer series of discussions that also involves MPO forecasters and the VDOT staff who run the travel demand model. The *benefits* are a clearer understanding of how the MPO forecast quality affects the utility of the travel demand model and, by extension, more useful modeling results.

There is another potential benefit associated with Recommendations 1 and 3 that may or may not materialize in the future. If localities take a greater role in planning, constructing, or maintaining their transportation systems in the future than has been the case in the past, accurate travel demand forecasts—which require accurate socioeconomic forecasts—may take on greater importance at the local level. Thus, a mechanism to communicate updates of socioeconomic data more frequently (Recommendation 1) and an ability to identify a forecast range rather than only a single value (Recommendation 3) may be of interest to localities that take a more active role in designing their transportation systems.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the information provided by interviewees: Bob Ball (Virginia Department of Transportation), John Bishop (Frederick County), Mark McCaskill and Matt Miller (Roanoke Valley-Alleghany Regional Commission), Bob White (Virginia's Region 2000), Andrew Williams (Central Shenandoah PDC), Rick Youngblood (VDOT), and Tim Youmans (City of Winchester). This project also benefited from the participation of an active steering committee composed of Paul Agnello, Ed Azimi, Larry Caldwell, Bahram Jamei, Bill Mann, Rick Tambellini, and Rick Youngblood. All steering committee members are affiliated with VDOT. Audrey Moruza of Virginia Transportation Research Council (VTRC) provided insight into some of the intangible benefits and costs associated with the four recommendations, Randy Combs of VTRC provided assistance with the graphics, and Linda Evans of VTRC provided editing.

REFERENCES

Garber, N.J., and Hoel, L.A. *Traffic & Highway Engineering*, 4th Ed. Cengage Learning, Toronto, Ontario, Canada, 2009.

Hanson, S., and Giuliano, G. *The Geography of Urban Transportation*, 3rd ed. The Guilford Press, New York, 2004.

Institute of Transportation Engineers. *Transportation Planning Handbook*, 2nd Ed. Prentice Hall, Englewood Cliffs, NJ, 1992.

Martin, W.A., and McGuckin, N.A. *NCHRP Report 365: Travel Estimation Techniques for Urban Planning*. Transportation Research Board, Washington, DC, 1998.

Meyer, M.D., and Miller, E.J. *Urban Transportation Planning*, 2nd Ed. McGraw-Hill, New York, 2001.

Michael Baker Jr., Inc. *Lynchburg MPO 2000 Model Development Technical Report.* Virginia Department of Transportation, Richmond, 2005.

Murdock, S.H., Hamm, R.R., Voss, P.R., Fannin, D., and Pecotte, B. Evaluating Small-Area Population Projections. *Journal of the American Planning Association,* Vol. 57, No. 4, 1991, pp. 432-443.

Roanoke Valley Area Metropolitan Planning Organization. *Roanoke Valley Area Metropolitan Planning Organization Long-Range Transportation Plan: 2025 Technical Report.* Roanoke, VA, 2006.

Transportation Research Board, Subcommittee on Census Data for Transportation Planning. *Census Data for Transportation Planning.* Washington, DC, September 2002. http://www.trbcensus.com/taz.html. Accessed September 2008.

U.S. Census Bureau. *Population and Household Economic Topics.* Washington, DC, 2007. http://www.census.gov/population/www/index.html. Accessed September 2007.

U.S. Department of Transportation. *Census Transportation Planning Package.* Washington, DC, 2006. http://www.fhwa.dot.gov/ctpp/. Accessed June 5, 2007.

U.S. Department of Transportation. *Transportation Planning Capacity Building: Metropolitan Planning Organization (MPO) Database.* Washington, DC, 2007. http://www.planning.dot.gov/metro.asp. Accessed March 2008.

Virginia Department of Highways & Transportation. *Lynchburg Area Transportation Study: Year 2000 Transportation Plan*. Richmond, 1980.

Virginia Department of Highways & Transportation. *Lynchburg Area Transportation Study: Year 2000 Transportation Plan Technical Report.* Richmond, 1983.

Virginia General Assembly. *Code of Virginia*. Richmond, 2007. http://leg1.state.va.us/000/src.htm. Accessed September 2007.

Wegmann, F., and Everett, J. *Minimum Travel Demand Model Calibration and Validation Guidelines for State of Tennessee*. University of Tennessee Center for Transportation Research, Knoxville, 2008. http://ctr.utk.edu/TNMUG/misc/valid.pdf. Accessed March 2008.

Weldon Cooper Center for Public Service. *Demographics and Workforce.* Charlottesville, VA. www.coopercenter.org/demographics. Accessed September 2008.

APPENDIX A

EXAMPLE OF ROANOKE VALLEY-ALLEGHANY REGIONAL SOCIOECONOMIC FORECASTING PROCEDURE

This appendix illustrates how RVARC updates base year data (Step 1), projects values for the future (Step 2), and verifies forecasts with local jurisdictions (Step 3). The procedure used by RVARC in 2001 to forecast socioeconomic variables for year 2025 using 2000 base year data is highlighted here. The authors offer a simplified example for each step to illustrate how actual calculations were performed.

1. Update Base Year Data (2000).

Variables updated included population, housing units, households, passenger vehicles available, and employment. Ideally, the U.S. Census Bureau's Census Transportation Planning Package (CTPP) is used for identifying the base year data. However, the CTPP is typically published 4 to 6 years after each decennial census. For example, the 2000 CTTP was published in 2004 (Federal Highway Administration, 2006). The 2025 forecast was completed in 2001, prior to the publication of the 2000 CTPP. Therefore socioeconomic data from the previous 1995 update were used to determine 2000 base year conditions (with the exception of population, for which 2000 U.S. Census data were used). Once 2000 CTPP data were published in 2004, base year data were updated to reflect the true demographic characteristics of the region more accurately. A description and example are provided to explain how each variable was updated.

Population

Population was updated at the zonal level by aggregating 2000 U.S. Census block data for each TAZ. Table A1 provides an example of updated population (base year 2000) for TAZ "X":

Table A1. 2000 U.S. Census Data for Population for TAZ "X"

Block Group	Total Population
1	127
2	36
3	36
4	30
5	26
Total	225

Base Year 2000 Population TAZ "X" $= \sum$ *(Population Block Group*$_{N)}$ *= 225*

Housing Units

Ideally, 2000 CTPP data would be used to update the housing units variable. However, as noted previously, this projection was completed in 2001 and the 2000 CTTP was not released until 2004. Therefore, housing units data were updated using the most recent socioeconomic data from 1995. A scale factor equal to the ratio of 1995 population to 1995 housing units was used to estimate housing units in 2000 for each TAZ. An overall population to housing units ratio for the study area was not applied to each TAZ; instead, it was assumed that the population to housing units ratio was uniquely different for each TAZ. Table A2 provides an example of updated housing units (base year 2000) for TAZ 206 in Salem, Virginia.

Table A2. 1995[a] and 2000[b] Population for TAZs 205, 206, and 207 in City of Salem, Virginia

Update Year	Zone	Population	Housing Units	Population: Housing Units Ratio
1995	205	1551	583	2.66
	206	311	132	2.36
	207	1034	398	2.60
2000	205	1689		
	206	301		
	207	781		

[a]Fifth Planning District Commission, *1995 Transportation Planning Data for Roanoke Metropolitan Planning Area,* Roanoke, VA, May 1998.
[b]Roanoke Valley Area Metropolitan Planning Organization, *RVAMPO Long-Range Transportation Plan 2025 Technical Report,* Roanoke, VA, 2006.

Given the 1995 population, 1995 housing units, and 2000 population data, base year 2000 housing units were estimated for TAZ 206 in the City of Salem as 128 units.

$$\text{HousingUnitsTAZ206}_{2000} = (\text{PopulationTAZ206}_{2000}) * \left(\frac{\text{HousingUnitsTAZ206}_{1995}}{\text{PopulationTAZ206}_{1995}} \right) = (301) * \left(\frac{132}{311} \right) = 128$$

The same calculation was used to determine housing units for TAZ 205 and 207. Table A3 shows the estimated housing units for base year 2000 in bold type.

Table A3. 1995[a] and 2000[b] Population and Housing Units for TAZs 205, 206, and 207 in City of Salem, Virginia

Update Year	Zone	Population	Housing Units	Population: Housing Units Ratio
1995	205	1551	583	2.66
	206	311	132	2.36
	207	1034	398	2.60
2000	205	1689	**635**	2.66
	206	301	**128**[c]	2.36
	207	781	**300**	2.60

Numbers in bold type indicate the estimated housing units for base year 2000.
[a]Fifth Planning District Commission, *1995 Transportation Planning Data for Roanoke Metropolitan Planning Area,* Roanoke, VA, May 1998.
[b]Roanoke Valley Area Metropolitan Planning Organization, *RVAMPO Long-Range Transportation Plan 2025 Technical Report,* Roanoke, VA, 2006.
[c]*Example:* For Zone 206, the 1995 ratio of population to housing units was 2.36. In year 2000, given that the population for this zone was 301 and the number of housing units was unknown, the number of housing units was forecast to be 301/2.36 = 128.

Households

Similar to the 1995 data used to calculate the number of housing units, a scale factor equal to the ratio of 1995 population to 1995 households was used to estimate the number of households in 2000. An overall population to households ratio for the study area was not applied to each TAZ; instead, it was assumed that the population to households ratio was uniquely different for each TAZ. Table A4 provides an example of updated households (base year 2000) for TAZ 206 in Salem, Virginia.

Table A4. 1995[a] and 2000[b] Population for TAZ 205, 206, and 207 in City of Salem, Virginia

Update Year	Zone	Population	Households	Population: Households Ratio
1995	205	1551	583	2.66
	206	311	118	2.64
	207	1034	372	2.78
2000	205	1689		
	206	301		
	207	781		

[a]Fifth Planning District Commission, *1995 Transportation Planning Data for Roanoke Metropolitan Planning Area,* Roanoke, VA, May 1998.
[b]Roanoke Valley Area Metropolitan Planning Organization, *RVAMPO Long-Range Transportation Plan 2025 Technical Report,* Roanoke, VA, 2006.

The following expression was used to determine the number of households in TAZ 206 for year 2000:

$$\text{Households TAZ206}_{2000} = (\text{Population TAZ206}_{2000}) * \left(\frac{\text{Households TAZ206}_{1995}}{\text{Population TAZ206}_{1995}}\right) = (301) * \left(\frac{118}{311}\right) = 114$$

The same calculation was used to determine households for TAZs 205 and 207. Table A5 shows the estimated households for base year 2000.

The same calculation was used to determine households for TAZs 205 and 207. Table A5 shows the estimated households for base year 2000 in bold type.

Table A5. 1995[a] and 2000[b] Population and Households Data for TAZs 205, 206, and 207 in City of Salem, Virginia

Update Year	Zone	Population	Households	Population: Households Ratio
1995	205	1551	583	2.66
	206	311	118	2.64
	207	1034	372	2.78
2000	205	1689	**635**	2.66
	206	301	**114**[c]	2.64
	207	781	**281**	2.78

Numbers in bold type indicate the estimated households for base year 2000.
[a]Fifth Planning District Commission, *1995 Transportation Planning Data for Roanoke Metropolitan Planning Area,* Roanoke, VA, May 1998.
[b]Roanoke Valley Area Metropolitan Planning Organization, *RVAMPO Long-Range Transportation Plan 2025 Technical Report,* Roanoke, VA, 2006.
[c]*Example:* For Zone 206, the 1995 ratio of population to number of households was 2.64. In year 2000, given that the population of this zone was 301 and the number of households was unknown, the number of households was forecast to be 301/2.64 = 114.

Passenger Vehicles Available

Similar to the housing units and households variables, a ratio was used to approximate the number of passenger vehicles available in 2000. The ratio of 1995 population to 1995 passenger vehicles available was used to estimate passenger vehicles available in 2000 for each TAZ. An overall population to passenger vehicles available ratio for the study area was not applied to each TAZ; instead, it was assumed that the population to passenger vehicles available ratio was uniquely different for each TAZ. Table A6 provides an example of updated passenger vehicles available (base year 2000) for TAZ 206 in Salem, Virginia.

Table A6. 1995[a] and 2000[b] Population for TAZs 205, 206, and 207 in City of Salem, Virginia

Update Year	Zone	Population	Passenger Vehicles Available	Population: Passenger Vehicles Available Ratio
1995	205	1551	1154	1.34
	206	311	300	1.04
	207	1034	625	1.65
2000	205	1689		
	206	301		
	207	781		

[a]Fifth Planning District Commission, *1995 Transportation Planning Data for Roanoke Metropolitan Planning Area*, Roanoke, VA, May 1998.
[b]Roanoke Valley Area Metropolitan Planning Organization, *RVAMPO Long-Range Transportation Plan 2025 Technical Report,* Roanoke, VA, 2006.

Given the 1995 population, 1995 passenger vehicles available, and 2000 population data, base year 2000 passenger vehicles available were estimated to be 290 for TAZ 206 in the City of Salem, Virginia.

$$\text{Vehicles TAZ}206_{2000} = (\text{Population TAZ}206_{2000}) * \left(\frac{\text{Vehicles TAZ}206_{1995}}{\text{Population TAZ}206_{1995}}\right) = (301) * \left(\frac{300}{311}\right) = 290$$

Table A7 shows population and passenger vehicles available for the three zones in the City of Salem. The estimated number of passenger vehicles available for base year 2000 is shown in bold type.

Table A7. 1995[a] and 2000[b] Population and Passenger Vehicles Available for TAZs 205, 206, and 207 in City of Salem, Virginia

Update Year	Zone	Population	Passenger Vehicles Available	Population: Passenger Vehicles Available Ratio
1995	205	1551	1154	1.34
	206	311	300	1.04
	207	1034	625	1.65
2000	205	1689	**1260**	1.34
	206	301	**290**[c]	1.04
	207	781	**473**	1.65

Numbers in bold type indicate estimated number of passenger vehicles available for base year 2000.
[a]Fifth Planning District Commission, *1995 Transportation Planning Data for Roanoke Metropolitan Planning Area,* Roanoke, VA, May 1998.
[b]Roanoke Valley Area Metropolitan Planning Organization, *RVAMPO Long-Range Transportation Plan 2025 Technical Report,* Roanoke, VA, 2006.
[c]*Example:* For Zone 206, the 1995 ratio of population to passenger vehicles was 311/300 = 1.0367 (rounded to 1.04 when displayed in Table A7). In year 2000, given that the population of this zone was 301 and the number of passenger vehicles available was unknown, the number of passenger vehicles available was forecast to be 301/1.0367 = 290.

Employment

As with other variables, employment was difficult to update for base year 2000 because the 2000 CTTP data were not released until 2004. As a result, previous updated socioeconomic data were used to adjust for the change in employment from 1995 to 2000.

VEC records for 1995 and 2000 (Virginia Employment Commission, 2007), which detailed information about the workforce in the Roanoke Valley metropolitan area, were obtained to estimate the base year employment data. These data were examined to determine the change in the number of employees between 1995 and 2000 for the metropolitan area. Because of limited resources and the minimum change in size among small businesses in the area, only employers with more than 100 employees were reviewed for change in workforce size. In total, approximately 200 large businesses were reviewed.

First, each large business was appropriately matched with the correct TAZ. This required significant effort because some employers listed post office (P.O.) boxes as the address of record; a physical address is required to identify the geographical location of the place of employment. Second, for each TAZ, the number of employees in 1995 was compared to the number of employees in 2000 and the net change was documented for each TAZ. A zero net change was applied for businesses with one listing and multiple locations. For example, if a chain restaurant had one VEC listing yet several restaurants in the study area, a net change of zero was applied for the business.

As summarized in Table A8, employment was categorized into four groups to classify transportation planning data; the groups are described in detail by Cambridge Systematics, Inc., et al. (1996).

Table A8. Employment Types Used in 1995 Update of Socioeconomic Data for Roanoke Valley Metropolitan Area

Type	Employment Description	SIC[a] Codes	NAICS[b] Codes
A	Agriculture, Mining and Construction	1-19	11, 21, 23
B	Manufacturing, Transportation, Communications, Utilities and Wholesale Trade	20-51	22, 31-33, 42, 48-49
C	Retail Trade	52-59	
D	Office and Services	60-97	

[a]The U.S. Standard Industrial Classification (SIC) system classifies establishments by their primary activity.
[b]The North American Industry Classification System (NAICS) replaced the SIC system; however, several datasets are still available in SIC.

This particular categorization was used in the 1995 update. Errors found in the 1995 update were rectified with 2000 employment estimates. Those corrections were noted with the 2000 employment estimates in the *RVAMPO Long-Range Transportation Plan Technical Report* (Roanoke Valley Area MPO, 2006).

Employment categorization was not used with 2000 employment estimates; instead, 2000 estimates reflect total employment per TAZ. Publication of the 2000 CTTP offered more accurate employment data for future updates. Employment data in the 2000 CTTP were crosschecked with the VEC employment totals for each locality.

It was assumed that a certain amount of error is commonly associated with forecasts for metropolitan areas. Two sources of error are sample size and geographical location of localities. The U.S. Census "long form" is the source of CTTP data. These data measure only one in six households, which suggests that there is some error in the sample size. FHWA (2006) indicated that in the future, the CTTP will be based on the National Household Travel Survey (NHTS) but provided no exact date . In addition, the physical location of localities along the metropolitan jurisdictional boundaries may yield error. For example, Roanoke and Botetourt counties are not located entirely in the Roanoke Valley MPO area. Thus, the control totals of employment for a county contain some error.

2. Projected Year Data (2025).

The projected year data are estimated using the updated base year data. This particular forecast sought to project socioeconomic variables for 2025.

Population

A linear regression technique was used to compute the 2025 population for each TAZ. Past and current base year population data for 1990, 1995, and 2000 are plotted for each TAZ. The population data and plot are shown in Table A9 and Figure A1, respectively.

Table A9. Past and Current Population Data for 1990,[a] 1995, [a] and 2000[b] for TAZ 10 in Roanoke Valley MPO

Year	Population
1990	4,771
1995	4,822
2000	4,842

[a]Fifth Planning District Commission, *1995 Transportation Planning Data for Roanoke Metropolitan Planning Area, Roanoke Valley Area MPO* Roanoke, Virginia, May 1998.
[b]Roanoke Valley Area Metropolitan Planning Organization, *RVAMPO Long-Range Transportation Plan 2025 Technical Report*, Roanoke, Virginia, 2006.

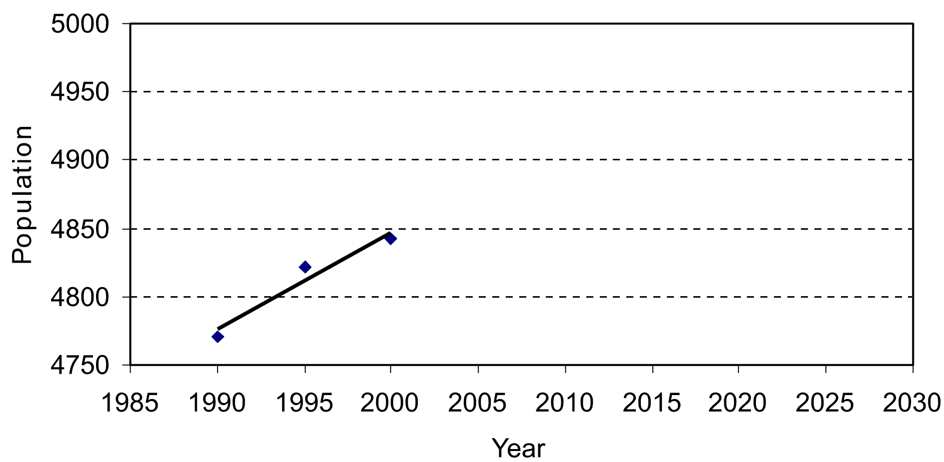

Figure A1. 1990-2000 Population Data for TAZ 10 in Roanoke Valley MPO. The data are from Fifth Planning District Commission, *Socio-Economic Data for the Roanoke Urban Study Area: 1990 Data and 2015 Projections*, Fifth Planning District Commission, Roanoke, VA, 1991.

A best fit line is applied to the data to estimate the population for the projected year. Based on the past historical trend and the most recent VEC projections (the 2010 VEC projection was used for this particular forecast), a population projection for 2025 was identified for each TAZ. For example, Figure A2 shows the 2025 population forecast for TAZ 10.

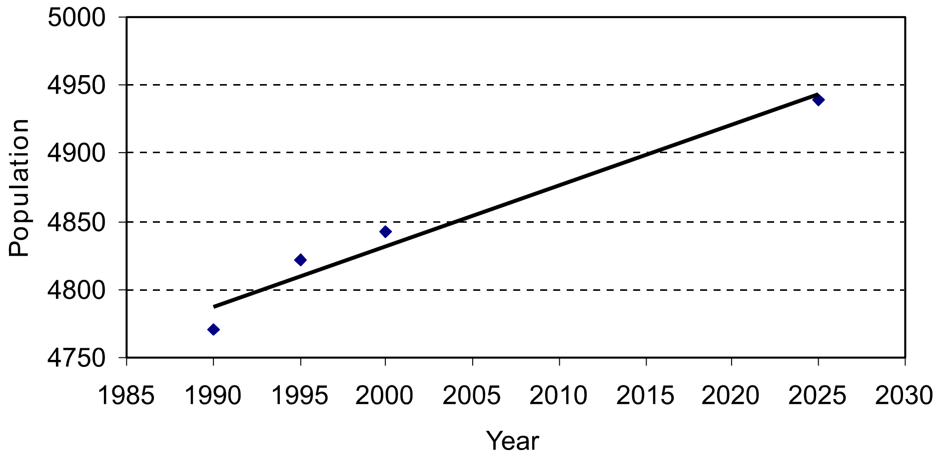

Figure A2. 2025 Estimated Population Data for TAZ 10 in Roanoke Valley MPO. The data are from Roanoke Valley Area MPO, *RVAMPO Long-Range Transportation Plan Technical Report 2025*, Roanoke, VA, 2006.

Employment

Projected employment figures for each TAZ were estimated based on historical trends and localities. Ideally, experienced employees familiar with the local jurisdictions and current land use plans offer valuable input. Local knowledge, such as planned land development, is valuable in forecasting the employment trends for the study area. This additional information influenced the final 2025 projection.

The *RVAMPO Long-Range Transportation Plan 2025 Technical Report* (Roanoke Valley Area MPO, 2006) provides base and projected year estimates, at the TAZ level, of the following socioeconomic variables: population, employment, housing units, households, and passenger vehicles available. Computational steps for obtaining forecast year values are given only for population and employment, but it was assumed that a linear regression technique, comparable to that described herein, was used to project housing units, households, and passenger vehicles available.

3. Verify Growth Allocations.

Following the initial forecast, the MPO conducts a review process to verify growth allocations with local planners. Once an initial forecast has been generated by the MPO, an official letter is sent to local planners to ask for feedback on the updated and forecast zonal level socioeconomic data.

References

Cambridge Systematics, Inc., Comsis Corporation, and University of Wisconsin-Milwaukee. *Quick Response Freight Manual.* Federal Highway Administration, Office of Planning and Environment, Milwaukee, 1996.

Federal Highway Administration. Welcome to the CTPP Guidebook. CD ROM. Washington, DC, 2006. http://www.fhwa.dot.gov/ctpp/. Accessed June 5, 2007.

Roanoke Valley Area Metropolitan Planning Organization. *RVAMPO Long-Range Transportation Plan Technical Report.* Roanoke, VA, 2006.

Virginia Employment Commission. *Virginia's Electronic Labor Market Access.* Richmond, 2007. http://velma.virtuallmi.com. Accessed May 18, 2007.

APPENDIX B

SELECTION OF LYNCHBURG REGION FOR CASE STUDY TO VALIDATE SOCIOECONOMIC FORECASTS

Four regions were candidates for the case study: Harrisonburg, Lynchburg, Roanoke, and Winchester. For each region, relevant documents were obtained, such as long-range transportation plans, technical appendices to these plans, and publications that contained socioeconomic data. Some documents were available only at the offices of MPO staff who were interviewed, whereas other documents were available through the VDOT Research Library. Tables B1 through B4 name the documents available for each region.

Table B1. Relevant Documents for Harrisonburg MPO

Document	Base Year	Horizon Year
Virginia Department of Highways and Transportation. *1995 Harrisonburg Thoroughfare Plan*, VDH&T, Richmond, Virginia, 1980. Available from the VTRC library.	1970	1995
Hayes, Seay, Mattern and Mattern. *Harrisonburg, Virginia Major Arterial Plan*, Virginia Department of Highways, Richmond, Virginia, 1966. Available from the VTRC library.	1962	1985

Table B2. Relevant Documents for Lynchburg/Central Virginia MPO

Document	Base Year	Horizon Year
Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan*, Richmond, 1980	1975	2000
Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan Technical Report,* Richmond, 1983	1975	2000
Michael Baker Jr. Inc., *Lynchburg MPO 2000 Model Development Technical Report* , Virginia Department of Transportation, Richmond, 2005	2000	2030
Virginia Department of Highways. *Lynchburg Area Transportation Study, Vol. I*, VDH, Richmond, Virginia, 1965. Available from the VTRC library.	N/A	N/A

Table B3. Relevant Documents for Roanoke Valley Regional Area

Document	Base Year	Horizon Year
Howard, Needles, Tammen & Bergendoff. *Roanoke Valley Regional Area Transportation Study: Major Arterial Highway Plan*, VDH, Richmond, Virginia, 1963.	1960	1980
Roanoke Valley Area MPO, *RVAMPO Long-Range Transportation Plan Technical Report 2025,* Roanoke, VA, 2006	2000	2025
Fifth Planning District Commission, *1995 Transportation Planning Data for Roanoke Metropolitan Planning Area, Roanoke Valley Area MPO* Roanoke, Virginia, May 1998.	1995	2020
Fifth Planning District Commission, *Socio-Economic Data for the Roanoke Urban Study Area 1990 Data and 2015 Projections*, Fifth Planning District Commission, , Roanoke, Virginia, 1991	1990	2015
Roanoke Valley Area MPO. *Roanoke Valley Area MPO 2035 Study Area Boundary and Traffic Analysis Zone Data Update*, Roanoke Valley Area MPO, Roanoke, Virginia, 2006.	2005	2035

Table B4. Relevant Documents for Winchester-Frederick MPO

Document	Base Year	Horizon Year
VHB. *Winchester-Frederick County MPO-2003 Travel Demand Technical Report*? Richmond, Virginia, 2005.	2000	2030

A review of the publications listed in Tables B1 through B4 showed that a retrospective case study was not feasible for all regions. For example, for the Winchester-Frederick MPO (Table B4), the horizon year of 2030 had not yet transpired, thus, it was not feasible to determine the accuracy of the forecasts for that region. In some cases, data were available only at the jurisdictional level.

The authors selected the Lynchburg region as the site for the case study in part because (1) a complete dataset was available and (2) the horizon year of 2000 had already transpired. An additional consideration was that one of the authors and one of the steering committee members had strong local knowledge of this particular region.

The *Lynchburg Area Transportation Study: Year 2000 Transportation Plan* (VDH&T, 1980) and the *Lynchburg MPO 2000 Model Development Technical Report* (Michael Baker Jr. Inc., 2005) were the primary sources for forecast and actual socioeconomic data for the case study. Additional socioeconomic data resources are listed in Table B5, although not all of these provide data at the zonal level.

Table B5. Sources for Actual Socioeconomic Data

Virginia Department of Transportation, Transportation Planning Division. *1978-1981 Socioeconomic Planning Data for Roanoke.* Richmond, n.d.
Virginia Employment Commission. *Virginia's Electronic Labor Market Access.* Richmond, 2007. http://velma.virtuallmi.com. Accessed May 18, 2007.
Weldon Cooper Center for Public Service, Demographic and Workforce Division. Annual Population Estimates. Charlottesville, VA, 2005. http://www.coopercenter.org/demographics/POPULATION%20ESTIMATES/Previous%20Estimates.php. Accessed June 5, 2007.
U.S. Census Bureau. American Fact Finder, 1990 Census Data Set. Washington, DC, 2000. http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=DEC&_tabId=DEC2&_submenuId=datasets_1&_lang=en&_ts=199286273162. Accessed May 18, 2007.
U.S. Census Bureau. American Fact Finder, 2000 Census Data Set. Washington, DC, 2000. http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=DEC&_tabId=DEC1&_submenuId=datasets_1&_lang=en&_ts=199286211781. Accessed May 18, 2007.
U.S. Department of Transportation, Bureau of Transportation Statistics. Census Transportation Planning Package CTPP 1990. Washington, DC, 2007. http://www.transtats.bts.gov/Tables.asp?DB_ID=620&DB_Name=Census%20Transportation%20Planning%20Package%20CTPP%201990&DB_Short_Name=CTPP%201990. Accessed June 18, 2007.
Federal Highway Administration. Census Transportation Planning Package CTPP 2000. Washington, DC, 2007. http://www.fhwa.dot.gov/ctpp/dataprod.htm. Accessed June 18, 2007.

References

Michael Baker Jr., Inc. *Lynchburg MPO 2000 Model Development Technical Report*. Virginia Department of Transportation, Richmond, 2005.

Virginia Department of Highways & Transportation. *Lynchburg Area Transportation Study: Year 2000 Transportation Plan.* Richmond, 1980.

APPENDIX C

CREATING NEW CASE STUDY GEOGRAPHY

Comparing Different Datasets (1980 and 2000) for Lynchburg Regional Case Study

The two datasets used in this case study were completed with different zonal geographies: the 1980 geography (when the forecasts were made) and the 2000 geography (when the forecasts could be compared to actual values). ESRI ArcGIS and Microsoft Excel software were used extensively to aggregate zone geographies and values to compare datasets. *Data frame* refers to the workspace used in ArcGIS to manipulate GIS layers, which are also referred to as spatial data. The following procedure was used to create the new geography.

1. Align zone geography.
2. Develop initial association between 1980 and 2000 TAZs.
3. Allocate 2000 TAZs to case study TAZs: Situation 1.
4. Allocate 2000 TAZs to case study TAZS: Situation 2.
5. Make 1980 zones comparable to case study zones.

Align Zone Geography

1. *Obtain maps of 1980 and 2000 zonal structures.* The 1980 geography was available only in hard copy format from the 1980 study (VDH&T, 1980), and the 2000 Lynchburg geography was available in digital format from the VDOT Lynchburg District Office. [Time required: 1 day.]

2. *Create jpeg image files of the 1980 geographies shown in Figures C1 and C2.* [Time required: 30 minutes.]

3. *In ESRI ArcGIS, add the 2000 zonal structure (Figure C3) to the data frame of a new map using ArcMap.* Adding the 2000 zonal structure as the first layer in a data frame sets the entire data frame projection to the custom VDOT Lambert conformal conic projection (VDOT, 2003) and additional layers will automatically adjust to the custom projection. A projection is a method used in cartography to represent the two-dimensional curved surface of the earth on a plane. The custom VDOT Lambert conformal conic projection has the following details that are critical if a VDOT map is to be overlaid accurately with another map that uses a different data projection. [Time required: 30 minutes.]

NAD1983 Lambert Conformal Conic
GEOGCS GCS North American 1983
DATUM North American 1983
SPHEROID GRS1980, 6378137.0, 298.257222101
PRIMEM Greenwich, 0.0, UNIT Degree, 0.0174532925199433
PROJECTION Lambert Conformal Conic
False Easting, 0.0
False Northing, 0.0
Central Meridian, -79.5
Standard Parallel 1, 37.0
Standard Parallel 2, 39.5
Latitude of Origin, 36.0
UNIT Meter

Figure C1. Outline of 1980 Zone Geography. The data are from Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan,* Richmond, 1980.

Figure C2. Outline of 1980 Insert Zone Geography, Rotated to Align with Figure C1. The data are from Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan,* Richmond, 1980.

Figure C3. 2000 Zonal Structure. The data are from Michael Baker Jr., Inc., *Lynchburg MPO 2000 Model Development Technical Report,* Virginia Department of Transportation, Richmond, 2005.

4. *Add topographic layers of Virginia, specifically primary and secondary roads, to the data frame.* Geographic attributes, available at the Virginia Department of Transportation (VDOT, 2008), assist with finding key intersections on the scanned map image and GIS layers for geocoding purposes. The attributes are primary roads, secondary roads, urban arterials, and water features. [Time required: 30 minutes.]

5. *Add the first image of 1980 geography (Figure C1) to the data frame.* Choose to have the image "fit to display" using the georeferencing toolbar. [Time required: 10 minutes.]

6. *Use the georeferencing toolbar to identify and add control points on the image that match with points on the GIS layers (roadways and zonal structure).* As more control points are added, the image will begin to morph and shift to the correct location. An even distribution of control points improves the accuracy of the image location; however, too many control points may distort certain areas of the image. Attempt to align the image with the GIS layers from Step 4, but recognize there will be some areas where this alignment is imperfect. [Time required: 2 hours.]

7. *Rectify and save the image once the image matches well with boundaries of the spatial data (GIS layers).* [Time required: 10 minutes.]

8. *Repeat Steps 5, 6, and 7 for the inset map of City of Lynchburg (Figure C2).* [Time required: 2.5 hours.]

Develop Initial Association Between 1980 and 2000 TAZs

9. *Arrange the order of layers in the data frame so that the 2000 TAZ shape file appears at the back of all layers, and adjust the transparency to 50% for both 1980 image maps.* These adjustments will help align the 2000 zones and the 1980 geography. [Time required: 10 minutes.]

10. *Create a new field titled "1980 Zone" in the attribute table of the 2000 TAZ shape file.* This can be done with the "add field" tool of the options drop-down menu. [Time required: 10 minutes.]

11. *For each 2000 TAZ, identify the most closely associated 1980 TAZ and mark that value in the "1980 Zone" attribute.* One of two special cases may occur during TAZ association: (1) a 2000 TAZ is located in more than one 1980 TAZ, or (2) a 2000 TAZ is partially located in the 1980 geography. For the first situation, allocate one of the 1980 TAZ values for association as that will require aggregation of the multiple 1980 TAZs involved. The second special situation is addressed in the section entitled "Allocate 2000 Zones to Case Study TAZs: Situation 2" (Steps 14 and 15). [Time required: 2 hours.]

Allocate 2000 Zones to Case Study TAZs: Situation 1

12. *Create "Case Study TAZ" geography using a numbering system that begins with "1," and document the 1980 TAZs and 2000 TAZs that represent the same area in an Excel spreadsheet.* Case Study TAZs are used to identify which TAZs must be aggregated. For example, the area represented by "TAZ 1" in 1980 may not correspond to the same area identified as "TAZ 1" in 2000. Accordingly, zones were aggregated to produce a new set of 68 case study TAZs that could be compared for both time periods. Figure C4 illustrates the process. In this example, TAZ 10 (from the 1980 study) is equivalent to the aggregation of TAZs 17 and 18 (from the 2000 study); this area is case study TAZ 9. Appendix D relates TAZs from 1980 and TAZs from 2000, and the new case study geography of 68 TAZs is shown in Figure C5. [Time required: 1 hour.]

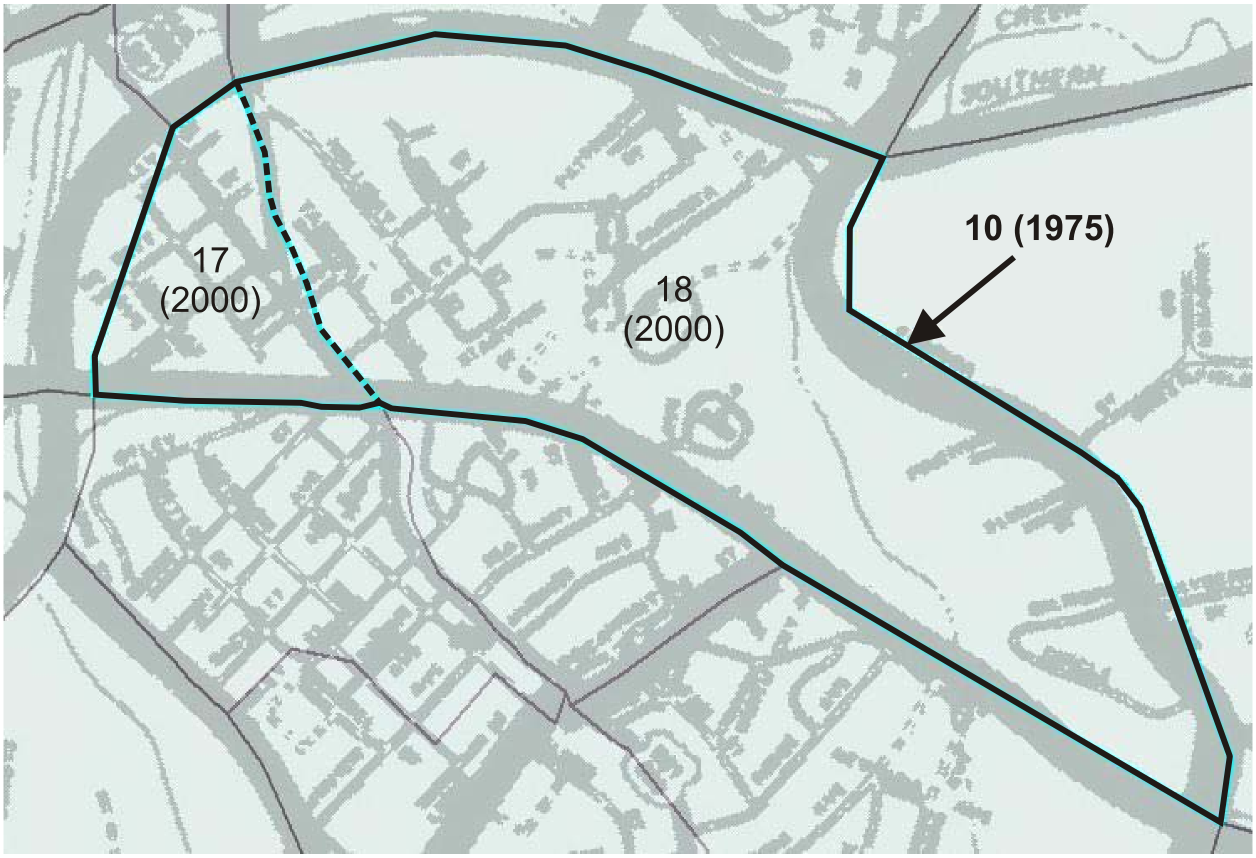

Figure C4. New Case Study TAZ 9: Aggregation of 2000 TAZs to Be Comparable to 1980 TAZs

13. *Aggregate features of data from the 2000 study (Michael Baker Jr., 2005) using the dissolve tool.* Note that 2000 TAZs without association to 1980 TAZs will be dissolved into "0." Within the dissolve tool, choose to calculate the sum of Year 2000 attributes including total population, households, vehicles, total employment, retail employment, and non-retail employment. As the features are dissolved, the sum is calculated for each attribute. For example, the total population for TAZs 76, 77, and 82 (Figure C3) from the 2000 study are summed to equal the value of case study TAZ 22. [Time required: 1 hour.]

Allocate 2000 Zones to Case Study TAZs: Situation 2

14. *Identify 2000 TAZs that are partially within the 1980 geography.* Some of the TAZs from the 2000 study are partially within the 1980 geography. Figure C6 illustrates this situation. Part of TAZ 209 from the 2000 study (Michael Baker Jr., 2005) represents the same area as TAZ 79 from the 1980 study (Virginia Department of Highways & Transportation, 1980). [Time required: 1 hour.]

15. *For TAZs that lay partially within the 1980 geography, create a new shape file and use the edit tool bar to subdivide each 2000 TAZ.* Subdivide each 2000 TAZ into two polygons; one new polygon should identify the area within the appropriate 1980 TAZ, and the other new polygon should represent the remaining portion of the 2000 TAZ that is not within the 1980 geography. TAZ 209 (Figure C6) was subdivided into two portions. [Time required: 2 hours.]

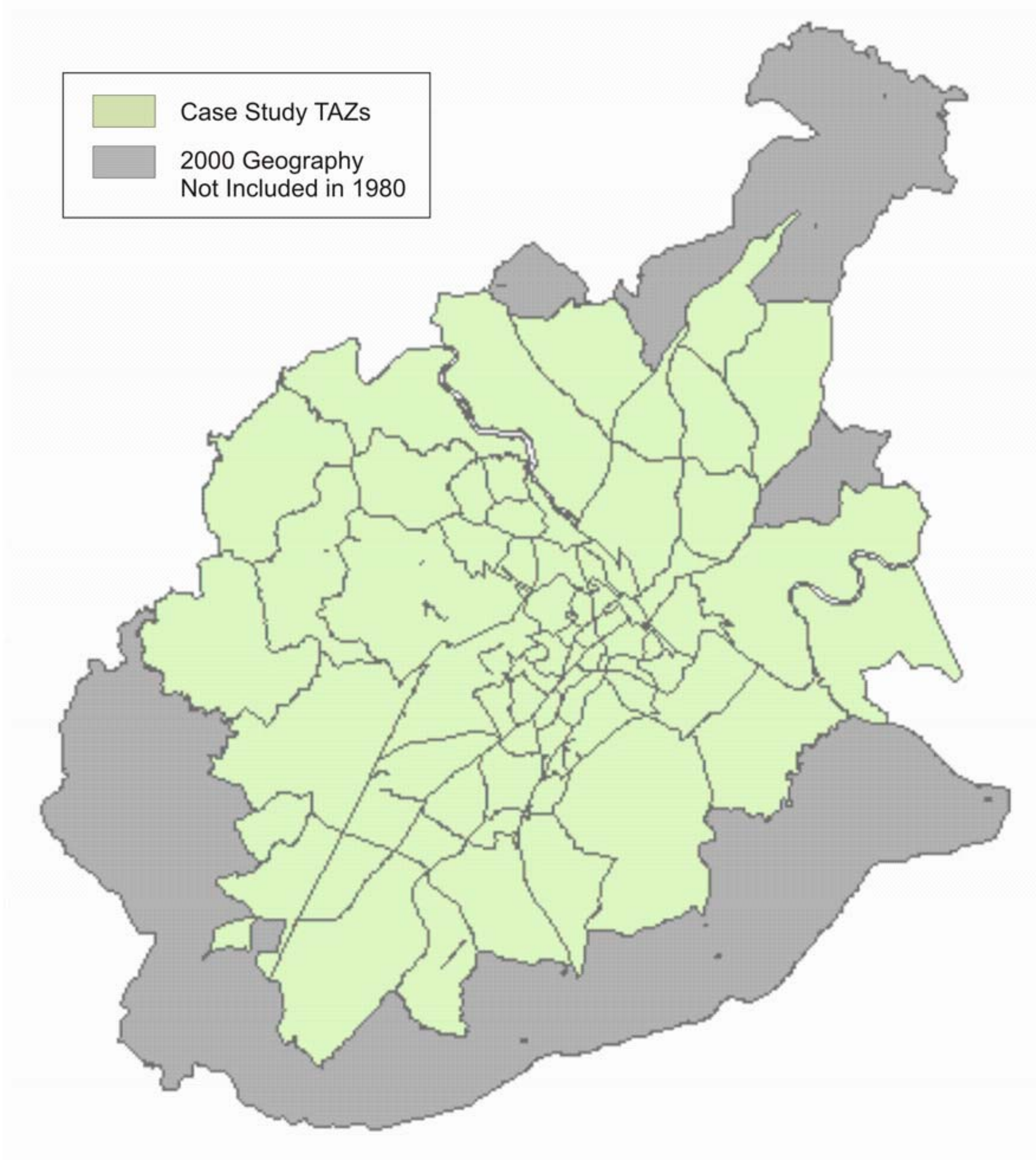

Figure C5. New Case Study Zonal Geography

16. *Calculate the area of each new subdivided polygon using the "Calculate Area" tool, and determine the percentage of total area that each 2000 TAZ contributes to the 1980 TAZ.* [Time required: 1 hour.]

17. *Extract attributes, and apply the percentages identified in Step 16 to determine the portion of values to add to the appropriate "Case Study TAZ."* It is assumed that the land use is homogeneous throughout each TAZ; therefore, the fraction of area within the 1980 geography should correlate to the fraction of socioeconomic values within the 1980 geography. [Time required: 2 hours.]

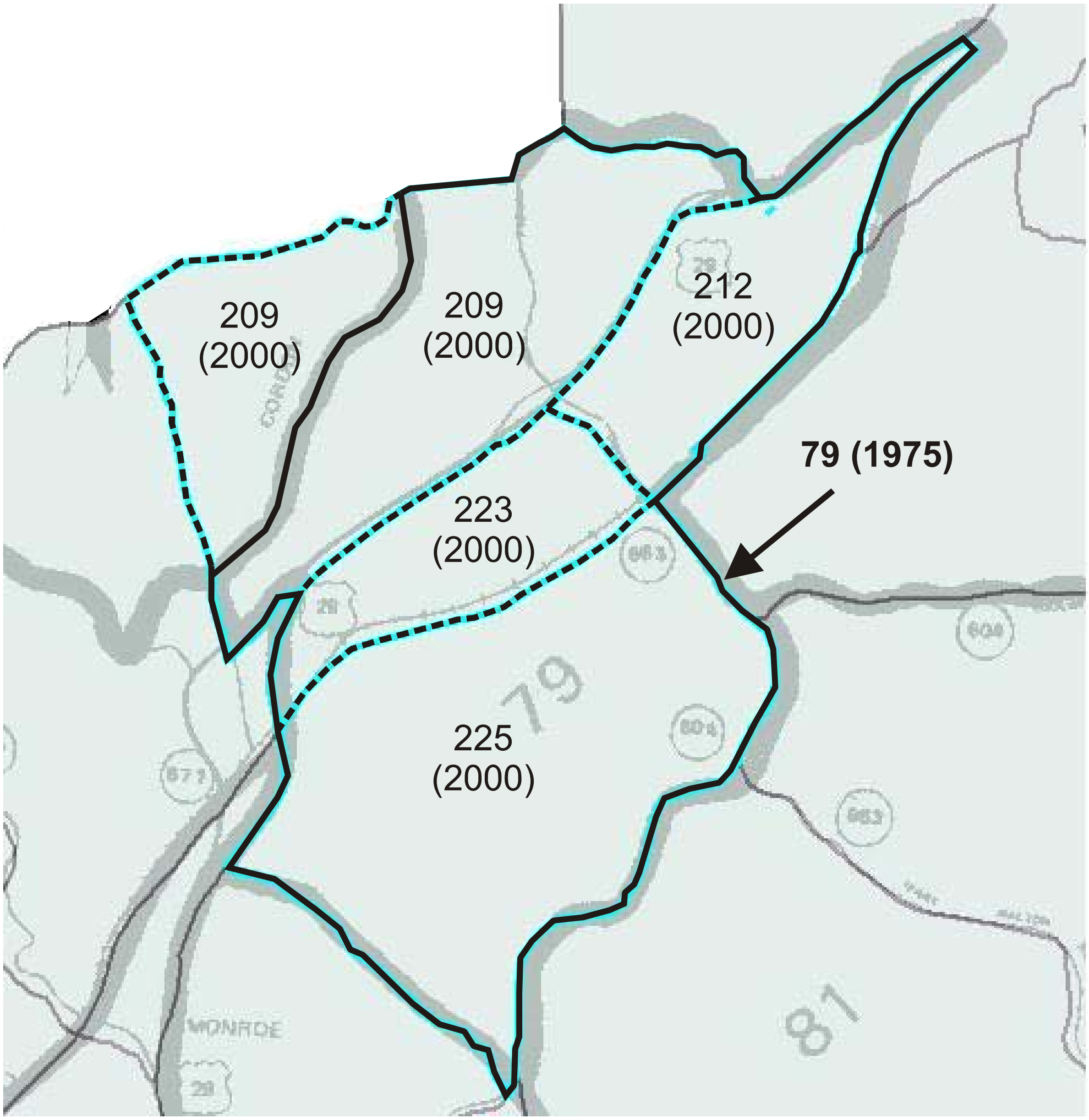

Figure C6. 2000 TAZ Partially in 1980 Geography. The data are from Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan*, Richmond, 1980, and Michael Baker Jr., Inc., *Lynchburg MPO 2000 Model Development Technical Report*, Virginia Department of Transportation, Richmond, 2005.

Make 1980 Zones Comparable to Case Study Zones

18. *Aggregate 1980 data, found in the Lynchburg Area Transportation Study Year 2000 Transportation Plan* (VDH&T, 1980), *to the appropriate "Case Study TAZ."* This makes the 1980 TAZs comparable with the 2000 dataset derived in Step 11. [Time required: 2 hours.]

19. *Proceed with comparing values of the two datasets at the "Case Study TAZ" geography unit.*

References

Michael Baker Jr., Inc. *Lynchburg MPO 2000 Model Development Technical Report.* Virginia Department of Transportation, Richmond, 2005.

Virginia Department of Highways & Transportation. *Lynchburg Area Transportation Study: Year 2000 Transportation Plan.* Richmond, 1980.

Virginia Department of Transportation. *VDOT Geo-Spatial Data Delivery Recommendations Technical Standard.* Richmond, September 2003. http://gis.virginiadot.org/VDOT_Geo_Spatial_Data_Delivery_Recommendations.pdf. Accessed September 2008.

APPENDIX D

CASE STUDY TAZ EQUIVALENCE

A new geographic area was created to compare 1980 and 2000 datasets appropriately. The new geography, "Case Study TAZs," identifies the same area from 1980 and 2000 geographies. Table D1 shows which 1980 TAZs and which 2000 TAZs are equivalent to the new Case Study TAZ.

$$TAZ_{\text{Case Study}} = TAZ_{1980} = TAZ_{2000}$$

Table D1. Case Study TAZ Equivalence

Case Study TAZ	**Jurisdiction**[a]	**1980 TAZs**[b]	**2000 TAZs**[c,d]
1[e]	City of Lynchburg	1, 7	1-3
2	City of Lynchburg	2	4, 5
3	City of Lynchburg	3, 4, 12	6-9, 37
4	City of Lynchburg	5	10
5	City of Lynchburg	6	11
6	City of Lynchburg	8	12
7	City of Lynchburg	9,11	14-16, 19, 20
8	City of Lynchburg, Campbell County	61	13, 21-25, 302-304, 318, 319
9	City of Lynchburg	10	17, 18
10	City of Lynchburg	13, 14	30, 35
11	City of Lynchburg	20-22	33, 45
12	City of Lynchburg	24	43
13	City of Lynchburg	15, 16	34, 36
14	City of Lynchburg	17	44, 46-48
15	City of Lynchburg	18	49
16	City of Lynchburg	19	38-40, 51
17	City of Lynchburg, Campbell County	62	41, 307-309, 311
18	City of Lynchburg	23	53, 60, 79, 83
19	City of Lynchburg	25	117, 120
20	City of Lynchburg	26	123
21	City of Lynchburg	27	72, 78
22	City of Lynchburg	28	76, 77, 82
23	City of Lynchburg	29	73, 80
24	City of Lynchburg	30	75, 81, 121, 122
25	City of Lynchburg	31	74
26	City of Lynchburg	32, 75	65, 66, 68-71, 87, 91, 95, 119
27	City of Lynchburg	33	28, 32
28	City of Lynchburg	34	124, 125
29	City of Lynchburg	35	26, 27, 29, 31
30	City of Lynchburg	36, 37, 39	128, 131, 132
31	City of Lynchburg	38	127, 129
32	City of Lynchburg	46	105, 109
33	City of Lynchburg	40, 43, 44	108, 110, 111, 126
34	City of Lynchburg	41	130

35	City of Lynchburg	42	115, 116
36	City of Lynchburg	45, 50	106, 107
37	City of Lynchburg	47	113
38	City of Lynchburg	48	98, 101
39	City of Lynchburg	49	99
40	City of Lynchburg, Bedford County	71	97, 401, 402
41	City of Lynchburg, Bedford County	51, 72, 73	88-90, 92-94, 96, 100, 102-104, 112, 114, 118, 408, 411
42	Amherst County	52	249, 250, 256
43	Amherst County	53	238, 253
44	Amherst County	54	239, 242, 243
45	Amherst County	55	240, 241, 244
46	Amherst County	56	222, 226, 227
47	Amherst County	81	224, 228, 229
48	Amherst County	57	230, 232, 236, 237 [233, 235][f]
49	Amherst County	58	231
50	Amherst County	59	245-248
51	Campbell County	60	337, 338
52	City of Lynchburg, Campbell County	63	42, 50, 52, 325, 326
53	Campbell County	64, 66	322, 330, 343
54	City of Lynchburg, Campbell County	65	55, 58, 59, 61-63, 324
55	City of Lynchburg, Campbell County	67	64, 67, 84-86, 336, 341
56	Campbell County	68	333-335, 339, 340, 350, 351
57	Bedford County	69	430, 433, 440, 443 [437, 441, 444]
58	Bedford County	70	400, 403, 404
59	Amherst County	74	409, 413, 414, 418-420, 422, 424-426, 428, 431, 435
60	Campbell County	76	320, 321, 323, 331, 345
61	City of Lynchburg, Campbell County	77	54, 56, 57, 342, 344
62	Amherst County	78	252, 254 [251, 255]
63	Amherst County	79	212, 223, 225 [209]
64	Campbell County	80	300, 306
65	Bedford County	82	415, 416, 421, 427
66	Bedford County	85	407
67	Bedford County	83	405, 406, 410, 412
68	Bedford County	84	434 [423, 429, 432, 436, 438]

[a]Jurisdictions were identified based on 1980 geography.
[b]Virginia Department of Highways & Transportation, *Lynchburg Area Transportation Study: Year 2000 Transportation Plan*, Richmond, 1980.
[c]Michael Baker Jr., Inc., *2030 Lynchburg Area Transportation Study*, Virginia Department of Transportation, Richmond, 2005.
[d]The following 2000 TAZs were outside the 1980 zonal structure and were not used in the case study: 200-208, 210-211, 213-221, 234, 301, 305, 310, 312-317, 327-329, 332, 417, 439, 442.
[e]For example, TAZs 1 and 7 from 1980 are the same areas as TAZs 1, 2, and 3 in 2000.
[f]Brackets indicate TAZs from 2000 geography that were partially included in the new case study TAZ.

APPENDIX E

COMPREHENSIVE CASE STUDY DATASET

Total Population

$TAZ_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
1	919	560	359	64%
2	2,980	2,443	537	22%
3	3,800	2,417	1,383	57%
4	800	486	314	65%
5	0	0	0	---
6	1,000	1,010	10	1%
7	3,000	1,881	1,119	59%
8	3,150	1,372	1,778	130%
9	800	635	165	26%
10	1,200	748	452	60%
11	600	520	80	15%
12	1,400	1,152	248	22%
13	0	8	8	100%
14	100	168	68	40%
15	0	19	19	100%
16	300	234	66	28%
17	36,100	2,734	33,366	1,220%
18	1,200	880	320	36%
19	1,400	1,935	535	28%
20	1,000	774	226	29%
21	1,700	1,944	244	13%
22	2,600	2,201	399	18%
23	1,900	1,613	287	18%
24	2,400	2,372	28	1%
25	1,000	994	6	1%
26	4,600	6,030	1,430	24%
27	1,300	1,260	40	3%
28	100	84	16	19%
29	1,100	765	335	44%
30	2,300	1,658	642	39%
31	1,800	1,717	83	5%
32	1,300	1,386	86	6%
33	1,600	1,799	199	11%
34	1,200	660	540	82%
35	2,200	1,994	206	10%
36	900	485	415	86%
37	1,200	945	255	27%
38	3,000	2,721	279	10%
39	1,300	1,167	133	11%
40	1,400	1,368	32	2%
41	8,500	7,359	1,141	16%
42	1,500	1,265	235	19%
43	2,200	1,738	462	27%
44	2,510	1,724	786	46%

$TAZ_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
45	3,500	2,909	591	20%
46	2,500	2,499	1	0%
47	1,500	1,318	182	14%
48	3,000	1,753	1,247	71%
49	3,300	1,105	2,195	199%
50	1,800	1,567	233	15%
51	1,700	2,810	1,110	40%
52	17,200	3,973	13,227	333%
53	2,350	1,529	821	54%
54	2,500	2,874	374	13%
55	6,600	6,790	190	3%
56	6,700	5,925	775	13%
57	1,550	2,508	958	38%
58	400	430	30	7%
59	3,000	5,509	2,509	46%
60	2,050	624	1,426	229%
61	4,200	3,436	764	22%
62	1,700	1,382	318	23%
63	1,200	956	244	26%
64	800	424	376	89%
65	1,000	1,711	711	42%
66	200	275	75	27%
67	900	1,650	750	45%
68	300	1,895	1,595	84%

Total Households

TAZ $_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
1	472	290	182	63%
2	1,110	799	311	39%
3	1,270	851	419	49%
4	264	187	77	41%
5	0	0	0	---
6	485	348	137	39%
7	1,117	827	290	35%
8	1,225	541	684	127%
9	254	248	6	2%
10	465	327	138	42%
11	247	255	8	3%
12	538	549	11	2%
13	0	5	5	100%
14	33	3	30	1,000%
15	0	9	9	100%
16	116	105	11	10%
17	2,740	1,170	1,570	134%
18	421	384	37	10%
19	690	834	144	17%
20	357	329	28	9%
21	664	927	263	28%
22	1,018	964	54	6%
23	697	680	17	3%
24	1,073	966	107	11%
25	12	25	13	52%
26	1,612	2,701	1,089	40%
27	553	538	15	3%
28	40	40	0	0%
29	452	299	153	51%
30	833	651	182	28%
31	851	717	134	19%
32	442	609	167	27%
33	485	633	148	23%
34	436	291	145	50%
35	1,039	938	101	11%
36	296	151	145	96%
37	392	359	33	9%
38	1,133	1,213	80	7%
39	435	425	10	2%
40	470	537	67	12%
41	3,372	3,033	339	11%
42	520	473	47	10%
43	880	730	150	21%
44	1,113	720	393	55%
45	1,200	1,140	60	5%
46	920	999	79	8%
47	540	486	54	11%
48	990	695	295	43%

TAZ $_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
49	200	178	22	12%
50	670	689	19	3%
51	710	1,150	440	38%
52	5,000	403	4,597	1,141%
53	915	671	244	36%
54	1,050	1,187	137	12%
55	2,240	2,704	464	17%
56	2,690	2,436	254	10%
57	675	939	264	28%
58	150	175	25	14%
59	1,170	2,223	1,053	47%
60	855	259	596	230%
61	1,400	1,474	74	5%
62	670	503	167	33%
63	440	385	55	14%
64	300	169	131	78%
65	330	608	278	46%
66	80	108	28	26%
67	390	638	248	39%
68	110	611	501	82%

Total Vehicles

TAZ $_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
1	492	119	373	313%
2	823	799	24	3%
3	899	1,047	148	14%
4	196	224	28	13%
5	0	0	0	---
6	563	240	323	135%
7	1,114	1,323	209	16%
8	1,561	854	707	83%
9	262	378	116	31%
10	477	409	68	17%
11	311	334	23	7%
12	745	774	29	4%
13	0	10	10	100%
14	33	6	27	450%
15	0	22	22	100%
16	196	216	20	9%
17	14,475	2,025	12,450	615%
18	620	810	190	23%
19	880	1,096	216	20%
20	269	398	129	32%
21	995	1,223	228	19%
22	1,372	1,642	270	16%
23	970	1,241	271	22%
24	1,340	1,484	144	10%
25	147	828	681	82%
26	2,043	3,730	1,687	45%
27	544	662	118	18%
28	70	62	8	13%
29	343	369	26	7%
30	730	723	7	1%
31	854	760	94	12%
32	729	1,011	282	28%
33	746	1,371	625	46%
34	276	372	96	26%
35	1,332	1,885	553	29%
36	293	298	5	2%
37	699	474	225	47%
38	1,712	2,171	459	21%
39	663	956	293	31%
40	790	1,107	317	29%
41	4,858	5,289	431	8%
42	480	1,093	613	56%
43	1,360	1,625	265	16%
44	1,744	1,166	578	50%
45	1,580	2,633	1,053	40%
46	1,510	1,920	410	21%
47	910	1,063	153	14%
48	970	1,544	574	37%

TAZ $_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
49	80	196	116	59%
50	1,050	986	64	6%
51	1,030	2,335	1,305	56%
52	5,518	3,270	2,248	69%
53	1,117	1,221	104	9%
54	1,860	2,141	281	13%
55	2,100	5,516	3,416	62%
56	3,647	4,834	1,187	25%
57	1,163	2,042	879	43%
58	380	343	37	11%
59	1,309	4,582	3,273	71%
60	996	534	462	87%
61	1,320	2,831	1,511	53%
62	880	1,233	353	29%
63	750	736	14	2%
64	400	353	47	13%
65	410	1,288	878	68%
66	130	212	82	39%
67	460	1,379	919	67%
68	140	1,501	1,361	91%

Total Employment

TAZ CaseStudy	Forecast	Actual	Absolute Error	Percent Error
1	7,937	6,664	1,273	19%
2	1,220	403	817	203%
3	1,831	891	940	105%
4	178	130	48	37%
5	3,150	270	2,880	1,067%
6	74	19	55	289%
7	766	513	253	49%
8	434	1,359	925	68%
9	95	91	4	4%
10	1,859	538	1,321	246%
11	980	388	592	153%
12	438	382	56	15%
13	1,420	1,560	140	9%
14	2,465	3,868	1,403	36%
15	3,150	3,152	2	0%
16	3,143	2,924	219	7%
17	4,307	272	4,035	1,483%
18	487	2,319	1,832	79%
19	3,265	4,617	1,352	29%
20	748	803	55	7%
21	386	421	35	8%
22	916	285	631	221%
23	144	196	52	27%
24	1,615	737	878	119%
25	443	490	47	10%
26	694	5,613	4,919	88%
27	689	636	53	8%
28	1,602	798	804	101%
29	1,372	468	904	193%
30	1,075	44	1,031	2,343%
31	766	210	556	265%
32	260	549	289	53%
33	879	581	298	51%
34	318	73	245	336%
35	381	270	111	41%
36	11	70	59	84%
37	891	1,661	770	46%
38	320	748	428	57%
39	82	104	22	21%
40	85	279	194	70%
41	1,982	3,290	1,308	40%
42	58	67	9	13%
43	392	386	6	2%
44	649	1,207	558	46%
45	815	911	96	11%
46	73	198	125	63%
47	4	22	18	82%
48	59	55	4	6%

TAZ $_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
49	2,801	1,841	960	52%
50	254	350	96	27%
51	439	533	94	18%
52	814	1,487	673	45%
53	521	725	204	28%
54	730	2,397	1,667	70%
55	791	3,935	3,144	80%
56	198	1,059	861	81%
57	64	429	365	85%
58	61	16	45	281%
59	335	4,655	4,320	93%
60	90	9	81	900%
61	904	1,397	493	35%
62	31	84	53	63%
63	125	135	10	7%
64	5,316	2,841	2,475	87%
65	121	571	450	79%
66	44	34	10	29%
67	34	77	43	56%
68	25	47	22	46%

Total Retail Employment

TAZ CaseStudy	Forecast	Actual	Absolute Error	Percent Error
1	2,095	298	1,797	603%
2	77	53	24	45%
3	136	34	102	300%
4	87	13	74	569%
5	24	0	24	---
6	13	0	13	---
7	210	179	31	17%
8	21	93	72	77%
9	68	0	68	---
10	288	140	148	106%
11	134	4	130	3,250%
12	285	242	43	18%
13	96	321	225	70%
14	1,090	1,341	251	19%
15	0	236	236	100%
16	157	125	32	26%
17	51	88	37	42%
18	436	516	80	16%
19	319	85	234	275%
20	124	23	101	439%
21	103	86	17	20%
22	70	109	39	36%
23	14	43	29	67%
24	223	231	8	3%
25	0	0	0	---
26	196	788	592	75%
27	256	266	10	4%
28	1,259	295	964	327%
29	216	69	147	213%
30	127	20	107	535%
31	14	22	8	36%
32	1	9	8	89%
33	91	99	8	8%
34	16	0	16	---
35	338	55	283	515%
36	0	0	0	---
37	4	3	1	33%
38	202	314	112	36%
39	28	7	21	300%
40	11	80	69	86%
41	303	785	482	61%
42	31	10	21	210%
43	54	131	77	59%
44	314	336	22	7%
45	449	544	95	17%
46	59	66	7	11%
47	0	0	0	---
48	20	14	6	43%

TAZ $_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
49	40	0	40	---
50	99	161	62	39%
51	82	102	20	20%
52	116	249	133	53%
53	19	107	88	82%
54	75	246	171	70%
55	307	1,386	1,079	78%
56	156	43	113	263%
57	6	47	41	87%
58	0	0	0	---
59	119	629	510	81%
60	0	0	0	---
61	577	412	165	40%
62	4	24	20	83%
63	72	67	5	7%
64	0	0	0	---
65	1	0	1	---
66	3	0	3	---
67	8	14	6	43%
68	5	0	5	---

Total Non-Retail Employment

TAZ $_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
1	5,842	270	5,572	2,064%
2	1,143	490	653	133%
3	1,695	503	1,192	237%
4	91	370	279	75%
5	3,126	2,916	210	7%
6	61	399	338	85%
7	556	117	439	375%
8	413	384	29	8%
9	27	398	371	93%
10	1,571	73	1,498	2,052%
11	846	6,366	5,520	87%
12	153	350	197	56%
13	1,324	780	544	70%
14	1,375	140	1,235	882%
15	3,150	91	3,059	3,362%
16	2,986	188	2,798	1,488%
17	4,256	153	4,103	2,682%
18	51	2,527	2,476	98%
19	2,946	1,803	1,143	63%
20	624	506	118	23%
21	283	1,239	956	77%
22	846	176	670	381%
23	130	24	106	442%
24	1,392	335	1,057	316%
25	443	19	424	2,232%
26	498	334	164	49%
27	433	857	424	49%
28	343	1,658	1,315	79%
29	1,156	482	674	140%
30	948	70	878	1,254%
31	752	540	212	39%
32	259	215	44	20%
33	788	97	691	712%
34	302	4,532	4,230	93%
35	43	189	146	77%
36	11	434	423	97%
37	887	2,799	1,912	68%
38	118	1,841	1,723	94%
39	54	47	7	16%
40	74	431	357	83%
41	1,679	2,151	472	22%
42	27	255	228	89%
43	338	985	647	66%
44	335	367	32	9%
45	366	67	299	444%
46	14	132	118	89%
47	4	9	5	56%
48	39	382	343	90%

TAZ $_{CaseStudy}$	Forecast	Actual	Absolute Error	Percent Error
49	2,761	199	2,562	1,287%
50	155	2,549	2,394	94%
51	357	1,238	881	71%
52	698	871	173	20%
53	502	4,825	4,323	90%
54	655	618	37	6%
55	484	61	423	695%
56	42	63	21	33%
57	58	22	36	164%
58	61	2,841	2,780	98%
59	216	16	200	1,250%
60	90	34	56	165%
61	327	57	270	474%
62	27	571	544	95%
63	53	1,016	963	95%
64	5,316	1,266	4,050	320%
65	120	2,505	2,385	95%
66	41	4,026	3,985	99%
67	26	41	15	37%
68	20	184	164	89%

APPENDIX F

SUMMARY OF EFFECTIVE FORECASTING PRACTICES

Recommendation 2 suggests that MPOs consider creating, attending, or otherwise assisting with the implementation of a forum for disseminating effective socioeconomic forecasting practices. As a starting point for such a forum, 10 effective practices identified during the course of this research are given here: some were provided by interviewees and others were based on the literature review and the case study. These 10 practices are not necessarily comprehensive. Rather, they summarize the state of the practice that may be advanced by an appropriate forum as suggested in Recommendation 2 of this report.

1. Update regional forecasts more frequently than every 5 years.

In the Lynchburg regional area case study conducted during this study, 80% of the error in population forecasts resulted from only two zones where anticipated land development did not occur. Thus, identifying key changes, such as new industries that will or will not come to a region, as quickly as possible may be the single largest step an MPO can take to reduce forecast error. The finding from the literature that it is difficult to develop projections for smaller geographical areas (Murdock et al., 1991) implies that changes that would affect such areas, such as a rezoning, should be noted as quickly as possible. Although more frequent updates can be initiated by the MPO, localities can also assist in this effort by providing updates to the MPO as anticipated changes in projected land use (e.g., rezonings) become known.

2. Recognize that despite a region's best efforts, forecasts will have some error. Thus, consider developing two sets of forecasts: (1) the best estimate, and (2) this estimate modified by a high or a low percentage.

In the Lynchburg case study, even after the impact of the two zones noted previously was addressed, there was some forecast error for individual zones. The "high" or "low" percentage selected may be based on the information presented in Table 8 of this report or local knowledge. This practice is also supported by the literature that examined 2020 transportation alternatives in Volusia County (Florida) using three sets of projections: low, medium, and high numbers of households (Zhao and Chung, 2006).

3. After the travel demand model has been executed with the two sets of forecasts suggested in Practice 2, assess how the recommendations that follow from the travel demand model might be affected.

This practice is supported by a Kansans study (Eustace et. al., 2005) in which the authors noted that although a 20-year evaluation of socioeconomic forecasts in one location showed poor accuracy, the resultant actions taken as a result of executing the travel demand model (e.g., the action was to determine which streets to widen based on traffic forecasts, where those traffic forecasts were based on these socioeconomic forecasts)—had not been adversely affected.

4. **Consider whether the various types of forecast errors that are possible, such as discrepant population forecasts or trip generation forecasts, are likely to *compound* or *cancel*.**

This practice is supported by Rodier (2003). In this study, a 10-year validation effort in Sacramento (California) showed that although population growth had been overestimated, the expected trip generation rates had been underestimated such that the two types of errors tended to cancel. Further, as noted in the Lynchburg regional case study in this report, individual zone forecast errors tended to cancel such that a regional forecast error was relatively small.

5. **If performing a trend analysis, consider the extent to which previous trends will likely be good indicators of future trends.**

Meyer and Miller (2001) gave the example of initial transportation investments influencing growth to a greater degree than subsequent investments (since these subsequent investments are made in a location that already enjoys heightened accessibility).

6. **Consider the extent to which economic development (or other exogenous factors) may influence forecasts.**

The *Transportation Planning Handbook* (Institute of Transportation Engineers, 1992) explains that an economic analysis might be provided by groups that have an interest in monitoring the economy, such as a local chamber of commerce or a local university.

7. **Use a judicious mix of analytical procedures and local knowledge, the latter of which is critical for shorter term forecasts.**

Based on a Lansing (Michigan) regional study, Hendricks et al. (1997) noted: "Ideally, local knowledge would account for most of the near-term forecasts and the analytical procedures would be used for longer-term forecasts." Further, interviewees in the current study noted the use of local knowledge for correcting zone boundaries.

8. **When presenting possible forecasts to a steering committee, ask them to comment not just on the forecast (such as the employment in 2030 for a given subset of exurban zones) but also on the inherent assumptions (such as the extent to which that exurban area will remain an attractive employment location relative to other zones within the region).**

Schenker and Balfe (1973), reporting on a southeastern Wisconsin case study, suggested previous predictions could have been improved by "presenting this committee not with the prepared array of forecasts but with the assumptions on which the forecasts are based."

9. Use the American Community Survey as appropriate to update certain trends, such as number of vehicles per household.

Cambridge Systematics, Inc., et al. (2007) noted that American Community Survey (ACS) data are available on a yearly basis rather than a decennial basis, which is the case with some U.S. Census data. The ACS is replacing the "long form" associated with the decennial Census as a key source of socioeconomic data (Cambridge Systematics, Inc., et al., 2007). ACS data are not a panacea for obtaining perfect socioeconomic information; e.g., care must be taken for areas that have populations that change dramatically over the course of a year, such as a city where university students comprise a significant component of the general population (Cambridge Systematics, Inc., et al., 2007).

10. Discuss with the district planner or persons executing the travel demand model the types of data that are required for the model for that particular region.

Comments from the interviewees in this study (Miller, 2008) and related literature (VDOT, 2007) suggested this practice. Some data requirements are quite clear; e.g., ideally, zone employment will be classified using the North American Industry Classification System (NAICS) (VDOT, 2007). Other data-related decisions may benefit from interaction between socioeconomic forecasters and modelers. For example, although it is desired that zones use U.S. Census block group boundaries, there may be cases where zones need to be smaller than a block group (VDOT, 2007); identifying these cases may thus be a productive topic of discussion. Another example where discussion or formal guidance may be beneficial is the topic of deciding the boundary for the MPO (Miller, 2008).

References

Cambridge Systematics, Inc., NuStats, McGuckin, N., and Ruiter, E. *NCRP Report 588: A Guidebook for Using American Community Survey Data for Transportation Planning.* Transportation Research Board, Washington, DC, 2007. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_588.pdf. Accessed June 18, 2008.

Eustace, D., Russell, E.R., and Landman, D.E. *Development of Multiple Growth Strategies in Developing Traffic Forecasts: A Robustness Approach* (Abstract). Kansas State University, Manhattan, 2005.

Hendricks, S.C., Costinett, P.J., Outwater, M.L., Hamilton, P.T., and Hershkowitz, P. Socioeconomic Forecasting Model for the Tri-County Regional Planning Commission. In *Sixth TRB Conference on the Application of Transportation Planning Methods.* Transportation Research Board, Washington, DC, 1997. http://ntl.bts.gov/lib/7000/7500/7504/789762.pdf. Accessed June 17, 2008.

Institute of Transportation Engineers. *Transportation Planning Handbook*, 2nd Ed. Prentice Hall, Englewood Cliffs, NJ, 1992.

Miller, M. Email to Danielle McCray, April 22, 2008.

Murdock, S.H., Hamm, R.R., Voss, P.R., Fannin, D., and Pecotte, B. Evaluating Small-Area Population Projections. *Journal of the American Planning Association*, Vol. 57, No. 4, 1991, pp. 432-443.

Meyer, M.D., and Miller, E.J. *Urban Transportation Planning*, 2nd ed. McGraw-Hill, New York, 2001.

Rodier, C.J. *Verifying the Accuracy of Regional Models Used in Transportation and Air Quality Planning*. Mineta Transportation Institute, San Jose, CA, 2003. http://transweb.sjsu.edu/mtiportal/research/publications/documents/verifyingmodels.htm. Accessed June 17, 2008.

Schenker, E., and Balfe, M. Population and Employment Forecast: A Case Study. *Traffic Quarterly*, Vol. 27, No. 4, 1973, pp. 529-540.

Virginia Department of Transportation, Transportation and Mobility Planning Division. *Virginia Travel Demand Modeling Policies and Procedures Manual*. Version 1.22. Richmond, 2007. http://www.virginiadot.org/projects/resources/vtm/VTM_Policy_Manual.pdf. Accessed June 18, 2008.

Zhao, F., and Chung, S. *A Study of Alternative Land Use Forecasting Models*. Florida Department of Transportation, Tallahassee, 2006. http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PL/FDOT_BD015_10_rpt.pdf. Accessed June 23, 2008.