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research report

Feasibility of Using Jobs/Housing Balance in Virginia Statewide Planning

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16. Abstract:

The *Code of Virginia* (§ 33.1-23.03) requires that the Statewide Transportation Plan include "quantifiable measures and achievable goals relating to . . . job-to-housing ratios." Such ratios reflect *jobs/housing balance,* defined as an equivalence in the numbers of an area's jobs and area residents seeking those jobs. This report identifies planning policies based on jobs/housing balance, examines the impact of such balance on commuting, and demonstrates how to measure this balance using Virginia data.

The research suggests that the *Code* requirement may be satisfied by using the ratio of jobs to labor force, as this ratio is highly correlated with the job-to-housing ratio (based on examining 1980, 1990, and 2000 data) and is computationally feasible, at the jurisdictional level, on an annual basis. Alternative approaches for satisfying the requirements of the *Code* are also described in the report; these alternative approaches require additional effort but may be productive in certain circumstances.

A simple longitudinal model developed using changes in Virginia jurisdiction commute time from 1990 through 2000 estimates that the average impact of a given urban jurisdiction improving its balance by 20% is a reduction in commute time of about 2 minutes. This effect is evident only if several factors, such as the manner in which the urban region is defined, are carefully controlled. Otherwise, there is no significant impact of a change in jobs/housing balance on a given jurisdiction's commute time. This finding is within the wide range of impacts of jobs/housing balance noted in the literature.

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FINAL REPORT

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EXECUTIVE SUMMARY

Introduction

Jobs/housing balance, defined as an equivalence in the number of an area's jobs and the number of the area's residents seeking those jobs, has generated public interest for two main reasons. First, by encouraging jobs and housing to be located close to each other, it is hoped that the 27% of vehicle miles traveled (VMT) that are attributable to commuting (based on 2001 National Household Transportation Survey data [Hu and Reuscher, 2004]) can be reduced (California Planning Roundtable [CPR], 2008). Second, by encouraging the construction of employment sites and residential sites in close proximity, it is hoped that progress may be made toward several social objectives—better air quality, better access to employment, a greater number of housing choices, and the spread of the benefits of transportation infrastructure across diverse economic groups (Giuliano, 1991; Levine, 1998; Macek et al., 2001; Zhang et al., 1999).

Because the *Code of Virginia* (§ 33.1-23.03) requires that (1) the Statewide Transportation Plan (STP) include goals and measures *relating to* jobs-to-housing ratios and (2) that the Commonwealth Transportation Board consider these goals in developing the Virginia Department of Transportation's Six-Year Improvement Program (SYIP), this study identified planning policies based on jobs/housing balance, examined the impact of such balance on commuting, and demonstrated how to measure this balance using Virginia data.

Potential Policies Based on Jobs/Housing Balance

In various U.S. locations, five types of policies have been proposed or implemented that rely on jobs/housing balance; a sixth policy is not to establish a policy.

1. *Redirect future land development*. Washington, Florida, and California have used the ratio of jobs to housing to redirect future growth: jobs/housing ratios were a consideration in Washington's Puget Sound Regional Council's (2008a) land use plans for 2040; initial calculations of such ratios at redevelopment projects in Seattle, Washington (Frank, 1994), and Fort Ord, California (Klim and Bilse, 1999), led planning staff to seek alternative land development proposals that would yield more balanced ratios. Florida's state land use planning agency has demonstrated a willingness to use jobs/housing balance as a factor when reviewing land use amendments developed by localities (McDaniel, 2009).

2. *Diagnose local land use regulations that prohibit achievement of jobs/housing balance*. Jobs/housing balance may be used to identify locations where local zoning restrictions prevent jobs and housing from being located in close proximity (Peng, 1997); such a policy does not seek to alter the price of housing otherwise. These zoning restrictions include prohibition of accessory dwelling units, the location of small convenience stores in otherwise residential-only neighborhoods (Atlanta Regional Commission, 2002), and minimum lot sizes (Levine, 1998). Several authors

have noted the impact of growth restrictions on achieving balance (e.g., Cervero, 1996).

3. *Provide private or public incentives to increase jobs/housing balance*. Incentives may appeal to the private and public sectors: examples are Bellevue, Washington, where developers were permitted to add 4 square feet of office area for each additional square foot of residential area they provided (Cervero, 1989), and California, which provided grants to localities that allocated residential building permits and had a relatively high jobs/housing ratio (California Department of Housing and Community Development, 2007).

4. *Implement tax-base sharing.* Factors such as population and the number of school-age children may be used to redistribute some portion of regional commercial property tax revenues among localities (Hinze and Baker, 2005; Myers, 2005). Such a policy may prevent localities from pursuing commercial development at the expense of residential development (Cervero, 1989). Although such policies have been implemented in the Minneapolis–St. Paul, Minnesota, region (Cervero, 1989; Hinze and Baker, 2005) and the Meadowlands in New Jersey (Myers, 2005) there are legal and administrative considerations that affect their applicability to Virginia (Roberts, 2009; Virginia Chapter, 2009).

5. *Identify locally specific transportation and land use initiatives*. One example is implementing better transit service to connect residents to employment centers (Singa et al., 2004) or low-income residents to affordable housing (Chicago Metropolitan Agency for Planning, 2009). Under this policy option, a diagnosis of an imbalance does not indicate an immediate course of action but rather requires each region to identify specific causes of the imbalance before taking further action (CPR, 2008).

6. *Do not use jobs/housing balance as the basis for a transportation policy.* Some have argued that other measures that directly impact travel, such as tolls or transit quality, are more effective for reducing congestion than jobs/housing balance (Cervero, 1995; Downs, 2004). Others have argued that causality between jobs/housing balance and travel behavior is not sufficiently strong to implement such policies: Miller and Ibrahim (1998) suggested that a better predictor of commuting is distance to high-density employment locations, and Giuliano (1991) suggested no link could be found between such balance and commute length.

Note that there is no single numerical criterion that comprises a universal standard for defining *good balance.* For example, one performance measure that indicates the extent to which a location is balanced is the ratio of jobs to housing in the location relative to adjacent areas. Such balanced ratios have been characterized as about 1.25 (Singa et al., 2004); 1.0 to 1.29 (Armstrong et al., 2001); 0.8 to 1.2 (Frank, 1994); and 1.2 to 2.8 (Peng, 1997); the last was based on the fact that values in this range showed little variation in terms of vehicle travel.

Impact of Jobs/Housing Balance on Commuting Behavior

A review of more than a dozen studies quantified the impacts of jobs/housing balance on commute distance or commute travel time; 11 such studies are highlighted here.

No Impact on Commuting

Four studies showed no impact of jobs/housing balance on commute travel time or distance. Giuliano (1991) found no relationship between jobs/employment ratios and commuting distance based on Los Angeles data and attributed the lack of causality to other factors that influence location decisions, such as households containing more than one worker and commuting costs being comparatively small related to housing costs. A study of 13 pairs of planned and unplanned communities showed no difference in commute distance (Zehner, 1977). Miller and Ibrahim (1988) found that the jobs/housing ratio did not explain the variation in VMT in Toronto (Canada) once other factors, such as the distance of a given zone to a high-density employment area and rail transit, were considered. Yang and Ferreira (2005) showed weak correlations (0.10 and 0.11) between commute times and jobs/housing ratios.

An explanatory factor as to the reason commuting may not be affected by jobs/housing balance is that balance in a given location does not guarantee that residents will have nearby employment sites: although the Los Angeles suburb of Valencia had a jobs/housing ratio of approximately 1.0, about one half of the residents worked in the city of Los Angeles ("An Age of Transformation," 2008). Cervero (1996) stated that the reason a similar phenomenon occurred in Pleasanton, California (which saw its jobs/housing balance grow despite the fact that most persons living in Pleasanton worked elsewhere), is that housing costs for most Pleasanton residents exceeded the average salary for most Pleasanton workers. In addition, Downs (2004), Giuliano (1991), and Gordon et al. (1991) suggested that jobs/housing imbalances are only temporary and that without interference from zoning ordinances, residents and firms will bring themselves into balance.

Modest or Substantial Impact on Commuting

Four studies showed modest impacts on commuting. Bento et al. (2003) reported an elasticity of 0.006 between annual VMT and an indicator of jobs/housing imbalance; by comparison, stronger elasticities between annual VMT and income (0.06) or distance to the nearest transit stop (0.009) were noted. Downs (2004) computed a maximum transportation-related impact of a dramatic increase in jobs/housing balance as 9.5%. Peng (1997) reported that Portland, Oregon, data showed that the jobs/housing ratio affected commute distance substantially only for the relatively few areas where there was an extreme imbalance (about 17% of the region). Cervero (1995) found that planned communities in the United States had a 13.3% shorter commute time than those in unplanned communities.

Three studies showed substantive impacts of the jobs/housing ratio on commute time or distance. Wang and Chai (2009) found that individuals living and working in the same district had statistically significantly lower travel times than those who worked elsewhere; the finding was accentuated because some portions of the city were so congested that motorized travel was slower than nonmotorized travel such that distance was a strong surrogate for travel time. Frank (1994) found that work trips terminating in census tracts in Washington's Puget Sound region that had a balanced jobs/household ratio were, on average, 28% shorter than work trips ending in tracts with an unbalanced ratio. Cervero and Duncan (2006) found that for each 10% increase in total jobs within 4 miles of a residence in the San Francisco Bay Area, VMT was reduced by 2.99%. (If jobs were matched to residents, this reduction was 3.29%.)

An explanatory factor with regard to the reason commuting has been affected by jobs/housing balance is that there are situations where balance has been associated with the decision to live and work in the same community. Cervero (1989) showed that jobs/housing balance is associated with the behavior of living and working in the same community, with a correlation coefficient of -0.57 for jobs/housing balance and the percentage of a community's employment positions filled by local residents. Based on data from the Minneapolis region, Levine (1998) found that jobs/housing policies were most likely to affect low- and middle-income single-worker households.

Ways to Measure Jobs/Housing Balance

The most straightforward way to measure jobs/housing balance is through a ratio of employment to population, total housing units, occupied housing units (which are households), or labor force. [Although jobs/employed population is not identical to jobs/housing, the rationale for using the former ratio as a surrogate for the latter is that both ratios refer to a type of balance—the equivalence of employment opportunities and the persons who seek them—in a given location.] Of the three possibilities for the denominator of a jobs/housing ratio (total housing, occupied housing, and employed population), CPR (2008) suggested that the best was employed population, in part because the resulting ratio, i.e., employment to employed population, would be approximately 1.0 and thus easier to understand.

Data for the Richmond, Virginia, region showed that four ratios based on Virginia Employment Commission (VEC) jobs estimates (jobs/households, jobs/total housing, jobs/labor force, and jobs/population), as well as a fifth ratio (jobs/population according to Bureau of Economic Analysis jobs data), yielded similar findings relative to the regional average, as shown in Figure ES1. All four VEC-based ratios were highly correlated (>0.96). A caveat to these findings is that these ratios were calculated here at the jurisdiction level; had they been computed at the census tract level, it is possible that the correlation would have been lower.

The similarity of the ratios shown in Figure ES1 applies to other jurisdictions in Virginia and other time periods. Jurisdiction data from 1980, 1990, 2000, and 2006 show correlations of at least 0.99 for population, labor force, and housing and 0.93 to 0.96 for jobs/labor force and jobs/total housing.

More sophisticated approaches have also been used in lieu of jobs/housing ratios. One is the imbalance indicator (Bento et al., 2003). The extent to which a region's jobs and housing are not balanced is reflected by the difference between the cumulative proportion of employment and the cumulative proportion of population. Figure ES2 provides an imbalance indicator for the

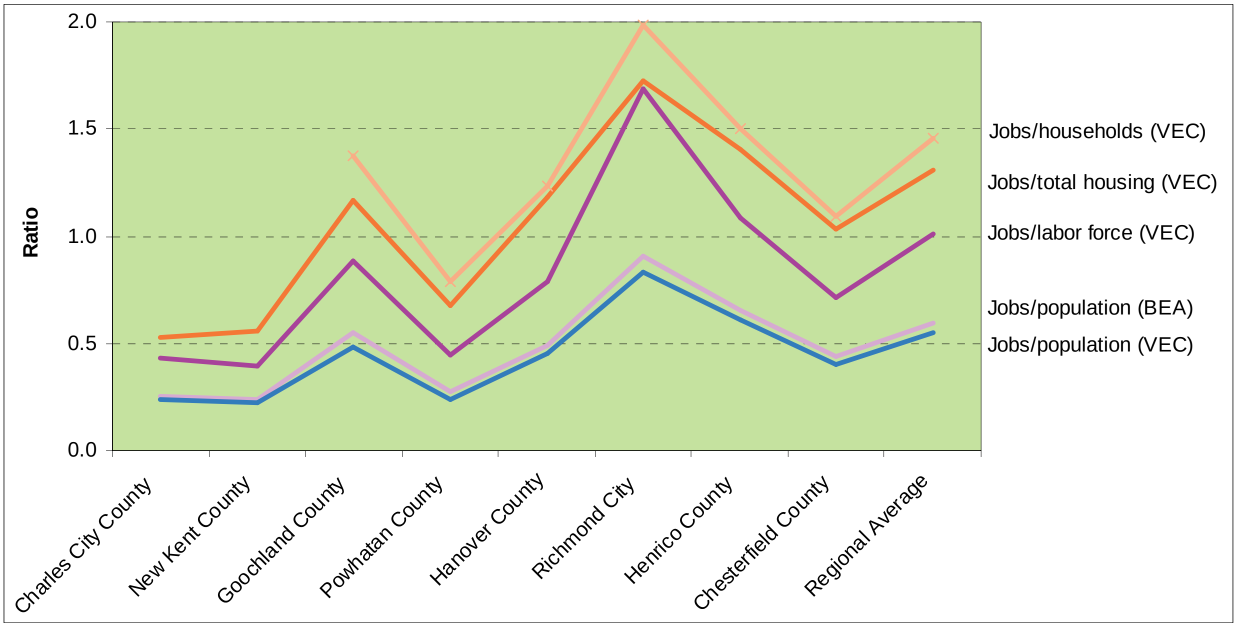

Figure ES1. Ratios Portraying Jobs/Housing Balance in the Richmond, Virginia, Metropolitan Area (2006). Data sources were jobs (Bureau of Economic Analysis, 2009; Virginia Employment Commission, undated); households (U.S. Census Bureau, 2008a); total housing (U.S. Census Bureau, 2008b); labor force (Virginia Employment Commission, undated); and population (Weldon Cooper Center for Public Service, 2009a).

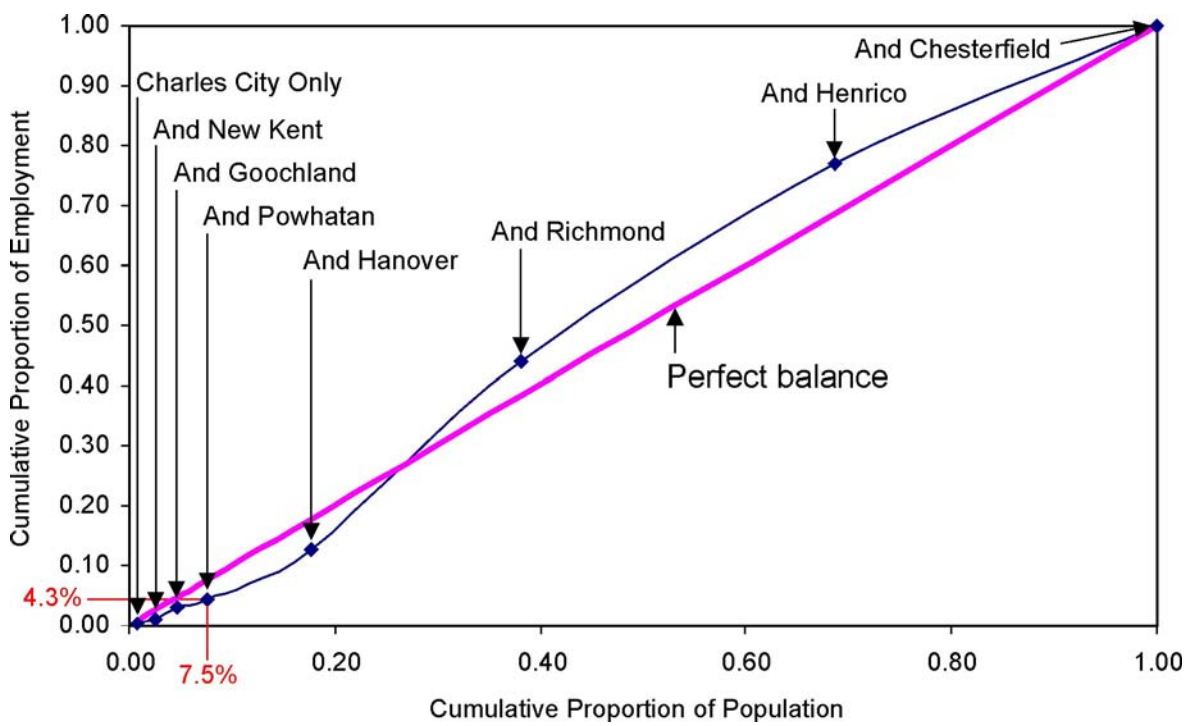

Figure ES2. Application of Jobs/Housing Imbalance Indicator (Bento et al., 2003) to Richmond, Virginia, Metropolitan Area. For example, the 4 least populated counties (Charles City, New Kent, Goochland, and Powhatan) represented 7.5% of the region's population and 4.3% of the region's employment. The area between the two lines represents the extent to which the region's jobs and housing are not balanced. Data sources were population (Weldon Cooper Center for Public Service, 2009b) and employment (Bureau of Economic Analysis, 2009).

Richmond, Virginia, metropolitan area, where population exceeds employment for the five smallest jurisdictions (Charles City through Hanover in Figure ES2). (In a perfectly balanced region, cumulative employment would equal cumulative population for each jurisdiction.)

An alternative approach is the linear dissimilarity index, which measures the extent to which subareas contain equal numbers of jobs and housing. The lowest possible value for this index is 0 (which occurs if each subarea has exactly as many houses as jobs). The highest possible value is 1, which occurs if each subarea has jobs or housing but not both. A variation is the exponential dissimilarity index (Marion and Horner, 2008), which accounts for the case of a jobs-rich and a jobs-poor area being located in different jurisdictions but quite close to each other.

Impact of Virginia Jobs/Housing Balance on Commute time

- *At the regional level, there was virtually no correlation between the change in the planning district commission (PDC) travel time over a 10-year period and the change in jobs/housing balance (measured as the linear dissimilarity index).* This is not surprising since a variety of other factors may influence travel time more than jobs/housing balance.

- *At the jurisdictional level, an impact was detected.* The disparity between each jurisdiction's jobs/labor force ratio and the PDC's jobs/labor force ratio was calculated. Then, the disparity between each locale's average commute time and the PDC's average commute time was calculated. This approach sought to measure the extent to which jobs/labor force ratio influenced commute time by controlling for regional differences in commuting behavior. Correlations were -0.71 to -0.72 for 1980, 1990, and 2000 and -0.77 for 2006. Figure ES3 is a scatter plot of these disparities where the three PDCs were combined into a super-region; for example, Stafford has a jobs/labor force ratio that is about 0.30 below the super-region average and a commute time that is almost 8 minutes greater than the super-region average. Such approaches show that for two jurisdictions located in the same region, if jurisdiction x has a 20% higher balance than jurisdiction y, then jurisdiction x's commute time will be 3.4 minutes lower than that of jurisdiction y (when only urban regions are considered) or 5.3 minutes (when all Virginia regions are considered).

- *A combined regional and local model that predicts 2000 commute times for urban jurisdictions was calibrated, with all terms found to be statistically significant.* (The model was valid only for select urban regions.) The model is shown in Equation 1:

  Jurisdiction commute time in 2000 = 0.79A + 101.07B – 1.07C + 7.09D + 11.58   [Eq. 1]

  where

  A = Jurisdiction commute time in 1990

  B = PDC dissimilarity index in 2000 – PDC dissimilarity index in 1990

  C = Jurisdiction jobs/labor force – PDC jobs/labor force

Figure ES3. Jobs/labor Force Disparity Versus Travel Time Disparity for the Super-Region of the Northern Virginia PDC, the Rappahannock-Rapidan PDC, and the George Washington Regional Council for Year 2000. Data sources were travel times (U.S. Census Bureau, 2002) and jobs and labor force (Virginia Employment Commission, undated).

D = Proportion of persons commuting outside their jurisdiction of residence in 2000 – Proportion of such commuters in 1990.

Note that 11.58 is the intercept, which is simply added to the right hand side of Equation 1 to obtain a more accurate estimate of the jurisdiction commute time in 2000.

A sensitivity analysis showed that the combined effect of the three variables related to jobs/housing balance—i.e., variables B, C, and D—was only about one half of the impact of variable A (the commute time in 1990). That is, a 20% change in variable A decreased travel time by 4.2 minutes and a 20% change in variables B, C, and D decreased commute time by 2.2 minutes. Interestingly, according to variable B (the linear dissimilarity index), there was an improvement in jobs/housing balance in the urban regions for the period 1990 through 2000.

Conclusions

- *A variety of policies related to jobs/housing balance have been proposed; fewer have been implemented.* Those implemented include redirecting future land development and offering incentives to increase housing in areas where it is needed. Some literature specifically advises against using jobs/housing balance as a technique to reduce congestion.

- *The most common performance measure for assessing jobs/housing balance is the ratio of jobs to housing in one location relative to adjacent areas.* Other performance measures include the ratio of employment to population, the dissimilarity index, and the imbalance indicator.

- *Jobs/housing balance may be measured in at least two ways using Virginia data at the jurisdiction level:*

    — *To assess a jurisdiction's balance relative to the region at a given instant in time,* compare the ratio of the jurisdiction's employment and labor force to the regional ratio of employment to labor force. Positive values mean a surplus of jobs to labor force; negative values mean a jobs-poor area. Jurisdictional employment/labor force ratios are highly correlated (0.93 to 0.96) with ratios of jobs to total housing units.

    — *To assess how a region's jobs/housing balance changes over time,* compute the change in the linear dissimilarity index, which is based on employment and labor force values for the various jurisdictions that comprise the region. Positive values (an increase over time) mean jobs/housing balance is decreasing; negative values mean it is increasing.

- *Virginia jurisdictional data show that at a given point in time, above-average jurisdiction commute times are correlated with below-average jurisdiction jobs/labor force ratios after controlling for the region in which these jurisdictions are located. This correlation exceeded -0.7 for all time periods examined: 1980, 1990, 2000, and 2006.*

- *Longitudinally, Virginia data showed that jobs/housing balance has a statistically significant impact on a jurisdiction's average commute time in select urban areas. This impact is evident only when other factors are carefully controlled.*

- *According to the longitudinal model used for Virginia urban areas, the impact of jobs/housing balance on commuting is within the wide range of findings from other studies.* Some literature indicated no impact on commuting; other sources indicated a 28% reduction in VMT or a 13.3% reduction in travel time. In Virginia, the longitudinal model shows that a 10% increase in employment in one jobs-poor jurisdiction in a large congested urban region reduced travel time by about 1.4%.

- *Virginia jurisdictional data show that the impact of jobs/housing balance on commute time depends on whether the impact is measured spatially at a single point in time or longitudinally.*

    — At a single point in time, a jurisdiction for which jobs/housing balance is 20% higher than that of another jurisdiction (in the same region) could expect to have a 3.4-minute lower commute time (if only urban areas are considered) or a 5.3-minute lower commute time (if all jurisdictions statewide are considered). However, such an analysis does not prove jobs/housing balance caused a drop in travel time: although balance may have caused such a decrease, it is also possible that other factors associated with this balance (e.g., transit service, compact development, etc.) caused the decrease.

— A longitudinal analysis that indirectly attempted to control partially for these factors by examining how jobs/housing balance influenced each jurisdiction's travel time over a 10-year period showed more modest impacts: a 20% increase in a given jurisdiction's jobs/housing balance decreases commute time by 2.2 minutes (if only urban areas are considered) and has no impact if all jurisdictions are considered.

Options for Incorporating Jobs/Housing Balance Into the Development of the Statewide Transportation Plan or the Six-Year Improvement Program

There are at least two ways that jobs/housing balance can be used in Virginia's STP and/or the development of the SYIP given the requirements of the *Code of Virginia* (§ 33.1-23.03). Either option can be used; it is not necessary to use both.

1. *Determine whether a proposed transportation project improves the connection between a jurisdiction with a high jobs/labor force ratio and a low jobs/labor force ratio where "high" and "low" are determined relative to the regional average*. This option can be implemented at present, as described in the full report.

2. *Determine whether a proposed transportation project improves the exponential dissimilarity index for the region.* This option requires additional effort, as is described in the full report.

Because this study examined data only at the jurisdiction level rather than at the more detailed census tract level, a variant of the two options is to perform analyses using smaller geographic units, such as census tracts. The reason for such a modeling step is to determine the extent to which jobs/housing balance affects commute times. It is recognized that commute times are affected by a variety of variables based on transportation system characteristics (highway congestion levels, transit availability, operational strategies); employer characteristics (e.g., proximity of employers to various transportation facilities, flextime policies); personal characteristics; fuel costs; and so on. Thus, the purpose of this additional work would be to determine the importance of jobs/housing balance, if any, on commute times despite the existence of these other factors.

Table A3 of Appendix A mentions additional research questions that could be considered in the future. If Virginia does pursue jobs/housing balance as per the options provided here, it would be informative to compare the future change in balance to the change that occurred from 1990 through 2006.

FINAL REPORT

FEASIBILITY OF USING JOBS/HOUSING BALANCE IN VIRGINIA STATEWIDE PLANNING

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INTRODUCTION

The *Code of Virginia* (§ 33.1-23.03) requires that Virginia's Statewide Transportation Plan (STP) "include quantifiable measures and achievable goals relating to . . . job-to-housing ratios." This plan is the responsibility of the Commonwealth Transportation Board (CTB), with the "assistance of the Office of Intermodal Planning and Investment" (§ 33.1-23.03). Most recently, the office developed *VTrans2035: Virginia's Long-Range Multimodal Transportation Plan,* which has a horizon year of 2035 (Office of Intermodal Planning and Investment, 2010). The *Code* further requires that the CTB "shall consider such goals in evaluating and selecting transportation improvement projects for inclusion in the Six-Year Improvement Program [SYIP]."

Although the purpose of using this ratio may be to improve transportation and land use coordination, the problem facing Virginia's Office of Intermodal Planning and Investment is that the best approach for calculating quantifiable measures relating to job-to-housing ratios and establishing related achievable goals is not known. Further, although the *Code* clearly requires the consideration of such goals by the CTB when selecting projects for inclusion in the SYIP, it does not specify the degree to which such goals must be used relative to other factors. So long as such goals are considered, the CTB is in compliance with the *Code* whether a goal related to job-to-housing ratios is a dominant or secondary factor in project selection.

In addition, the *Code* does not specify *how* such ratios should be used in the STP. In the formulation of the research, Davis (2009) and Tischer (2009) asked what policies the state should consider relative to jobs/housing ratios, especially if jobs/housing balances were to worsen in some metropolitan areas (Davis, 2008). Although the range of possible policies was not known at the inception of this research, the researcher knew that policies based on jobs/housing ratios had been proposed, implemented, and/or evaluated elsewhere in the United States. Accordingly, a first step was to identify such policies in the literature.

Because some literature refers to metrics comparable to, but distinct from, "jobs-to-housing ratios" (an example being the ratio of jobs to employed population), this report uses the term *jobs/housing balance* to refer to the equivalence of employment opportunities and persons who seek those employment opportunities in a given location. Thus, a "job-to-housing" ratio is one, but not the only, approach to assess jobs/housing balance. Given that the *Code* specifies measures and goals "relating" to "job-to-housing ratios," it was appropriate to consider the broader term *jobs/housing balance* as this term relates to job-to-housing ratios.

PURPOSE AND SCOPE

The purpose of this study was to identify ways in which jobs/housing balance, defined as an equivalence in the numbers of jobs and residents seeking those jobs, may be used to influence state or regional planning policies. In particular, this study sought to be as comprehensive as possible in applying such concepts to Virginia.

The study had three objectives:

1. *Identify jobs/housing policies that have been proposed or implemented elsewhere.* This objective satisfies the request to identify potential policy responses.

2. *Identify ways in which jobs/housing balance may be measured and goals related to such measurements, and demonstrate such measurements using Virginia data.* This objective addressed the explicit requirement in the *Code of Virginia* (§ 33.1-23.03).

3. *Quantify the impacts of jobs/housing balance on commute time based on data from other states and data from Virginia.* Achieving this objective may help decision makers determine the importance of jobs/housing balance relative to other factors. This objective was incorporated into this study because one reaction to previous socioeconomic projections (Miller, 2009) was that it was possible that congestion could increase in major metropolitan areas where the jobs/housing balance might worsen (Davis, 2008). Therefore, quantifying how such a balance might affect commute time appeared to be an appropriate endeavor.

Regarding Virginia data, the scope of the third objective was limited in two ways. First, the smallest unit of geographical analysis used was a jurisdiction rather than a census tract. Second, commute time was limited to data obtained through the decennial census (1980, 1990, and 2000) and the American Community Survey (for the period 2005-2007).

METHODS

Four tasks were carried out to achieve the study objectives.

1. *Review the literature.* The literature was examined to identify potential policies, determine how jobs/housing balance could be defined, and quantify the impacts of balance on commuting behavior as reported elsewhere.

2. *Collect longitudinal Virginia data.* Appendix A summarizes the creation of a longitudinal Virginia dataset for the period 1980 through 2008. Data that could be used to measure jobs/housing balance in a consistent manner on an annual basis were sought at the jurisdictional level. Data elements included population (Weldon Cooper Center, 2009a,b); employment and labor force (Virginia Employment Commission [VEC], undated); housing units (Minnesota Population Center, 2004a; U.S. Census

Bureau, undated [b], 1992, 2008a, 2008b); proportion of commuters commuting outside their jurisdiction of residence (Spar, 1984; U.S. Census Bureau, undated [c], 1999, 2003); and commute time frequencies (Minnesota Population Center, 2004b,c; U.S. Census Bureau, undated [a], 2002). Generally, employment and labor force data are available in electronic format from 1990 to the present and are available in paper format prior to 1990. Total housing units are available on an annual basis only since 2000; prior to 2000, housing is available on a decennial basis. Occupied housing data are also available on a decennial basis; for jurisdictions with a population over 20,000, they are available from the 2005-2007 American Community Survey (U.S. Census Bureau, undated [a]).

Note that definitions of these data elements may depend on the data source. For example, jobs as reported by VEC are based on the Quarterly Census of Employment and Wages. The Bureau of Labor Statistics (BLS) (2005, 2008) explains that these data reflect filled jobs (thus two jobs held by the same person would be reported in this dataset as two jobs); further, jobs that are not covered by unemployment insurance, such as self-employed farmers, are not reported. Accordingly, another data source, the Bureau of Economic Analysis (BEA), which does include some self-employed persons not covered by BLS (Prytula, 2009), will give different jobs totals than those reported by VEC.

3. *Use Virginia data to define jobs/housing balance.* The literature review yielded multiple ways in which jobs/housing balance could be defined. Virginia data were used to apply each definition reported. This application helped ensure that the logic of the definition was understood and that it was feasible to acquire the necessary data.

4. *Quantify the impact of jobs/housing balance on commute time using Virginia data.* As explained in Appendix A, average commute time data were tabulated from the U.S. Census Bureau (undated [c], 1999, 2003) for the 1990, 2000, and 2006 years and from the Minnesota Population Center (2004b) for the 1980 year. Then, a relationship between average commute time and jobs/housing balance was sought at three geographical levels of analysis: the regional or planning district commission (PDC) level, the jurisdiction level, and a combined regional and PDC level. In instances where a statistically significant relationship was found, the impact of jobs/housing balance on commute time was quantified.

RESULTS

The results are presented across four sections.

1. polices based on jobs/housing balance
2. impact of jobs/housing balance on behavior
3. ways to measure jobs/housing balance
4. relating Virginia jobs/housing balances to commute times.

The first two sections are based on the literature review, and the third and fourth sections use Virginia data.

Policies Based on Jobs/Housing Balance

Jobs/housing balance has conceptual promise as an instrument of either congestion-reduction (by shortening commute trip length) or social equity (by providing better access to employment and/or providing more affordable housing).

The California Planning Roundtable (CPR) (2008) wrote: "It is traffic congestion, more than any other single factor, that fuels interest in jobs-housing balance." According to Hu and Reuscher (2004), data from the 2001 National Household Travel Survey attributed about 27% of household vehicles miles traveled (VMT) to commuting trips. Thus, a land use metric to reduce commute VMT appears meritorious. Although indicating home-based work trips are 20% of VMT, CPR (2008) placed greater importance on the work trip than the percentage alone suggests, noting that it is often the case that peak periods of travel, when demand may exceed capacity, occur as a result of commuter traffic. The Atlanta Regional Commission (ARC) (2002) stated an "inherent logic" in aligning jobs and households in an effort to reduce VMT.

Social goals related to jobs/housing balance have been noted, including enabling impoverished groups to find employment or better employment (Cervero, 1989; Downs, 2004; Macek et al., 2001; Thakuriah et al.; 2003); improving accessibility of employment for all groups (Lindquist, 1998; Zhang et al., 1999); eliminating zoning practices that exclude the availability of affordable housing in suburban areas (Giuliano, 1991); improving affordable housing for those persons who choose to live near their place of employment (Levine, 1998); and possibly improving air quality to the extent that vehicle trips in well-balanced areas are replaced by walking and transit trips (Levine, 1998). Macek et al. (2001) called for better jobs/housing balance in urban areas when, according to their report, 1995 National Personal Transportation Survey data for the New York City metropolitan area (which includes portions of Connecticut, New Jersey, and Pennsylvania) indicated that captive transit riders have a lower probability of employment than would otherwise be the case because of poor access to employment centers. In some cases, the potential to achieve social goals is considered more important than travel improvements; three of the aforementioned reports (Downs, 2004; Giuliano, 1991; Levine, 1998) do not support jobs/housing balance as a congestion-reduction measure.

To achieve either the congestion-related or social goals, five categories of policies based on some measure of jobs/housing balance have been implemented or proposed:

1. Redirect future land development.

2. Diagnose local land use regulations that prohibit achievement of jobs/housing balance.

3. Provide private or public incentives to increase jobs/housing balance.

4. Implement tax-base sharing or other state-based programs.

5. Identify locally specific transportation and land use initiatives.

These policies are not mutually exclusive.

Policy 1: Redirect Future Land Development

Levine (1998) characterized jobs/housing balance as the "middle ground" between policies supporting compact development and policies accepting suburbanization because even decentralized locations can yield shorter trips provided work and job sites are in close proximity. Thus, jobs/housing balance has been used to redirect growth in an effort to reduce VMT. Such changes in land development may occur through regional planning (Puget Sound Regional Council); state laws that empower a state land use agency to require localities to consider jobs/housing balance (Florida); and redevelopment of individual land parcels (California and Seattle).

Washington's Puget Sound Regional Council (PSRC) (2008a) explicitly referred to jobs/housing balance in its 2040 regional plan, noting that jobs should be added to areas with excess housing and that housing should be added to areas with excess jobs. The supporting Environmental Impact Statement (PSRC, 2008b) considered five growth alternatives and used the ratio of jobs to housing in 2 of 45 performance measures used to evaluate alternatives. For example, King County had a jobs/housing ratio of 1.6 whereas other areas had a ratio of 1.0 (PSRC, 2005). Thus, one of the performance measures was the percentage of jobs in cities outside King County for each of the five growth alternatives (PSRC, 2008b). For this performance measure, the two best alternatives placed 13% of jobs in such cities, compared to the worst-performing alternative that placed only 8% of jobs in such cities. Testimony to the U.S. Congress indicated that improved jobs/housing balance, along with more compact growth, was expected to result in freeway/interstate congestion in the region increasing by 65%, rather than 150%, between 2000 and 2040 ("Testimony by Charles Howard," 2008).

Florida's House Bill 697 required that future land use plans consider multiple factors, including "the discouragement of urban sprawl; energy-efficient land use patterns accounting for existing and future electric power generation and transmission systems; greenhouse gas reduction strategies . . . " (Florida House of Representatives, 2008). Implementation of this policy is accomplished through Florida's Department of Community Affairs, which reviews amendments to county land use plans and determines compliance with the Florida Administrative Code. For example, the department evaluated a Wakulla County proposed comprehensive plan amendment that would convert more than 200 acres from an agricultural use to a residential and commercial use (McDaniel, 2009). The department's objection to the amendment and subsequent recommendation included the following language:

> House Bill 697, which became law on July 1, 2008, requires any proposed Future Land Use Map amendment to discourage urban sprawl and promote energy-efficient land use patterns . . . .
>
> The land use category and/or Future Land Use Map should be revised to address energy efficient land use patterns and greenhouse gas reductions, including the mixture of uses and balance

> between the residential and non-residential uses. . . . The amendment should identify what strategies will be used to reduce vehicle miles traveled including emphasis on alternative modes of travel, more compact mixed-use development, *greater jobs-housing balance*, and higher densities in appropriate places (emphasis added) (McDaniel, 2009).

As was the case with PSRC, Florida's approach pursued jobs/housing balance in tandem with other land use policies, such as compact development.

Jobs/housing balance has been used as a determinant of a major land redevelopment strategy. The closure of Fort Ord in Monterey, California, resulted in a large tract of land (28,000 acres) becoming available for an estimated 18,000 jobs and 13,500 households (Klim and Bilse, 1999). Because the original land use plans showed that the site would have more jobs than could be supported by persons living at the site, resulting in a large amount of morning inbound commute traffic, the land use plans were reworked to include additional housing such that the number of jobs at the site matched the number of workers who would live at the site.

Frank (1994) noted that the Seattle Commons redevelopment project was examined more closely because jobs/housing ratios were shown to have a significant influence on commute travel time and travel length in the Puget Sound region, with ratios of 0.8 to 1.2 jobs/household being desirable. The project was expected to yield a ratio of three jobs/household and would be located near the central business district (CBD), which also had more jobs than households. City planning staff were asked to examine an additional model alternative—one that would generate additional housing—in the Environmental Impact Statement associated with the redevelopment effort.

Policy 2: Diagnose Local Land Use Regulations That Prohibit Achievement of Jobs/ Housing Balance

Jobs/housing ratios have been proposed as a diagnostic measure to detect local land use ordinances that prohibit achievement of jobs/housing balance. Cervero and Landis (1995) argued that efforts to achieve a jobs/housing balance can be misunderstood as efforts to dictate where individuals should choose to live and work rather than efforts to remove market distortions. As an example, the authors mentioned a zoning change that prevented construction of 1,500 housing units near a particular employment center despite a jobs/housing unit ratio of more than 3.0. The authors noted:

> Imbalances are rooted in fiscal zoning (shunning housing in favor of office, shops, and other high tax-yielding uses) and NIMBY-ism (the "not in my backyard" attitude that assumes more housing equates to more traffic and crowded schools) (Cervero and Landis, 1995).

Peng (1997) echoed this view, describing jobs/housing balance as a failure of planning but not of the market and suggested that efforts should be made to remove obstacles to such a balance, citing as an example downtown revitalization efforts that "replace deteriorated housing with offices and luxury apartments rather than with high-density affordable housing, causing jobs and housing to become more imbalanced." Because Peng (1997) identified two primary obstacles to jobs/housing balance—local opposition to more development and tax incentives that favor commercial rather than residential development—it appears that computation of jobs/housing ratios may help planners identify locations where these two barriers alone (independent of the market) hinder adjacent residential and commercial development.

Accordingly, the ARC (2002) suggested changes to zoning ordinances to allow certain practices such as accessory dwelling units, units that serve as both a home and an employment site for the resident, mixed land uses, and small convenience stores in otherwise residential-only neighborhoods. Levine (1998) identified minimum lot sizes as a requirement that might prevent single-worker low-to-middle income households from finding housing closer to their employment sites. Gordon et al. (1991) suggested that planners should seek to eliminate zoning ordinances that prevent employment sites from being situated near residences.

Policy 3: Provide Private or Public Incentives to Increase Jobs/Housing Balance

After finding that housing cost and availability influence individuals' choice of where to live, Cervero (1989) suggested that imbalances between jobs and housing result from restrictive zoning and high housing costs. Accordingly, Cervero (1989) offered a variety of local incentives, suitable for consideration when a request for rezoning is made, for reducing such imbalances. Examples were allowing developers to build extra office space for each increment of housing they also provide; swapping zoning between one location and another; allocating residential and commercial building permits in tandem; and using jobs/housing ratios as a factor in development reviews. ARC (2003) suggested explicit consideration of jobs/housing ratios when developers or employers propose new construction. For example, in exchange for rezoning a tract of land from rural to industrial use, a county might require that an employer provide housing that is likely to meet the needs of a portion of the new employment (ARC, 2003). Bellevue, Washington, is one location where a developer incentive was deemed productive: for every square foot of residential area they added, developers were permitted to add 4 square feet of office area (Cervero, 1989).

California initially established a public incentive program for regions to address jobs/housing imbalances (Armstrong et al., 2001); this program was later formally named the Jobs-Housing Balance Incentive Grant Program (California Department of Housing and Community Development, 2007). The $25 million grant program was intended to encourage localities to provide housing in areas with high growth in employment and a high jobs/housing ratio. Eligibility was determined in part based on whether a locale had approved 12% more housing construction permits in 2001 than the annual average of the three previous years. For each unit approved above this threshold, a per-unit grant was made based on the extent to which the area was a high employment demand area. The ratio of jobs to housing was a factor in this determination: for example, areas with a jobs/housing ratio of at least 0.91 and an average annual employment growth of 6,400 new jobs received $1,300 per unit whereas areas with a ratio of at least 0.56 and an average annual employment growth between 1,000 and 6,400 jobs received $900 per unit. Although most of the grants applied to land use improvements (e.g., athletic fields, community centers, and playgrounds), some local transportation improvements were implemented, such as construction of trails, bicycle lanes, bus shelters, and sidewalks.

Public and private incentives have also been considered in tandem. LeGates (2001) noted that an earlier incarnation of California's incentive program could support a variety of land use initiatives. Some of these targeted the private sector, such as density bonuses for developers (allowing higher densities in exchange for a portion of the development being reserved for affordable housing) and transfer development rights (where a landowner with commercially zoned land in a jobs-rich area might have the land rezoned residential; the landowner is then given rights to develop commercial land elsewhere). Others targeted the public sector, such as tax increment financing for redevelopment (in which the increase in property taxes resulting from certain redeveloped areas accrues to the development authority rather than to the locale) and a reduction of building permit fees (to encourage more housing creation).

Policy 4: Implement Tax-Base Sharing or Other State-Based Programs

Citing regional coordination as difficult to implement because it may reduce localities' authority regarding land use, Cervero (1989) suggested "tax-base sharing" as a state-level way of balancing jobs-housing ratios. Under such a program, local governments pool a portion of their commercial property tax revenues; those pooled funds may be redistributed based on population or the ratio of jobs to households. The program may discourage localities from seeking commercial development at the expense of residential development and thus help balance jobs/housing ratios in areas where there is an excess of jobs (Cervero, 1989). At the time, the metropolitan region in the United States that implemented tax-base sharing was the Minneapolis–St. Paul Region (Cervero, 1989); the region cited two explicit goals of the program that directly related to jobs/housing balance (Hinze and Baker, 2005):

> To increase the likelihood of orderly urban development by reducing the impact of fiscal considerations on the location of business and residential growth and of highways, transit facilities, and airports
>
> To establish incentives for all parts of the area to work for the growth of the area as a whole,

The shared revenues are redistributed based on the locale's population and a formula that incorporates property assessment levels in each locale relative to the region as a whole (Hinze and Baker, 2005).

Tax-base sharing has also been used in New Jersey's Meadowlands, where localities pay 40% of their tax revenues above what they collected in 1970 into a regional fund that is then distributed to each locale based on (1) the number of schoolchildren and (2) the proportion of land designated as wetlands (Myers, 2005). Tax-base sharing may be prohibited, however, if courts interpret such sharing as a "legislative contract" (e.g., affecting local government's legislative powers) as opposed to a "proprietary contract" (e.g., comparable to an agreement between the locale and any other party whereby the contract would be upheld) (Myers, 2005). Because of the possibility that tax-base sharing could be viewed as a legislative contract, Myers (2005) noted that states may need to enact laws that directly enable localities to share tax bases.

Certain forms of revenue sharing are feasible in Virginia, but there are restrictions on where this can be done and the purpose it can serve (Virginia Chapter, 2009). For example, the state permits all jurisdictions in PDCs 1 through 5 and 10 through 15 to enter revenue sharing agreements for the purpose of economic development; usually, such agreements require a county referendum and "approval by a special three-judge court appointed by the Virginia Supreme Court" (Virginia Chapter, 2009). A review of Roberts (2009) identified two conditions in

Virginia that do not appear to encourage revenue sharing agreements: (1) there is a moratorium on cities annexing urbanized portions of counties [thus a county is not compelled by threat of annexation to "share its wealth" with an adjacent city], and (2) because of the complete separation of a city and a surrounding county, no residents inhabit both jurisdictions [which reduces the tendency to compromise].

Kroll and Singa (2008) suggested that localities left to their own choices without state input will tend to address shorter term issues—notably, local opposition to growth and the [positive] revenue-generating impacts of job growth—rather than longer term problems pertaining to commute time and distance and availability of workers. Thus, these authors suggested that the jobs/housing ratio coupled with the proportion of a county's income required for housing be used to prioritize where affordable housing is most needed. (For example, a high jobs/housing ratio coupled with a high percentage of mean or median income required for housing would suggest that a county has a high need for affordable housing.)

Policy 5: Identify Locally Specific Transportation and Land Use Initiatives

California, Illinois, and Washington, as examples, have used jobs/housing ratios within a very specific localized context. CPR (2008) advised that jobs/housing ratios be tracked only as "generalized indicators" rather than used as specific decision points through which policies are implemented. It identified specific initiatives that can be considered—facilitating mixed use development, using pricing of parking and driving to influence use of the transportation system, and examining how infrastructure investments are funded—but it emphasized that the ratios can provide only an initial indication of a problem:

> Productive policy responses depend on delving deeper into the causes of the imbalance and developing specific policies to address the localized conditions that cause the perceived imbalance. Because the urban-suburban development process is complex and not easily predictable, responsive local policies will likely cover a wide range of options from creating affordable housing to economic development to transit-oriented transportation solutions to congestion pricing and parking supply management strategies (CPR, 2008).

For example, CPR (2008) suggested creating land development databases that store information at the parcel level, which regions can use to establish information. (Presumably one application of such databases in Virginia would be to track jobs/housing ratios of proposed developments, compare them to the ratio in the given locale and surrounding locales, and use this information to negotiate a local response to a rezoning request.)

The literature acknowledges that improved transportation may achieve the goals of jobs/housing balance (PSRC, 2008a). An example of improved transportation in Southern California was provided by Singa et al. (2004). Recognizing that the region had an average of 1.25 jobs per occupied household, the authors examined policy options for the Westside Cities within the region; these were jobs-rich areas that were expected to grow from a ratio of 2.0 in 2000 to a ratio of 2.3 in 2030. Given that other literature has suggested that a jobs/housing ratio does not necessarily indicate a particular level of commuting (Cervero, 1996; Sultana, 2006), three diagnostic tools employed by the authors suggested that this high ratio might indeed in this case indicate a long commute:

1. a higher portion of inbound commuters using single-occupant vehicles (75%) relative to the rest of the region

2. a higher portion of inbound commuters (92.4% of persons working in 2030 in the Westside Cities will not live there) compared to lower inbound commuting percentages for other portions of the region (57.2% in Los Angeles City or 25.5% in Los Angeles County)

3. a high portion of outbound commuters (despite the fact that Westside Cities has an abundance of jobs, a large number of persons living there work elsewhere, which the authors attributed to a mismatch between skills residents possess and skills required by employers in those locations).

Transportation policy options proposed by Singa et al. (2004) included improved bus services and new rapid transit services (which could connect residents to these employment centers), especially if such coordination involved these employment centers directly (e.g., universities, hospitals, and "major entertainment facilities"). Singa et al. (2004) also provided a variety of land use options such as infill development (especially in places where jobs are abundant), provision of housing types, mixed use development, and land use policies that make alternative transportation modes more attractive (such as traffic calming and water fountains, which may make walking more desirable).

The Chicago Metropolitan Agency for Planning (2009) calculated a dissimilarity index of 0.30 for the region (calculations performed at the town level). While acknowledging that an index of 0.0 (perfectly balanced) was not the goal, the agency noted that the fact the dissimilarity index had grown from a value of 0.25 suggested that the imbalance was increasing. The agency also noted the existence of low-paying jobs in high employment areas, some of which had few affordable housing options. One policy option being explored by the agency was to improve bus circulation service, which would strengthen connections between areas with lower paying jobs and areas with affordable housing. The agency further recommended including metrics in the planning process that quantify how investments improve access to employment. (An example of such a metric is the number of jobs within a specified distance of transit facilities that offer reverse commuting services.)

In a study of San Juan's (Puerto Rico) proposed new rail system, Zhang et al. (1999) compared three policy scenarios—increased residential density, increased job opportunities, and a combination of the two—in the vicinity of the rail system. They suggested targeting both affordable housing and low-wage jobs in the development of station land use plans. They suggested that increased residential and commercial opportunities could not only increase regional mobility but could also provide an equity benefit in that households that had previously lived in areas with poor accessibility could relocate to areas that were well served by the new rail system.

Summary of Jobs/Housing Balance Policies and Applicability to Virginia

Table 1 identifies examples of the five policies noted. A weakness of Table 1 is that it does not illustrate the areas that chose not to implement jobs/housing policies. Downs (2004) stated that balancing jobs/housing ratios through explicit policies is difficult: each mechanism for achieving balance (adding housing or curtailing jobs in regions with excess jobs; adding affordable housing to regions that have expensive housing but low-paying jobs; and curtailing housing growth or increasing job creation in regions with excess housing) either is controversial or places a large cost on a particular party. For example, a high-tech business may not want to be the first to move to an employment-poor suburban area if the business enjoys economies of scale from its present location near other high-tech businesses. Thus Table 1 demonstrates that although it is possible to implement policies, it may not be feasible or desirable to do so in all locations.

Table 1. Examples of Policies Using Jobs/Housing Balance

Policy	Example	Location (Source)	Status[a]
1. Redirect future land development	Select regional growth strategies that achieve greater jobs/housing balance.	Puget Sound (PSRC, 2005, 2008a,b)	Implemented
	Empower a state agency to ensure localities consider jobs/housing balance.	Florida (McDaniel, 2009)	Implemented
	Revise a redevelopment plan of a land tract such that jobs and housing are balanced.	Fort Ord, California (Klim and Bilse, 1999)	Implemented
2. Diagnose local land use regulations that prohibit achievement of jobs/housing balance	Eliminate ordinances prohibiting accessory dwelling units and mixed land uses.	Atlanta (ARC, 2002)	Proposed
	Eliminate minimum lot sizes.	Minneapolis (Levine, 1998)	Proposed
3. Provide private or public incentives to increase jobs/housing balance	Provide incentives to developers who improve jobs/housing balance.	Bellevue, Washington (Cervero, 1989)	Implemented
	Provide grants to locales with a high jobs/housing ratio who award a certain number of building permits.	California (California Department of Housing and Community Development, 2007)	Implemented
4. Implement tax-base sharing or other state-based programs	Redistribute a portion of tax revenues collected by each locale to localities based in part on factors such as population and number of school children.	Minneapolis (Hinze and Baker, 2005)	Implemented
		New Jersey (Myers, 2005)	Implemented
	Use jobs/housing ratio and the proportion of a county's income required for housing to determine where affordable housing is most needed in the state.	California (Kroll and Singa, 2008)	Proposed
5. Identify locally specific transportation and land use initiatives	Improve bus services and add new rapid transit services connecting residents to employment centers.	Los Angeles, California (Singa et al., 2004)	Proposed
	Improve bus circulation service, which would strengthen connections between areas with lower paying jobs and areas with affordable housing.	Chicago (Chicago Metropolitan Agency for Planning, 2009)	Proposed

[a]*Implemented* means a statute, ordinance, plan, or policy has been established by some governing body adopting the policy. *Proposed* means the idea has been recommended but the literature reviewed did not indicate that the policy had been adopted by decision makers.

It is unknown which of the five policies are most applicable in Virginia because decisions regarding their implementation generally require state and regional cooperation. However, based on the information shown in Table 1 and the language of Virginia's STP (Office of Intermodal Planning and Investment, 2010), it appears that the most feasible policies at this point in time are policy 1 (redirect future land development) and policy 3 (provide private or public incentives to increase jobs/housing balance); they have been successfully implemented elsewhere and are mentioned, albeit at a high level, in Virginia's STP. For example, the STP mentions the specific example of the CTB being given an analysis of a proposed transportation project's ability to connect a jobs-rich and jobs-poor area as a factor in project selection (hence policy 3) as well as "land use commitments" for residential development in a jobs-rich area (hence policy 1). Policies 2 and 5 appear feasible but less so at the state level given they are implemented at the regional level and, based on Table 1, have been proposed but not implemented elsewhere. Policy 4 (tax base sharing) appears to require either additional legislation or statutory changes.

The Null Policy Option

Several authors (Cervero, 1995; Downs, 2004; Giuliano, 1991; Gordon et al., 1991; Miller and Ibrahim, 1998) have suggested that a policy based on jobs/housing balance for the purpose of congestion reduction should not be pursued given that better policies for reducing congestion are available. Helling (2000) and Sultana (2006) did not indicate opposition to jobs/housing policies but identified caveats that may influence the utility of such policies.

Downs (2004) noted that jobs/housing balance can reduce congestion by a modest amount but indicated that other measures, such as tolls charged during periods of peak travel, are more effective. Cervero (1995) suggested that mechanisms that directly affect transportation demand and supply, such as transit quality, parking prices, and vehicle taxes, are most effective. Miller and Ibrahim (1998) suggested that because the distance to a high-density employment location was a better predictor of commute VMT than the ratio of employment to population, policies should be adopted that encourage "concentrated regional employment centers."

Giuliano (1991) stated that a jobs/housing ratio should be used for transportation policy only if two tests are met: (1) a "balance" of jobs and housing cannot be achieved under prevailing patterns of development, and (2) the balance must influence commuting patterns. The author indicated jobs/housing balance fails both tests in the Los Angeles, California, region: Orange County (a suburb) moved from unbalanced to balanced as jobs followed residential growth (test 1), and no relationship was found between commute length and jobs/housing balance for individual parts of the Los Angeles area (test 2). Gordon et al. (1991) suggested that a goal of achieving jobs/housing balance in Los Angeles should not lead to encouraging growth in downtown areas per se, since employment remained relatively flat therein, but rather should result in removing zoning restrictions that prohibit commercial land development in residential locations.

An intriguing distinction regarding the political impact of jobs/housing balance was noted by a review of Downs (2004) and Giuliano (1991). Giuliano (1991) noted that other solutions that can reduce congestion may be controversial or expensive (e.g., high tolls charged during the peak hour), whereas, by contrast, jobs/housing balance is more popular (presumably because it does not connote an explicitly controversial or expensive implementation mechanism). Downs (2004) suggested several implementation mechanisms as noted previously (e.g., reducing job growth in high-employment locations) that can alter jobs/housing balance and are potentially controversial or resource intensive. Consideration of both studies (Downs, 2004; Giuliano, 1991) raises the concern that jobs/housing balance may have intuitive appeal until one considers specifically how changes in this balance are implemented, at which point one must compare the costs of implementing these changes with the costs of implementing other congestion-reduction solutions.

Although not explicitly focused on jobs/housing balance, Helling (2000) noted that growth in temporary employment suggests greater attention should be paid to employment accessibility in general rather than only to an individual's current workplace. An extension of this argument suggests that matching individual jobs to individual employment positions is less critical than would be the case if one's employment remained stable. Sultana (2006) argued insufficient attention had been given to the impact of two-worker households, suggesting that researchers should examine "the extent to which commuting flow volumes are increasingly the result of dual-earner households" [rather than presuming such increases in volume result from reduced jobs/housing balance].

Impact of Jobs/Housing Balance on Behavior

The effect of jobs/housing balance may be examined in at least two ways: (1) its impact on travel distance (VMT) or commute time, and (2) its impact on urban form (e.g., where people choose to live).

Impact of Jobs/Housing Balance on VMT or Commute Time

More than a dozen studies were reviewed that quantified the impact of jobs/housing balance on VMT or commute time. Although some are difficult to summarize, four demonstrate no or almost no impact, four show a modest impact relative to other factors that influence commuting choices, and three demonstrate a substantive impact.

1. Jobs/housing balance has no impact on VMT because of other factors.

Although one would expect balanced areas to have shorter commutes, Giuliano (1991) found no relationship between employment/population ratios and commuting distance in the Los Angeles area. For example, outer county employment centers (with an unbalanced employment/population ratio of 2.27) had shorter commutes (8.3 miles) than downtown Los Angeles (with a more balanced ratio of 1.47 and a longer commute of 13.9 miles). The reason no causal relationship (between jobs/employment ratios and commute length) was found is that too many other factors influence commute length. Giuliano (1991) indicated these factors were the fact that (1) many households have more than one worker; (2) commuting costs are relatively small compared to housing costs; (3) other considerations, such as school quality, influence residential location decisions; and (4) household and employment locations change relatively rapidly, that is, there is no guarantee that a given commercial building in year 2008 will not be converted to residential use in 2009. Downs (2004) supported the concept of relatively rapid change in household and employment locations, noting that even if a region were suddenly balanced it would likely lose that balance as other factors, such as availability of amenities, influenced residential location decisions.

2. No difference in VMT is observed between planned versus unplanned communities.

Downs (1992) cited a study that suggested proximity of jobs to housing did not affect commute times. In that study, 13 "comprehensively planned new communities" (Zehner, 1977) were paired with more conventional communities; almost all were located on the edge of a major metropolitan area. For example, the planned community of Reston, Virginia, was compared with the unplanned community of West Springfield, Virginia; both are suburbs of Washington, D.C. Other metropolitan areas included Chicago, Cincinnati, Houston, Los Angeles, Palm Beach, and San Francisco. There was "virtually no difference" in commute distances or times, with median values of 9.9 miles and 24.8 minutes for planned communities and 10.8 miles and 24.8 minutes for planned conventional communities. For one "freestanding" planned community (Lake Havasu City located 150 miles from Phoenix), the values were 0 miles and 8 minutes.

3. Jobs/housing balance has no impact on VMT once other factors are explicitly modeled.

Miller and Ibrahim (1998) found that for the Toronto, Canada, area, the ratio of jobs/housing, as well as the number of jobs, did not materially improve the ability to predict commuting VMT. The authors divided Toronto into 1,404 zones and identified three variables—the distance of each zone from Toronto's CBD; the distance of each zone to the closest high-density employment area (other than the CBD); and whether the zone was within 0.6 mile of rail transit—that explained 45.2% of the zonal variation in commute VMT per employee. When the authors added either the ratio of employment to population within 3 miles of each zone or a normalized variable representing the number of jobs within 3 miles of each zone, the model explained 45.4% of the zonal variation in commute VMT per employee. Miller and Ibrahim (1998) reported: "Both variables are marginally significant (93 percent confidence level, one-tailed test) and do not improve the overall goodness of fit of the model." Elsewhere, Giuliano (1991) noted that the ratio of jobs to housing approaches the regional average of 1.35 for areas between 10 and 50 miles from the CBD.

4. Correlation between jobs/employed residents and overall commute times is quite low.

Yang and Ferreira (2005) used decennial census data in Boston and Atlanta to test the correlation of jobs per employed resident and actual commute times. When data were tabulated by employment site (e.g., for a given tract, the relationship between commute times for all persons working in that tract and the jobs/employment ratio for the 10 closest tracts), positive correlations were found ranging from 0.38 (Boston in 1980) to 0.48 (Boston in 1990). Negative, and weaker, correlations were found between jobs/employed resident and actual commute times as tabulated by residence, with correlations between -0.13 (Boston in 1990) and -0.33 (Boston in 1980 and 2000). Ultimately, however, Yang and Ferreira (2005) dismissed the use of jobs/employed residents because when commute times by residence and workplace are combined (e.g., how does the jobs/housing ratio influence commute times for all residents in a given tract and all persons working in the same tract), the correlation between commute times and jobs/housing ratios was very low (e.g., 0.11 for Boston in 2000 and 0.10 for Atlanta in 2000).

The authors stated that the ratio of jobs/employed residents "tell us little about the net effect on commuting of local changes in the ratio of jobs and workers." Instead, Yang and Ferreira (2005) recommended that the minimum average commute time be used because it has some correlation with actual commute time and it includes a measure of commuting cost. (For example, it appears that the inclusion of commuting cost enables one to test explicitly the impact of specific transportation policies on minimum average commute time.)

5. A 10% increase in jobs/housing imbalance increases annual VMT by 114 per household.

Based on the 1990 National Personal Transportation Survey, Bento et al. (2003) reported an elasticity of 0.006 between annual VMT and a jobs/housing imbalance indicator. (This imbalance indicator measures the disparity between employment and population: each locale in a region is ranked in ascending order of employment and the cumulative proportion of employment is plotted against the cumulative proportion of population.) In practical terms, a 10% increase in the indicator yields an annual VMT increase of about 114 miles. By comparison, other factors influencing annual VMT in the same study were an increase of one working adult male (7,450 miles); a 10% increase in income (568 miles); a 10% increase in road density (135 miles); and a 10% increase in the distance to the nearest transit stop (167 miles), leading the authors to conclude that jobs/housing imbalance has a modest impact on annual VMT.

6. Increasing jobs/housing balance yields a maximum reduction of 9.5% in commute distance.

Downs (2004) reported that even a dramatic change in jobs/housing balance may have a modest impact on VMT, citing as proof a model that estimated the "maximum possible reduction" attributable to a balanced jobs/housing ratio. For a hypothetical region, the model compared an imbalanced scenario (with ratios of jobs to employed residents of 0.50 in the exurbs, 1.00 in the suburbs, and 1.33 in the central city) to a balanced scenario (with corresponding ratios of 0.75, 1.01, and 1.16 for the exurbs, suburbs, and central city, respectively). The model showed a reduction of 9.5% in commute distance for the region. Because Downs (2004) described this as the largest possible reduction from jobs/housing balance, it is inferred that a considerably smaller reduction would be likely if a less ambitious policy were implemented.

7. Disparities in jobs/housing ratios account for VMT differences for only 17% of the region.

Giuliano (1995) reported that only cases of "extreme imbalance" with regard to jobs/housing ratios affected commute length. Peng (1997) echoed this view, concluding that based on Portland, Oregon, data, only a jobs/housing ratio of less than 1.2 or greater than 2.8 substantially affects VMT (the average jobs/housing ratio for that region was 1.5). Peng found that when the ratio was 0.8—hence an extremely jobs-poor region—an increase of 0.1 in the ratio would reduce per-capita home-based work-related VMT by 0.441 miles. However, when the ratio was 1.3, an increase of 0.1 would reduce such VMT by 0.053 mile. Peng (1997) noted that most (83%) of the traffic analysis zones in the region had ratios between 1.0 and 2.8, "where changing jobs-housing ratios will have a small impact on VMT"; this led to the author's conclusion that regional per-capita impacts of jobs-housing policy will be negligible. The author formulated a U-shaped curve that reflected the fact that for a given location, increasing jobs/housing balance will tend to reduce VMT generated by residents but increase VMT generated by non-residents. Although these findings are specific to work-related trips, the author reported that other types of trips showed similar patterns, noting also that home-based non–work-related VMT per capita was greater than home-based work-related VMT per capita and that work-related trips were longer than non–work-related trips.

8. Planned communities have a 13.3% shorter commute time than unplanned communities.

Cervero (1995) matched master planned communities (typically communities with mixed residential and commercial uses, pedestrian walkways) and non–master planned communities in the United States on the basis of population, income, household rents, and distance from the CBD such that commute times and jobs/housing ratios could be compared. A total of nine communities were studied; they were located in California, Florida, Georgia, Maryland, Texas, and Virginia. There was evidence that individual planned communities enjoyed commute reduction benefits: for example, the unplanned community of Dale City, Virginia, had a substantially longer commute (40.8 minutes) than did its matched planned community, Reston, Virginia (27.0 minutes). Reston also had a substantially higher jobs/housing ratio (1.58) than did Dale City (0.39). For the United States as a whole, however, Cervero (1995) characterized the commuting benefits as "fairly modest," with average commutes from planned communities (25.3 minutes) being somewhat less than those from unplanned communities (29.2 minutes)—hence a reduction of 13.3%. Cervero (1995) stated that the difference was "significant at < 0.10 level"[a paired *t*-test using Cervero's data showed that $p = 0.08$].

However, the causal linkage between jobs/housing balance and transport impact is not observed when communities in Britain, Stockholm, and Paris were compared: some areas with the least balanced jobs/housing ratios had the greatest public transportation use. Cervero (1995) concluded that such planned communities in Europe affect transport behavior not because of balanced jobs/housing ratios but because of other factors, such as "integrated transport infrastructure."

9. Increased jobs/housing balance yields a statistically significant reduction in commute time.

Wang and Chai (2009) found that a binary classification of jobs/housing ratio (where *1* was coded for individuals having job and housing in the same district and *0* was coded for individuals having job and housing in different districts) was a statistically significant predictor of commute time based on Beijing (China) data. The results showed that the variable representing jobs/housing balance had a strong negative effect on total commute time (the total effect was reported as -0.6443 in the structural equations model). Jobs/housing balance also significantly increased the probability of walking or bicycling, both of which significantly lowered commute times relative to those of automobile drivers or transit passengers.

Wang and Chai (2009) noted that "speedy motorized transport" is not necessarily associated with short commute times because of heavy congestion (noting that in some areas travel on bicycle is faster than auto travel), which should accentuate the explanatory power of a variable, such as jobs/housing balance, that is associated with the use of non-motorized modes. It should be noted that in contrast to the other studies named thus far, jobs/housing balance in the study by Wang and Chai (2009) was directly measured for each individual (e.g., does person *x* live in the same district) rather than the more aggregate jobs/housing ratios commonly used (e.g., jobs in district *x* / housing in district *x*).

10. Areas with balanced jobs and housing see a 28% decrease in commute VMT.

Frank (1994) described a detailed study of census tracts in Washington's Puget Sound region, where tracts with balanced jobs/household ratios (defined as 0.8 to 1.2 jobs per household) were associated with an average trip distance of 6.87 miles. This distance was 28% less than the average trip distance of 9.5 miles for trips terminating in unbalanced tracts (defined as having ratios outside the range of 0.8 to 1.2 jobs per household). The difference was statistically significant. Not surprisingly, travel time for trips terminating in balanced tracts (17.29 minutes) was significantly shorter than travel times for trips terminating in unbalanced tracts (22.88 minutes).

11. Every 10% increase in jobs reduces VMT by 2.99% to 3.29%.

Cervero and Duncan (2006) modeled VMT as a function of job accessibility based on 16,000 two-day travel surveys for the San Francisco Bay area after controlling for other factors such as gender, driver's license, vehicle ownership, and public versus private sector employment. The model showed that each 10% increase in total jobs within 4 miles of a residence reduced VMT by 2.99%. Further, if job types were matched with resident employment, the reduction changed from 2.99% to 3.29%. The authors used three employment categories for this matching, summarized here as professional (e.g., finance, law); service (e.g., health care, food service); and blue-collar (e.g., construction and transportation).

12. The relationship between minimum and actual commute times has two interpretations: some interpret it to mean that jobs/housing balance affects commuting behavior and others interpret it to mean it does not.

Appendix B summarizes a category of studies by Giuliano (1995); Horner (2006, 2008, 2009); Horner and Murray (2003); Scott et al. (1997); Song (1992); and Yang and Ferreira (2005) that relates actual commute time to the "minimum" commute time, which is the commute time that would result if all commuters traveled to the nearest employment location. Generally, these studies found that the actual time is much larger than the minimum time but diverged in their interpretation. Giuliano (1995) and Scott et al. (1997) found that jobs/housing balance does not substantially affect commuting; after controlling for home prices, Giuliano (1995) noted that "mismatches" of jobs and labor force do not explain much of the discrepancy. However Horner and Murray (2003) and Song (1992) noted a correlation between actual and minimum commute times; Song (1992) suggested that polices have "potential," and Horner and Murray (2003) found that relocating a small portion of workers could have a substantial impact on the minimum commute time.

Summary of Impact on Commute VMT or Time

Table 2 summarizes the findings of these studies. Clearly, differences are evident. For example, Miller and Ibrahim (1998) found that distance to a high-density employment location was a better predictor of commute VMT than the ratio of jobs to people, leading the authors to discount jobs/housing ratios per se as the basis for a policy. By contrast, a review of Cervero and Duncan (2006) suggested that a 68% greater reduction in VMT is obtained when increasing the number of jobs (within 4 miles of a residence) than when increasing the number of retail and service locations (within 4 miles of a residence). [The researcher obtained the 68% reduction value by using the data reported by Cervero and Duncan and Equation 1 in their report.] This led the authors to view a policy based on jobs/housing more favorably than a policy based on mixing retail and employment sites (although the authors noted that both policies may be productive).

Impact of Jobs/Housing Balance on Urban Form

Urban form may be described as residential and commercial patterns of development. Four studies (Downs, 2004; Giuliano, 1991; Gordon et al., 1991; Wang and Chai, 2009) considered how jobs/housing ratios evolve over time, whereas Levine (1998) considered how changes in zoning may influence where residential households choose to locate. Cervero (1989, 1996) and an article in *The Economist* ("An Age of Transformation," 2008) distinguished between a jurisdiction having equal numbers of jobs and residents and those jobs being filled by residents.

Evolution of Jobs/Housing Ratios Over Time

Giuliano (1991) acknowledged that practices exist that hinder jobs/housing balance, such as localities favoring commercial over residential development or the use of zoning to exclude low-income housing. However, the author showed patterns of suburbanization in the Los Angeles area where new suburbs initially have a low jobs/housing ratio that then increases toward balance as new employment follows the new housing. For example, the author noted that Orange County employment to population ratios increased from 0.19 in 1955 (when the county was primarily a residential suburban community) to 0.44 in 1989 (when the county had achieved a match between employment and population). This observation suggests that jobs/housing balance can be achieved without an explicit public policy.

Gordon et al. (1991) highlighted the same phenomenon in Orange County, California, writing that "spontaneous relocation decisions by firms and households do a very nice job of achieving balance." Downs (2004) also noted a jobs/housing imbalance is a fundamental and temporary result of development patterns in a metropolitan area. An implication of these works (Downs, 2004; Giuliano, 1991; Gordon et al., 1991) is the inference that jobs/housing ratios will tend to bring themselves into balance even without intervention.

Table 2. Studies Quantifying Impact of Jobs/Housing Balance on Commute Distance or Time[a]

Study	Location	Result	Interpretation
Giuliano (1991)	Los Angeles	Employment/population ratios have no impact on commute distance.	Factors besides jobs/housing balance explain commute distance.
Zehner (1977)	13 pairs of planned and unplanned U.S. communities	No difference in commute distance or time.	No impact on VMT.
Miller and Ibrahim (1998)	Greater Toronto (Canada) area	Ratio of jobs to people did not improve ability to predict VMT in model that included distance to employment area and transit availability.	Other factors that describe structure of urban environment are better predictors of VMT. Jobs/housing balance is partial surrogate for these factors.
Yang and Ferreira (2005)	Boston and Atlanta in 2000	Correlation between jobs/housing and overall commute times was quite low (0.11 and 0.10).	Rather than jobs/housing ratios, minimum commute time should be used to predict impact on overall commute time.
Bento et al. (2003)	1990 National Personal Transportation Survey	10% increase in imbalance indicator reduces annual VMT by 114 miles.	Other factors have greater impact on annual VMT such as 10% increase in income (+568 miles) or distance to road transit stop (+167 miles).
Downs (2004)	Balanced and imbalanced versions of hypothetical city	Balanced city reduces VMT by 9.5%.	Dramatic changes in jobs/housing balance have modest impact on VMT.
Peng (1997)	Portland, Oregon	Substantial impacts noted only for zones where jobs/housing ratios were very unbalanced—about 17% of the region.	Jobs/housing balance impacts VMT only for cases of extreme imbalance.
Cervero (1995)	9 pairs of planned and unplanned U.S. communities	13.3% reduction in travel times for planned communities.	Modest commute changes can arise from jobs/housing balance.
	New towns in Britain, Paris, and Stockholm	Greater transit use in towns with less balanced jobs/housing ratios.	More dramatic mode shifts arise from availability of transport infrastructure.
Wang and Chai (2009)	Beijing (China)	Survey respondents who live and work in same district have significantly shorter commute times than those who do not.	When jobs/housing balance means that respondent lives and works in same area, ability to use non-motorized transportation increases, which shortens commute time relative to longer, congested motorized commutes.
Frank (1994)	Puget Sound, Washington, region	28% reduction in commute distance for trips terminating in tract with balanced jobs/housing ratio.	Jobs/housing balance has statistically significant impact on VMT.
Cervero and Duncan (2006)	San Francisco Bay area, California	10% increase in jobs within 4 miles of residence reduces VMT by 2.99 to 3.29%.	Changes in jobs/housing balance have substantial impact on VMT.
Studies in Appendix B[b]	Atlanta, Baltimore, Hamilton (Canada) Orange County, California	Minimum commute time is substantially smaller than actual commute time. In some studies, times are correlated.	In some studies, jobs/housing balance does not have much impact on VMT because of the difference. In other studies, jobs/ housing balance may impact VMT because of correlation.

[a]Except for the last row, studies are listed in order of ascending impact of jobs/housing ratios on travel.
[b]These include Giuliano (1995); Horner (2006, 2008, 2009); Horner and Murray (2003); Scott et al. (1997); Song (1992); and Yang and Ferreira (2005).

Wang and Chai (2009) stated that before the 1980s, Beijing employers generally provided housing for their workers. A legacy impact of this system was that individuals worked and lived in the same district, thereby encouraging individual jobs/housing balance. The gradual elimination of this practice, and the substitution of market-based housing, is expected to reduce the number of cases of an individual's job and housing being in the same district. This trend will be exacerbated by where new housing is placed: higher income individuals tend to be employed by firms that do not provide such housing, and private housing tends to be found in the suburbs away from employment centers (where developers can obtain land more cheaply) (Wang and Chai, 2009). Thus, Beijing illustrates one area where jobs/housing balance is expected to worsen.

Impact of Elimination of Zoning Restrictions on Household Location Decisions

Levine (1998) found that policies that eliminate zoning restrictions, such as minimum lot sizes, near employment centers may influence the household location decisions of a subset of the population: single-worker households with low-to-moderate incomes. To detect whether workers would choose to live near their employment sites provided they could afford such housing, the author divided the Minneapolis region into 160 communities. Assuming residents' employment sites were fixed, a logit model was developed to predict residential locations based on commute time, residential density, the ratio of a community's housing price to a household's income, the number of boarded-up housing units, an indirect measure of funds available for local schools, and other variables. The model compared the impact of two variables that are expected to be decreased by a heightened jobs/housing ratio: (1) the ratio of price to income (which residents presumably desire) and (2) density (which residents presumably do not desire). After controlling for other factors, the model showed that households do generally prefer to have (1) lower ratios of price to income and (2) lower density.

Levine (1998) then used the model to identify population groups where lower price-to-income ratios have a greater impact on residential choice than lower density: these groups were low- and middle-income single-worker households and, to a lesser extent, low-income dual-worker households. From this finding, Levine concluded that although there is some ability for increased jobs/housing ratios to influence where households locate, this ability is "limited." Levine did not dismiss the use of jobs/housing balance to lower commutes but instead argued that zoning regulations that enforce minimum lot sizes may prevent a portion of these market segments—i.e., a portion of low-and medium-income households with a single worker—from living closer to their place of employment.

Urban Form Versus Commuting Behavior

One study (Cervero, 1989) showed a strong link between jobs/housing balance and the decision to live and work in the same community. When 1980 jobs/housing ratios from 22 cities in the San Francisco Bay area were compared to the percentage of local workers (e.g., the percentage of a community's employment positions filled by persons who live in the same community), Cervero (1989) reported a correlation coefficient of -0.57 between jobs/housing balance and the percentage of local workers, which the author characterized as "moderately strong." (A correlation coefficient of +1.0 or -1.0 shows a strong relationship; a coefficient of 0 shows no relationship.) (Note that a correlation coefficient of only 0.24 is calculated when correlating jobs/housing balance to the percentage of the labor force who work locally.)

However, Cervero (1996) used the case of Pleasanton, California, to demonstrate that achieving jobs/housing balance does not guarantee a change in commuting behavior. Although Pleasanton's ratio of jobs per employed resident grew from 0.42 in 1980 to 1.13 in 1990, the average commuting distance increased for a somewhat similar period (1985 to 1993). Despite the almost perfect balance (1.0 would be ideal assuming one job per resident), most persons living in Pleasanton worked elsewhere and most workers in Pleasanton lived elsewhere. In this particular case, although new jobs were created in Pleasanton for the period 1980 through 1990, workers could not live in Pleasanton because existing housing stock was "already occupied by traditional suburban households whose workers commuted to downtown jobs" (Cervero, 1996). This situation was exacerbated by growth restrictions in Pleasanton and the fact that the average salary for a majority of workers was below that required to purchase a typical home in the city.

Valencia (located in the suburbs of Los Angeles) is another example of jobs/housing balance not necessarily indicating a reduction in commuting distance: with a ratio slightly in excess of 1.0 (based on a reported 60,000 jobs, 20,000 homes, and an assumed 2.5 persons per dwelling unit), it is still the case that about one half of the persons living in Valencia work in Los Angeles ("An Age of Transformation," 2008).

Applicability of Previous Jobs/Housing Balance Studies to Virginia

At least three characteristics of the aforementioned studies influence the applicability of their findings to Virginia:

1. population (whether the findings apply to rural or urban areas)

2. consistency of job and housing types (matching expensive housing to high-paid jobs)

3. moderate versus extreme imbalances (e.g., does improved jobs/housing balance help all jurisdictions or only those where there is an extreme imbalance?).

Population

Almost all of the studies refer exclusively to urban areas, and the majority of Virginia's regions are considerably less urban than those in the studies. Table 3 aligns the estimated populations from the studies with Virginia areas that have somewhat comparable populations. (Because population was not given in several of the studies, the population data were estimated from other sources as necessary and as indicated in Table 3.) Based on consideration of population alone, the studies are most relevant for the Northern Virginia region and somewhat applicable for the Hampton Roads and Richmond regions. A few of the studies also apply to smaller urban areas. For example, Bento et al. (2003) incorporated urbanized locations from around the United States, which included the aforementioned large regions but also included a few smaller regions with populations under 200,000 such as Utica (New York) and Lowell (Massachusetts), which may be comparable to smaller Virginia areas such as Roanoke.

Table 3. Population Sizes in Studies and Relevant Virginia Regions

Study	Study Location and Approximate Population[a]	Virginia Areas with Comparable Population[b]
Wang and Chai (2009)	Beijing, 13.6 M	None
Giuliano (1991)	Los Angeles Metropolitan Area , 11.5 M[c] (U.S. Census Bureau, 1993)	Northern Virginia PDC, which, although it has a population of 2.2 M, is a part of the Washington, D.C., metropolitan area, which has a population of 5.5 M (U.S. Census Bureau, 2010)
Cervero and Duncan (2006)	San Francisco Bay Area, 7.1 M (Bay Area Alliance for Sustainable Communities, undated)	
Miller and Ibrahim (1998)	Greater Toronto, 3.7 M (City of Toronto Urban Development Services, 1997)	
Yang and Ferreira (2005)	Boston, 2.8 M to 3.4 M, and Atlanta, 2.1 M to 4.1 M[d] (Brookings Institution Center on Urban and Metropolitan Policy, 2003; U.S. Census Bureau, 1993)	
Cervero (1995)	Reston, Virginia, and comparably sized communities in large metropolitan areas such as Washington, D.C.–Baltimore and Atlanta, 3.0M (Office of Planning and Budget, 2002)	
Downs (2004)	Hypothetical city, 3 M	Northern Virginia PDC and Hampton Roads PDC (1.7 M)
Frank (1994)	Puget Sound, 2.7 M (Puget Sound Regional Council, undated)	
Levine (1998)	Minneapolis, 2.3 M	
Zehner (1977)	Suburban communities such as West Springfield or Reston, Virginia, located in metropolitan areas such as Cincinnati, 1.4 M; Houston, 2.0 M; Washington, D.C., 2.8 M; and Chicago, 7.0 M (U.S. Census Bureau, 1971)	Northern Virginia PDC, Hampton Roads PDC, and Richmond Regional PDC (1.0 M)
Peng (1997)	Portland, Oregon, 1.3 M (Oregon Transportation Institute, 2001)	
Bento et al. (2003)	114 urbanized regions in U.S. ≥ 50,000 and with densities > 1,000 people/mi^2	Urbanized portions of Northern Virginia and Richmond/Petersburg as they are included in list of 114 urbanized areas. Note that some other Virginia areas, such as Hampton Roads, Lynchburg, and Roanoke were not included in the study (Bento et. al., 2003) but meet the minimum density and population criteria for inclusion in the study.
Zehner (1977)	Although 12 of the 13 community pairs were on the edge of metropolitan areas, one planned community was "freestanding": Lake Havasu City and Kingman, with populations under 10,000	

[a]Population is that given in the study unless otherwise cited. In such cases, population was estimated for the year that appears to correspond best with the data used in the study (not necessarily the year the study was published).
[b]*PDC boundaries and populations* defined by Miller (2009).
[c]Total populations for Los Angeles, Orange, Riverside, San Bernadino, and Ventura counties.
[d]The range reflects the populations for the period 1980 through 2000.

Except for the fact that most of the studies in Table 3 are urban in nature, there does not seem to be a pattern regarding the impact of jobs/housing balance and urban area size; for example, two studies involving very large urban areas (Los Angeles with a population of 11.5 million and San Francisco with a population of 7.1 million) had substantially different outcomes: the former found jobs/housing balance has no impact, whereas the latter found this balance has a substantial impact. In sum, the studies in this report generally appear to apply to the more urban locations of Virginia. However, note that the population growth in the three most populous PDCs—Hampton Roads, Northern Virginia, and Richmond—is expected to account for approximately two thirds of Virginia's population growth from 2010 to 2035 (Miller, 2009).

Consistency of Job and Housing Types

Conceptually, it is desirable to match workers and jobs (e.g., to align “blue collar” workers with “blue collar” jobs). For example, O’Kelly and Lee (2005) indicated that average trip lengths varied from 4.27 to 7.78 miles in Wichita (Kansas) and from 3.72 to 5 miles in Boise (Idaho) based on type of occupation. As mentioned previously, Levine (1998) and Singa et al. (2004) illustrated the conceptual value of considering these matches, and Cervero (1996) and an article in *The Economist* (“An Age of Transformation,” 2008) demonstrated that having adjacent jobs and housing does not guarantee residents will work in adjacent jobs.

However, the studies that compared the impact of jobs/housing balance based on both (1) using all jobs and all housing and (2) accounting for job and housing types showed a more nuanced view. Not performing such a match does not necessarily eliminate the utility of jobs/housing balance. For example, Cervero and Duncan (2006) found that when matching by occupation, every 10% increase in jobs within 4 miles of a residence reduced VMT by 3.29%. When the authors did not do such matching, the percentage dropped but only from 3.29% to 2.99%. As shown in Appendix B, Giuliano (1995) predicted commute lengths in Baltimore based on travel costs and found that the predicted commute was about one-half as long as the actual commute—but inclusion of housing types in the model still raised the predicted commute length by about 20%, leading the author to conclude that mismatches did not explain why predicted and actual commutes differed. Yang and Ferreira (2005) computed the correlation between predicted and average commute time for Boston; the correlation was 0.33 (without matching job types and resident skills) or 0.35 (when matching did take place).

In sum, based on the studies reviewed, although matching is helpful, the failure to account for mismatches between housing prices and job types does not render jobs/housing balance meaningless.

Moderate Versus Extreme Imbalances

Not surprisingly, some studies suggested that the largest reductions in trip length or trip time occurred for extreme jobs/housing imbalances. For example, data from Peng (1997) showed that 8 times more VMT is reduced when the jobs/housing ratio is increased in an imbalanced as opposed to a balanced location. Frank (1994) showed a 28% drop in trip lengths for trips terminating in balanced tracts (relative to those terminating in balanced tracts). Zehner (1977) cited one planned community (not in a metropolitan area) with an 8-minute median commute time. Cervero’s (1995) illustration of Dale City’s (Virginia) commute being 51% longer than that of Reston (Virginia) also shows that specific cases can be identified where jobs/housing balance was associated with a substantial impact on commuting.

Generally, the reductions in Table 2, which reflect more average impacts, are smaller than these extremes. For example, although Dale City had a 51% longer commute time than Reston (Cervero, 1995), the study showed an average difference of 13.3%. Thus in applying these concepts to Virginia, one would expect average reductions to be less than for some cases where there are large imbalances.

Ways to Measure Jobs/Housing Balance

Jobs/housing balance may be measured as a direct ratio, a linear dissimilarity index, an exponential dissimilarity index, and an imbalance indicator. All of these are feasible with Virginia data.

Direct Ratio

To the extent that a ratio of jobs to housing reflects a location's balance between employment in the location and persons who live in the location, there are several ways to define a ratio of jobs (employment) to housing. *Employment* may be defined as wage and salary employment only (Giuliano, 1991); it may also include (or exclude) self-employed individuals, proprietors, or agricultural workers (Goetz, 2003). Housing may be defined as [total] housing units (King County Office of Budget, 2004) or occupied housing units (Armstrong et al., 2001; Singa et al., 2004). (Generally, an occupied housing unit is a household.) The ratio of jobs to housing was used in Virginia's Tri-County Parkway Location Study (Parsons Brinckerhoff Quade & Douglas, Inc., and AECOM Consulting Transportation Group, 2003). Other studies have used total population in lieu of housing but still in the context of discussing jobs/housing balance (Giuliano, 1991) or employed population (Giuliano, 1991; CPR, 2008). [Thus jobs/employed population is a surrogate for balance; for example, Giuliano (1991) used Orange County's increase in jobs/employed population (from 0.729 in 1974 to 0.847 in 1988) to show that the county's balance was improving given that it had been a residential suburb with a deficit of jobs. Conceptually, the idea behind the use of jobs/employed population is that if the employed population exceeds the number of jobs for a given location, then additional commuting is necessary in order for the population to work.] Of the three possibilities for the denominator of a jobs/housing ratio (total housing, occupied housing, or employed population), CPR (2008) suggested that the best metric was employed population, in part because there would be a ratio of approximately 1.0, which would make this ratio easier to understand).

The target values for the ratio are region specific. For example, according to Armstrong et al. (2001), the Southern California Council of Governments (SCAG) eschews a target value of 1.0 for the ratio of jobs to households and instead uses two discrete factors to assess whether jobs and households are in balance:

1. *The maximum distance commuters are willing to travel.* SCAG indicated this distance is about 14 miles, based on a 1990 public opinion survey that indicated "very little support for commute times over 30 minutes" multiplied by a 1999 average commute speed of 28.4 mph.

2. *The extent to which the ratio of jobs to households within the maximum commuting distance (i.e., 14 miles) differs from the average ratio for the entire region.* The regional average of jobs to households is 1.25, so SCAG defined an area as balanced if the jobs/housing ratios within 14 miles were close to 1.25. Armstrong et al. (2001) selected *close* as being the range from 1.0 to 1.29 since this range represented the "middle 20%" of the regional jobs/household ratios.

Table 4 shows four ratios for eight jurisdictions that comprise the modified Richmond (Virginia) Regional PDC for year 2006: jobs/total housing, jobs/household (e.g., jobs per occupied housing unit), jobs/labor force, and jobs/population. Each ratio was computed using nonfarm wage and salary employment available from BEA (2009) and VEC (undated). With one exception, Table 4 shows that relative to the regional average, two jurisdictions are jobs rich (Richmond and Henrico County) and the remaining jurisdictions are jobs poor. The exception is Goochland County, which shows a BEA jobs/household ratio (1.58) slightly higher than the regional average (1.57).

Figure 1 suggests that these ratios are highly correlated. Correlation coefficients of 0.96 to 0.99 are obtained using the VEC employment estimates shown in Table 4. For example, the plot showing the ratio of jobs/household generally has the same shape as the plot showing jobs/labor force: jurisdictions that are jobs rich by the former metric (e.g., City of Richmond) are also jobs rich by the latter. There is, however, some disparity in terms of degree of imbalance: whereas Richmond City has some imbalance according to jobs/total housing (1.73 versus a regional average of 1.31), the imbalance is more pronounced according to jobs/labor force (1.68 versus a regional average of 1.01). Figure 1 clearly shows that whether VEC or BEA employment is used does not change the interpretation of jobs/housing balance: plots of BEA jobs/population and VEC jobs/population have similar shapes. The correlation between VEC jobs/total housing and BEA jobs/total housing is greater than 0.99, and the correlation between VEC and BEA data for ratios of jobs/household, jobs/population, and jobs/labor force is similarly high.

Table 4. Candidate Ratios for Richmond Area for Year 2006[a]

	Jobs/Total Housing		Jobs/ Household[b]		Jobs/Labor Force		Jobs/ Population	
Area	**BEA[c]**	**VEC**	**BEA[c]**	**VEC**	**BEA[c]**	**VEC**	**BEA[c]**	**VEC**
Charles City	0.57	0.53	--[d]	--[d]	0.46	0.43	0.25	0.24
New Kent	0.61	0.56	--[d]	--[d]	0.43	0.40	0.24	0.22
Goochland	1.34	1.17	1.58	1.37	1.01	0.88	0.55	0.48
Powhatan	0.77	0.68	0.90	0.79	0.51	0.44	0.27	0.24
Hanover	1.27	1.18	1.32	1.23	0.85	0.79	0.49	0.45
Richmond	1.87	1.73	2.15	1.98	1.82	1.68	0.91	0.84
Henrico	1.50	1.40	1.60	1.50	1.16	1.09	0.65	0.61
Chesterfield	1.13	1.04	1.19	1.09	0.78	0.72	0.44	0.40
Average[e]	1.42	1.31	1.57	1.46	1.09	1.01	0.60	0.55

BEA = Bureau of Economic Analysis; VEC = Virginia Employment Commission.
[a]Data sources are jobs (BEA, 2009; VEC, undated); total housing units (U.S. Census Bureau, 2008b); occupied housing units (U.S. Census Bureau, 2008a); labor force (VEC, undated); population (Weldon Cooper Center for Public Service, 2009a).
[b]Occupied housing units (households) are available from the American Community Survey for the period 2005-2007 (U.S. Census Bureau, 2008a): in this table, these estimates are presumed to refer to year 2006.
[c]BEA data include only nonfarm wage employment.
[d]Occupied housing units are not available for areas with a population under 20,000 except from the decennial census.
[e]Average for all eight jurisdictions. For example, there are a total of 562,228 jobs (BEA, 2009) and a total of 397,088 housing units (U.S. Census Bureau, 2008b), so the ratio is 562,228/397,088 = 1.42.

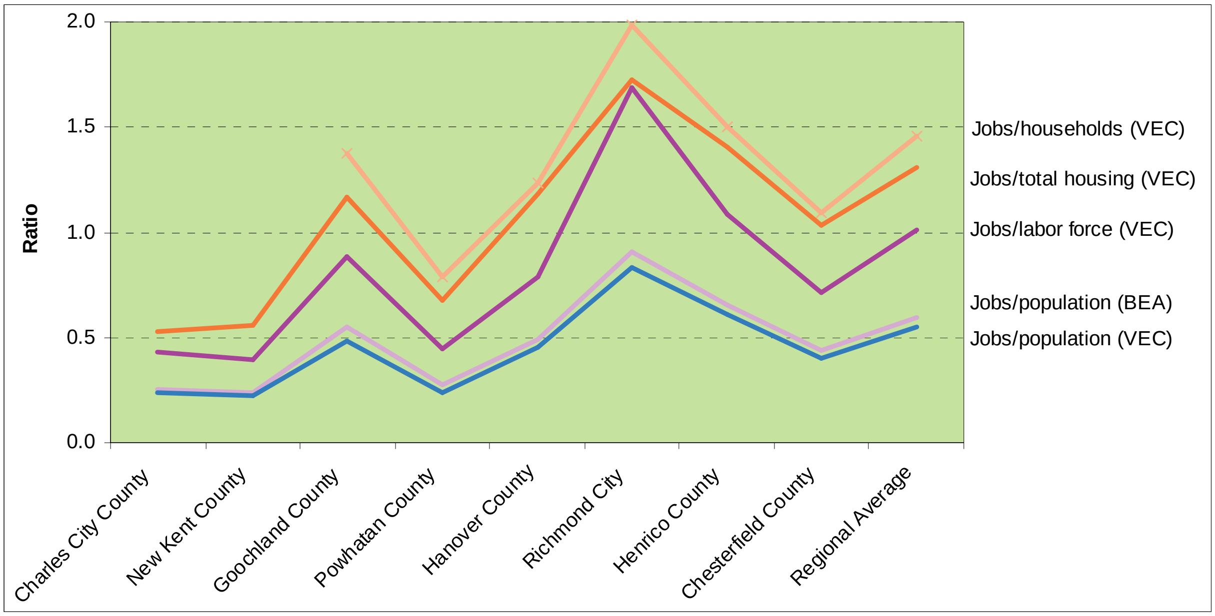

Figure 1. Ratios Portraying Jobs/Housing Balance in the Richmond Metropolitan Area (2006). Data sources are jobs (Bureau of Economic Analysis, 2009; Virginia Employment Commission, undated); households (U.S. Census Bureau, 2008a); total housing (U.S. Census Bureau, 2008b); labor force (Virginia Employment Commission, undated); population (Weldon Cooper Center for Public Service, 2009a).

Linear Dissimilarity Index

Marion and Horner (2008) suggested that a metric based on the ratio of jobs to housing or the minimum commute (Horner 2009) is limited, in part because "the assignments of workers to job locations do not resemble realistic commuting patterns." Equation 2 illustrates an index of dissimilarity as explained by Charron (2007) and Marion and Horner (2008) assuming there are *n* zones in the region. Letting h_i be the number of households, population, or employed residents living in each zone I; letting w_i be the number of employment positions in the same zone I; and letting h_{total} and w_{total} represent the total values for the region, an index of dissimilarity, D, is computed that will range between 0 and 1.0. If the region is completely balanced (e.g., every zone has the same number of population and jobs assuming one job per person), an index of 0 is computed. If the region is perfectly unbalanced (e.g., no zone containing a job has a resident and no zone containing a resident has a job), an index of 1.0 is obtained. (Note that the denominator in Equation 2 keeps the index between 0.0 and 1.0 even if the regional average of jobs to households is not 1.0.) As an illustration, Table 5 applies Equation 2 to the metropolitan Richmond area and shows a dissimilarity index of 0.1345 using population for h and employment for w.

$$D = 0.5\sum_{i=1}^{n}\left|\frac{w_i}{w_{total}} - \frac{h_i}{h_{total}}\right| \qquad \text{[Eq. 2]}$$

An advantage of a dissimilarity index such as that shown in Equation 2 is that it enables a region to measure how its jobs/housing balance is improving, or worsening, even if the total quantity of housing or jobs in the region does not change (R. Case, personal communication, October 29, 2009).

Table 5. Computation of Dissimilarity Index for the Metropolitan Richmond Area[a]

I	Area	Employment (w)	Population (h)	$\left\lvert \frac{w_i}{w_{total}} - \frac{h_i}{h_{total}} \right\rvert$
1	Charles City	1,779	7,047	0.0043[b]
2	New Kent	4,048	16,810	0.0107
3	Goochland	11,069	20,048	0.0016
4	Powhatan	7,258	26,533	0.0153
5	Hanover	46,958	96,374	0.0189
6	Richmond	175,497	193,882	0.1062
7	Henrico	186,807	286,095	0.0283
8	Chesterfield	128,812	294,453	0.0837
n = 8	Total	562,228	941,242	[c]0.2689

[a]Employment obtained from Bureau of Economic Analysis (2009); population obtained from Weldon Cooper Center for Public Service (2009a).
[b]For example, for Charles City County this value is | 7,047/941,242 – 1,779/562,228| = 0.0043.
[c]Since the sum is 0.2689, the dissimilarity index is computed from Equation 2 as 0.5(0.2689) = 0.1345.

Exponential Dissimilarity Index

A weakness of Equation 2 is that it is possible a region could receive an unbalanced score simply because a jobs-rich zone was adjacent to a population-rich zone. Charron (2007) explicitly noted:

> However, intrazonal jobs-housing balance does not necessarily minimize commuting possibilities. In order to do, local imbalances must be coherent at the metropolitan scales so that any job-rich or residence-rich areas are surrounded by their opposite.

As a consequence, the authors of both studies (Charron, 2007; Marion and Horner, 2008) proposed modifications to Equation 2 that accounted for the possibility of a jobs-rich zone being adjacent to a housing-rich zone. One modification (Marion and Horner, 2008) was an exponential dissimilarity index as an alternative approach to assessing jobs/housing balance; the proposed index differentiated among different populations of interest (which could be employment sites and housing) and used an exponential decay term (comparable to that used in the gravity model), as shown in Equation 3 (Marion and Horner, 2008). This equation is similar to Equation 2 except (1) the exponential decay term has been included and (2) the numerator accounts for the impact of adjacent zones such that if zone A has an abundance of workers and zone B has an abundance of employment, then if zones A and B are quite close, the region will appear more balanced than if zones A and B are quite far apart.

$$D = 0.5\sum_{i=1}^{n}\left\lvert \frac{\sum_{j=1}^{m} w_j \exp(-\beta d_{ij})}{\sum_{i=1}^{n}\sum_{j=1}^{m} w_j \exp(-\beta d_{ij})} - \frac{\sum_{j=1}^{m} h_j \exp(-\beta d_{ij})}{\sum_{i=1}^{n}\sum_{j=1}^{m} h_j \exp(-\beta d_{ij})} \right\rvert \qquad \text{[Eq. 3]}$$

The utility of the exponential dissimilarity index is illustrated with Figure 2, which shows the ratio of jobs to population for Richmond area jurisdictions. For example, for jobs-poor Charles City County with a ratio of jobs to population of 0.25, which is far below the regional average of 0.60, adding a large number of jobs to the jurisdiction should increase job access for not only Powhatan residents but, to some extent, also for adjacent New Kent county residents (a county that is also jobs poor with a jobs to population ratio of 0.24). Adding 20,000 jobs to Powhatan increases the exponential dissimilarity index between 4% and 29% (depending on the value chosen for β and how intrazonal distances are measured), whereas such jobs improve the linear dissimilarity index by only 3%. Presumably, one reason for the larger increase in the exponential dissimilarity index is because the index accounts for the relative closeness of the new jobs (in Charles City County) that support New Kent County.

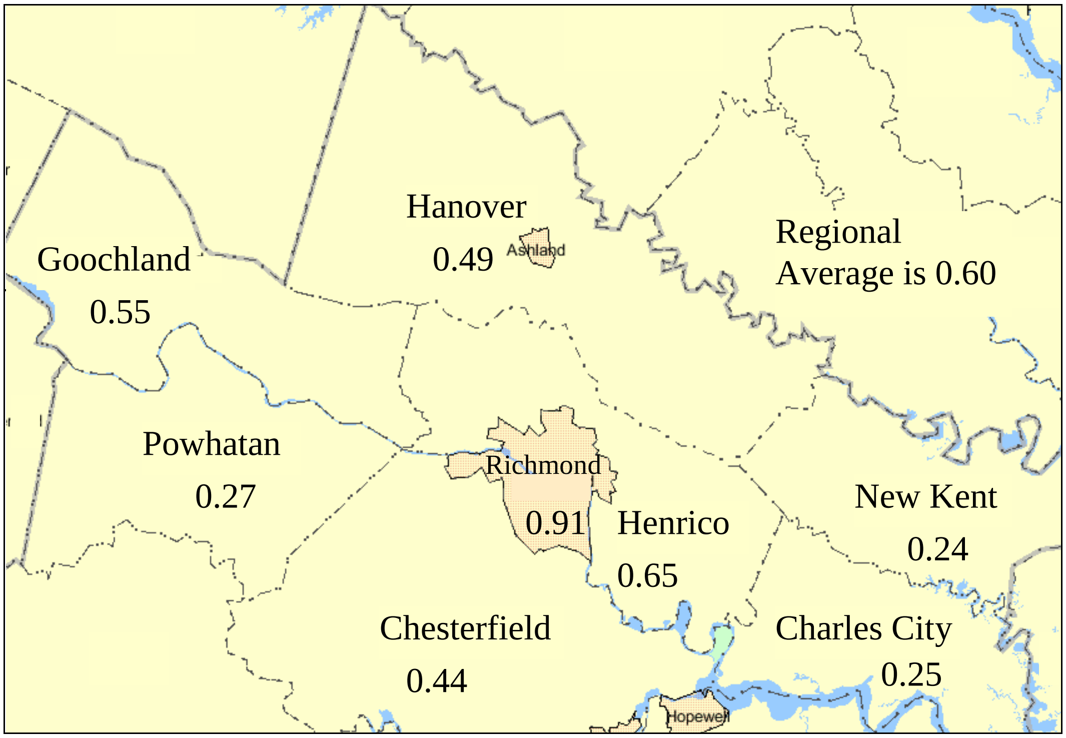

Figure 2. Employment Divided by Population for Eight Jurisdictions in the Richmond Region. For example, Table 5 shows that Chesterfield County's ratio of employment to population is 128,812 jobs/294,453 people = 0.44. Data sources are employment (Bureau of Economic Analysis, 2009) and population (Weldon Cooper Center for Public Service, 2009a).

Imbalance Indicator

Bento et al. (2003) noted the need to assess "the location of employment relative to population, or jobs-housing balance" that they then computed by tracking jobs and population. Rather than reporting a ratio, the authors reported a regional jobs/housing imbalance measure based on a plot of cumulative employment (on the vertical axis) against a plot of cumulative population (on the horizontal axis). A 45-degree line represents perfect balance, and imbalance is reported as the area between the plot and the 45-degree line divided by the area under the 45-degree line.

Figure 3 applies this concept to Virginia data using jurisdictions rather than travel analysis zones (which are much smaller, typically on the order of a census tract). For example, in 2007, the four least populated Richmond area jurisdictions were Charles City County (6,928), New Kent County (17,059), Goochland County (20,422), and Powhatan County (27,430). Since metropolitan Richmond has a total population of 952,502, the combined population of these four areas represented about 7.5% of Richmond's cumulative proportion of population, as shown on the horizontal axis. The 2006 employment from these four areas represented about 4.3% of Richmond's cumulative proportion of employment, as shown on the vertical axis. Assuming the difference between 2006 and 2007 is negligible, for these four jurisdictions (Charles City, New Kent, Goochland, and Powhatan), the population is greater than the number of jobs. Generally, the area between the two lines shown in Figure 3 represents the extent to which the region's jobs and housing are not balanced. When the curved line is below the perfect balance line (e.g., for the five jurisdictions of Charles City, New Kent, Goochland, Powhatan, and Hanover), the population is greater than the number of jobs; by contrast, for the next jurisdiction (Richmond), the number of jobs is greater than the population because the data point representing Richmond is above the perfect balance line.

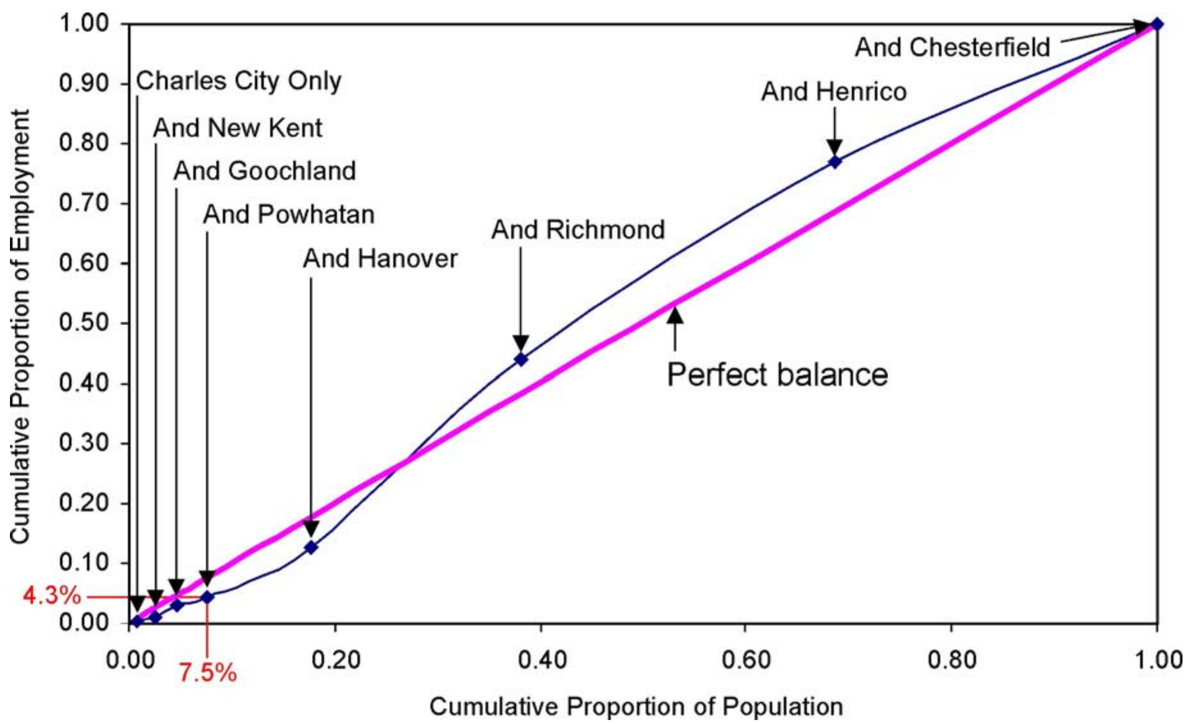

Figure 3. Application of Jobs/Housing Imbalance Indicator (Bento et al., 2003) to Metropolitan Richmond
Data sources are population (Weldon Cooper Center for Public Service, 2009b) and employment (Bureau of Economic Analysis, 2009).

Measures Based on Theoretical Commuting Distances

Appendix B summarizes studies that discuss measures based on minimum commute times (which result if each resident works at the nearest employment location) and studies that examine the commute times predicted under various types of economic or geographic models. Of particular interest are two studies that showed that failure to align job types and resident skills or housing prices did not, by itself, render jobs/housing balance irrelevant. Giuliano (1995) found a large discrepancy between predicted and actual commutes and that the inclusion of housing type into the model reduced this discrepancy only by a moderate amount, stating that "mismatches between jobs and workers do not account for a substantial part of observed commuting patterns." Yang and Ferreira (2005) found that correlations between minimum and average commute times ranged from 0.33 to 0.41 when skills and job types were not aligned; with such an alignment the correlations ranged from 0.35 to 0.45.

Summary of Ways to Measure Jobs/Housing Balance

There are several ways to assess jobs/housing balance. The most straightforward methods involve computing a ratio between jobs and population, total housing units, households (those housing units that are occupied), and labor force. At the jurisdictional level, these ratios are highly correlated. More sophisticated approaches include an imbalance indicator and an exponential dissimilarity index, the latter of which accounts for the case of jobs-rich and jobs-poor areas being located in different jurisdictions but quite close to each other. As all of these measures have been calculated with Virginia data, they are all feasible for use at this point in time, although some measures, such as the exponential dissimilarity index, require more effort than others, such as the ratio of jobs to labor force. In addition, as shown in Appendix B, measures based on the theoretical commute time or distance have been developed to examine the impact of some proposed land use policies, under the premise that although actual and theoretical commutes differ, calculated impacts on the latter may be used to forecast real impacts on the former.

It should be noted that all of the Virginia calculations herein were done at the jurisdictional level rather than at a census tract or transportation analysis zone level. The geographic level of analysis may be meaningful based on findings from Yang and Ferreira (2005), who assessed the extent to which three metrics are correlated—jobs per employed resident, job and labor accessibility (somewhat similar to the gravity model used in urban travel demand forecasting), and minimum average commute time (which would result if every resident commuted to the nearest feasible job location). Because these metrics were "significantly different from, or even inconsistent with each other in describing the same scenario of job-housing distribution," Yang and Ferreira (2005) suggested that contradictory results from other studies regarding the impact of jobs/housing ratios on commute time may result partly from how the jobs/housing ratio is defined.

Relating Virginia Jobs/Housing Balances to Commute Times

To quantify the impact of jobs/housing balance on commute time, a longitudinal dataset reflecting jurisdiction values for population, employment, labor force, and total housing units was created based on data from 2000 through 2008. The proportion of persons commuting outside their jurisdiction of residence and average commute time were acquired for the years 1980, 1990, and 2000 (for all jurisdictions). In addition, the latter two data elements were measured for each jurisdiction with a population in excess of 20,000 through the American Community Survey (U.S. Census Bureau, undated [a],[c]). Because these data were collected over a 3-year period (2005-2007), the single value obtained for each jurisdiction is hereinafter referred to as a "2006" data point. Appendix A details the data acquisition process.

Appendix A shows that the correlation noted in Figure 1 was not an aberration: there is a strong correlation among population, labor force, and housing at the jurisdiction levels, with correlations of at least 0.99 for 1980, 1990, 2000, and 2006 data (except a correlation of 0.988 for labor force and housing in 1980). It follows, therefore, that at the jurisdiction level, the correlation between jobs/housing and jobs/labor force is also strong, with correlations between 0.93 and 0.96 for the years 1980, 1990, 2000, and 2006. Thus, tracking the jobs/labor force ratio appears to be a suitable surrogate for tracking the jobs/housing ratio specified in the *Code of Virginia* (§ 33.1-23.03).

It is recognized that jobs/housing balance might have several dimensions in addition to the ratio of jobs/housing defined previously, such as the disparity index and the proportion of persons commuting outside their jurisdiction of residence. These data were used to explore the relationship of jobs/housing balance and commute time at three geographical levels of analysis:

1. regional (PDC) level
2. jurisdiction (city and county) level
3. combined regional and jurisdiction level.

Note that the modeling that relates jobs/housing balance to commute times is not required for compliance with the *Code* (§ 33.1-23.03). The purpose of this modeling is simply to determine the relative impact of jobs/housing balance on commute times given the other factors that also influence commute times. As a consequence, users of a jobs/housing balance metric will generally not need to replicate the calculations relating balance to commute times, such as those shown in Table 6.

Regional (PDC) Level of Analysis

Figure 4 divides Virginia into 21 modified PDCs. Six modifications were made to the PDC boundaries such that each county in Virginia was placed in exactly one modified PDC (Miller, 2009). For example, Surry County, which is a member of the Hampton Roads PDC and the Crater PDC, is included only with the Crater PDC in Figure 4.

Longitudinal Changes in Jobs/Housing Balance at PDC Level

The linear dissimilarity index improved from 1990 to 2006 in 12 of the 21 PDCs. There was not an obvious characteristic common to the PDCs where an improvement was noted. For example, although the dissimilarity index improved in the four PDCs with the largest 2006 population (Northern Virginia, George Washington, Richmond, and Hampton Roads), it also improved in the PDCs with the third and fifth smallest 2006 population (Middle Peninsula and Lenowisco), as shown in Figure 5. Although there was a tendency for areas with larger populations to undergo a greater improvement in the dissimilarity index relative to smaller areas, this trend was not statistically significant based on a comparison of the five largest and five smallest areas ($p = 0.22$).

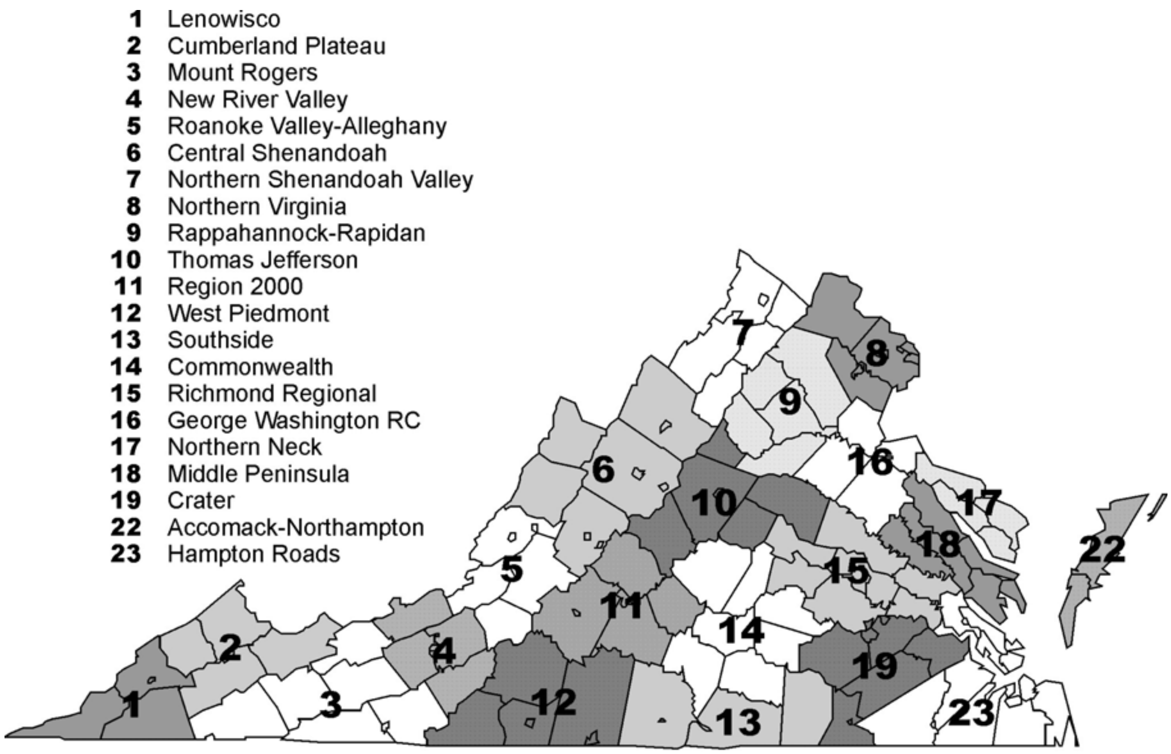

Figure 4. Virginia's 21 Modified Planning District Commissions. The numbers indicate the identification number of the particular PDC. Virginia does not have PDCs numbered 20 and 21 because in 1990, PDC 23 was created by merging PDCs 20 and 21 (Beamer, 1994).

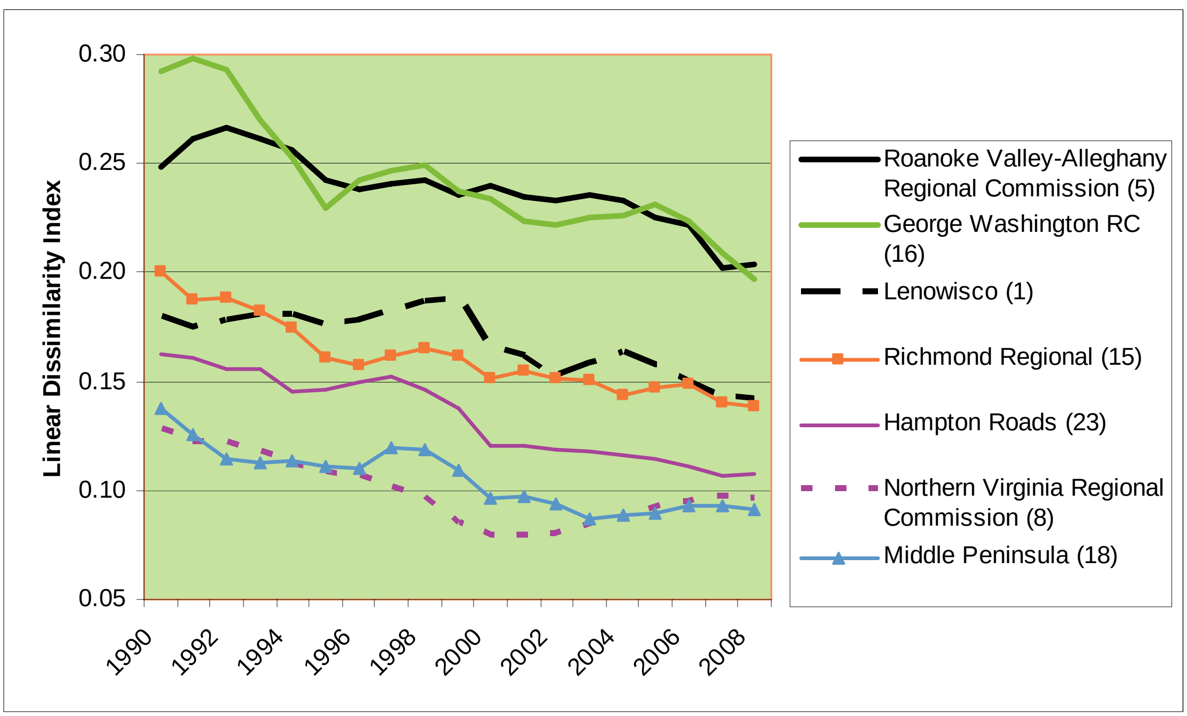

Figure 5. Change in Linear Dissimilarity Index for Select PDCs, 1990-2006. An index of 0 indicates perfect balance; an index of 1 indicates complete imbalance. Data source is Virginia Employment Commission (undated).

Relationships Between Jobs/Housing Balance and Travel Time at PDC Level

At the PDC level, there was virtually no correlation between the change in PDC travel time over a 10-year period and the change in the PDC linear dissimilarity index: based on 42 data points (21 PDCs from 1980 through 1990 and again from 1990 through 2000), the correlation coefficient was 0.19. In addition, at the PDC level, except in 2000, there generally was not a strong correlation between the PDC average commute time and the PDC jobs/labor force ratio at any given point in time (with correlations of -0.41, -0.64, -0.73, and -0.53 for 1980, 1990, 2000, and 2006, respectively). These results suggest that commute time at the PDC level is influenced by a variety of factors, only one of which is the ratio of jobs to labor force. The 2000 correlation (-0.73) was stronger than the other three correlations; further, significance testing (Hamburg, 1977) showed that the 1990 and 2000 correlations were statistically significant ($p < 0.05$) and the 1980 and 2006 correlations were not.

As an illustration of this weak correlation, Figure 6 presents the ratio of jobs/labor force and jobs/population for Virginia's 21 PDCs using 2006 data. (No travel time is shown for the Northern Neck PDC as the 2006 data did not include jurisdictions with a population under 20,000 and all Northern Neck jurisdictions had a population under 20,000.) The two ratios show a negative but weak correlation with average travel time, with correlations of -0.53 (jobs/labor force) and -0.27 (jobs/population). One implication of the weak correlations is that at the PDC level, factors other than jobs/housing balance may influence the average PDC's commute time. For example, although it has a relatively low jobs/labor force ratio of 0.77 relative to the statewide average of 0.89, the Accomack-Northampton PDC's relatively short average commute time (20 minutes) may be a result of substantially less congestion than in the more urbanized areas of Virginia.

Jurisdiction (City and County) Level of Analysis

It is also possible that the use of a regional average for travel time is masking differences among jurisdictions in an individual PDC. For example, within the George Washington Regional Commission, there are both jobs-rich areas (City of Fredericksburg and King George County) and jobs-poor areas (Caroline and Spotsylvania counties). If it were the case that jobs/housing balance did influence travel time, one would expect a better indicator of causality if the relationship between these two variables was examined while controlling for characteristics that might be unique to the region.

One way to account for jobs/housing balance while recognizing regional differences is to compute the "disparity" between each jurisdiction's travel time and the PDC travel time and to compute the disparity between each jurisdiction's jobs/housing balance and the PDC jobs/housing balance.

As an illustration of such disparity with 2000 data, Figure 7 shows the disparity between the travel time for each jurisdiction and the PDC travel time on the horizontal axis. For example, Fredericksburg had an average travel time of 26.6 minutes, whereas the PDC in which Fredericksburg is located, the George Washington Regional Commission, had an average travel time of 38.6 minutes; thus the disparity (approximately -12 minutes) is at the bottom of Figure 7.

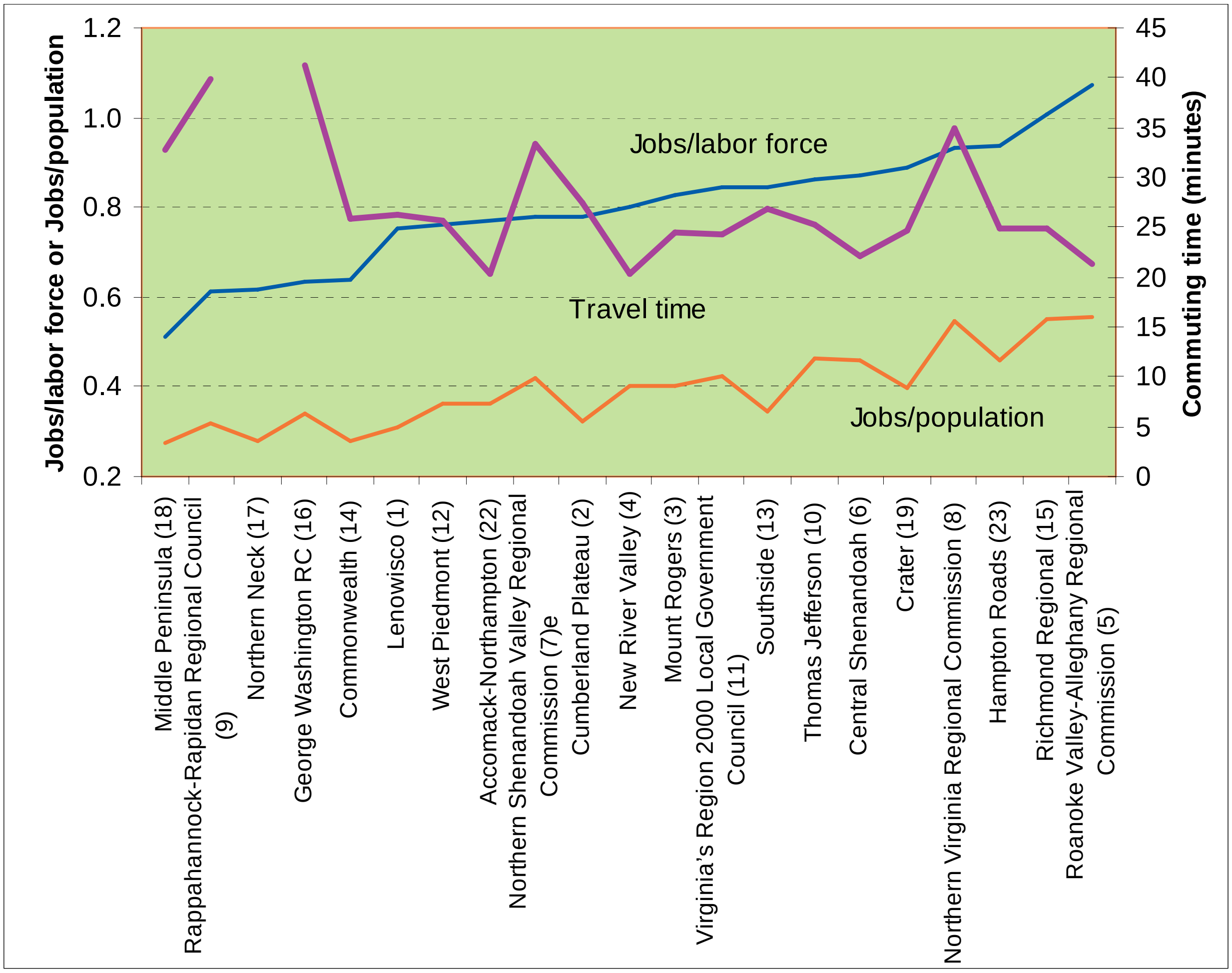

Figure 6. Jobs/Labor Force, Jobs/Population, and Travel time by PDC for 2006. Data sources are travel time (U.S. Census Bureau, undated [a]); population (Weldon Cooper Center for Public Service, 2009a); and jobs and labor force (Virginia Employment Commission, undated).

Similarly, the vertical axis shows the difference between Fredericksburg's ratio of jobs/labor force (2.3) and the George Washington Regional Commission's average (0.7), which is about 1.6, as shown on the right of Figure 7.

The implication of Figure 7 is that a relatively higher jobs/labor force ratio is associated with a relatively lower travel time, as shown by the jurisdictions in the lower right quadrant. In addition to Fredericksburg, examples of jurisdictions showing a similar association between relatively higher jobs/labor force ratios and relatively lower travel times include Bristol, Falls Church, Galax, Lexington, Lynchburg, Norfolk, Norton, Williamsburg, and Winchester. The converse is also supported by Figure 7: jurisdictions with relatively lower jobs/labor force ratios, such as Craig, Floyd, Surry, Powhatan, Stafford, and Fluvanna, have relatively higher travel times as shown in the upper left quadrant. In fact, of the 134 jurisdictions shown in Figure 7, 113 fit either into the upper left quadrant (relatively higher travel times and lower jobs/labor force ratios) or the lower right quadrant (relatively lower travel times and higher jobs/labor force ratios). It is thus not surprising that Figure 7 shows a negative correlation between the disparity

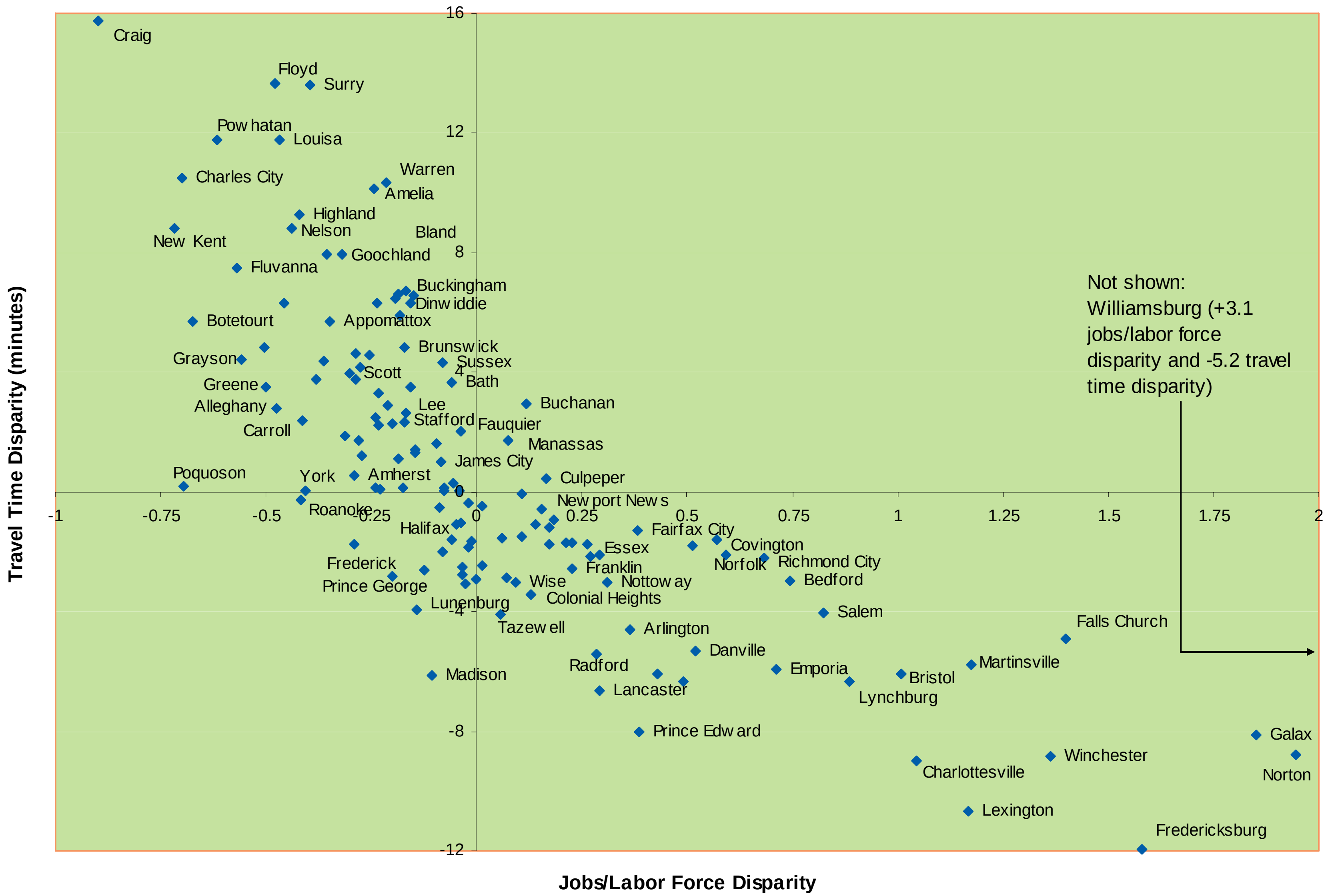

Figure 7. Travel Time Disparity Versus Jobs/Housing Disparity Based on Year 2000 Data. For example, the upper left corner shows Craig County's travel time was 16 minutes above the average travel time for the Roanoke Valley Alleghany Regional Commission (RVARC, Craig's region) and a jobs/housing ratio that was 1 unit below the ratio for RVARC. Data sources are travel time (U.S. Census Bureau, 2002) and jobs and labor force (Virginia Employment Commission, undated).

in local travel time and the disparity in jobs/labor force (-0.72), with higher jobs/housing balance associated with a lower travel time.

A comparable relationship is shown for other years: correlations between the jobs/housing disparity and the travel time disparity are -0.71 to -0.72 for 1980, 1990, and 2000 data and -0.77 for 2006 data. (Note that the 2006 data include only jurisdictions with at least 20,000 people.) These relationships do not prove causality: it cannot be said with regard to the upper left quadrant of Figure 7 that the lower jobs/housing balances cause higher travel times or that the higher travel times cause lower jobs/housing balances. Similarly, with regard to the lower right quadrant, Figure 7 alone does not prove that lower travel times cause higher jobs/housing balances (or vice versa).

The data in Figure 7 suggest that each additional 0.1 increment in a jurisdiction's jobs/labor force reduces the average commute time by 0.65 minute. (Thus, if the sum of all jobs in a PDC divided by the sum of the PDC's labor force yielded a ratio of 1.0, a jurisdiction within that PDC with a jobs/labor force ratio of 1.2 should see a commute time that is 1.3 minutes shorter than the PDC average commute time.) If all jurisdictions statewide are divided into jobs-rich areas (those with a jobs/labor force ratio greater than the average for their corresponding PDC) and jobs-poor areas (those with a jobs/labor force ratio less than the average for their corresponding PDC), the difference in commute time for year 2000 data is 6.4 minutes.

A critique of Figure 7 is that PDCs are not necessarily fully self-contained. For example, 2000 data showed that approximately 19% of individuals who lived in Spotsylvania County (in the George Washington Region) commuted to one of the nine jurisdictions in the Northern Virginia PDC. Accordingly, a super-region was created by determining the average jobs/labor force ratio and the average travel time for localities within three PDCs: the Northern Virginia PDC, the Rappahannock-Rapidan PDC, and the George Washington Regional Commission. Then the disparity between these super-regional average values and that of most jurisdictions within the three PDCs was computed, as shown in Figure 8. The correlation improved slightly (-0.83 rather than the value of -0.72 noted in Figure 7).

The correlation was not materially affected by other model specifications. For example, when 2006 data were examined, a correlation of -0.77 was obtained for all jurisdictions with a population over 20,000 whereas a correlation of -0.75 was obtained when only those shown in Figure 8 were examined. Further, repeating the analysis with urban areas only did not strengthen the correlation; for example, when only PDCs 8, 15, and 23 (Northern Virginia, Richmond, and Hampton Roads) were included, the 2000 correlation dropped from -0.72 to -0.66 and the 1990 correlation improved only slightly, from -0.71 to -0.72.

It should also be noted that the aforementioned correlations are valid only with regard to the *disparity* between a jurisdiction's travel time and the regional average travel time. When attempts where made to predict a jurisdiction's *exact* commute time solely as a function of the jobs/labor force ratio and the linear dissimilarity index, very low R^2 values were obtained, regardless of whether all jurisdictions ($R^2 = 0.29$) or only urban jurisdictions ($R^2 = 0.28$) were examined.

Figure 8. Jobs/Labor Force Disparity vs. Travel Time Disparity for the Super-Region of the Northern Virginia PDC, the Rappahannock-Rapidan PDC, and the George Washington RC (Year 2000 Data). Data sources are travel time (U.S. Census Bureau, 2002) and jobs and labor force (Virginia Employment Commission, undated).

Combined Regional and Jurisdictional Level of Analysis

Figures 7 and 8 suggest that a jurisdiction's commute time is affected by one dimension of jobs/housing balance (the jobs/labor force ratio). However, as shown in Figure 6, this relationship is not evident unless the effect of other factors, such as whether the jurisdiction is located in a congested area, is controlled. A practical question, therefore, is: What is the relative importance of jobs/housing balance given these other factors? That is, if jobs/housing balance could be altered today, what might be the impact on future commute time?

To answer this question, it was hypothesized that a jurisdiction's commute time in the future is a function of three elements

1. confounding factors, such as adequacy of transportation infrastructure, that are not necessarily captured by jobs/housing balance (a surrogate for these factors is the jurisdiction's commute time at present)

2. the extent to which the region where the jurisdiction is situated has seen an overall improvement or worsening of jobs/housing balance (a surrogate is the change in the PDC's linear dissimilarity index that was shown in Equation 2)

3. the extent to which the jurisdiction achieves jobs/housing balance relative to the rest of the region (a surrogate is the jobs/labor force disparity that was shown in Figures 7 and 8).

A model, shown as Equation 4, was developed based on these three elements. The model attempts to estimate "future" commute times (those in year 2000) using 1990 commute times, the change in the regional dissimilarity index from 1990 to 2000, and the jurisdiction's jobs/labor force disparity in year 2000. Equation 4 does not indicate whether jobs/housing balance alone reduces travel time or is merely a surrogate for other factors that coincide with such balance (such as higher density or better transit service). However, because it measures a change in jobs/housing balance, Equation 4 at least can detect whether such changes (or the hidden factors correlated with such changes) affect commute time for a specific jurisdiction.

Jurisdiction commute time in 2000 = A (Jurisdiction commute time in 1990)
+ B (PDC dissimilarity in 2000 – PDC dissimilarity in 1990)
+ C (Jurisdiction jobs/labor force disparity in 2000) [Eq. 4]

Although Equation 4 has conceptual promise, the relative weights of the variables were not immediately clear. For example, from examination of Equation 4 alone, it is not known whether the jobs/labor force disparity is more, less, or just as important as PDC dissimilarity in terms of explaining variation in jurisdiction commute time. It was also not initially clear whether Equation 4 should be applied statewide or in urban areas only. Accordingly, after Equation 4 was calibrated, a variety of modifications were made in an effort to determine which variables had a significant impact on travel time, given that such travel time has multiple influences. Table 6 shows the results of applying Equation 4 (step 1) and making successive alterations based on the results obtained from each step.

The result of steps 1 through 4 suggested that the dissimilarity term could have an impact on travel time but that the jobs/labor force term had no such impact. This latter result was initially surprising, given that jobs/labor force disparity was indeed correlated with travel time disparity as shown in Figure 7 and had a statistically significant impact ($p = 0.00$) in the corresponding equation. However, Figure 7 did not address a temporal component—in other words, *changes in balance*, as measured by jobs/labor force disparity, do not significantly influence commute time (unless a threshold of $p = 0.11$ rather than $p = 0.05$ is accepted).

As a consequence, a modified model (Eq. 5) added a term that included the proportion of persons commuting outside their jurisdiction of residence. The terms in this modified model were all statistically significant ($p < 0.05$) and based on the subsequent results in Table 6 appear necessary if jobs/housing balance is to be used to predict average commute time.

Jurisdiction commute time in 2000 = A (Jurisdiction commute time in year 1990)
+ B (PDC dissimilarity in 2000 – PDC dissimilarity in 1990)
+ C (Jurisdiction jobs/labor force disparity in 2000)
+ D (Proportion commuting outside their jurisdiction of residence in 2000 – Proportion commuting outside their jurisdiction of residence in 1990) [Eq. 5]

Table 6. Steps to Test and Improve the Model Shown in Equation 4

Step	Model Tested	Key Results	Interpretation
1	Calibrate Eq. 4 based on all jurisdictions in Virginia.	High R^2 (0.92) but only commute time is significant (p = 0.00).	Best predictor of jurisdiction's 2000 commute time is its 1990 commute time.
2	Remove jobs/labor force disparity from Eq. 4 and modify it to predict PDC commute time rather than jurisdiction commute time.	High R^2 (0.94). Commute time remains significant (p = 0.00), and dissimilarity is not significant (p = 0.09).	At PDC level of analysis, dissimilarity cannot be used to link jobs/housing balance to average commute time.
	Apply modified equation only to PDCs with populations above 200,000.	Dissimilarity is not significant (p = 0.20).	
3	To test for possibility of whether jobs/housing balance affects travel time in urban areas only, calibrate Eq. 4 based on jurisdictions in PDCs 8 (Northern Virginia), 15 (Richmond), 16 (George Washington), and 23 (Hampton Roads).	High R^2 (0.94). Commute time remains significant (p = 0.00), and dissimilarity is significant (p = 0.04) but *with the wrong sign* (e.g., implying that poorer jobs/housing balance decreases commute time).	It is possible, but not proven, that assuming Northern Virginia (PDC 8) and George Washington (PDC 16) are independent eliminates utility of dissimilarity variable.
4	Calibrate Eq. 4 based on jurisdictions in same PDCs as noted in step 3, but add jurisdictions in PDC 9 (Rappahannock-Rapidan). Because PDCs 8, 9, and 16 might be interdependent, create a "new PDC" that represents jurisdictions in these 3 PDCs. This continues the urban area focus initiated in step 3.	High R^2 (0.92). Commute time remains significant (p = 0.00), dissimilarity is significant (p = 0.00) and with proper sign, but jobs/labor force disparity is not significant (p = 0.11).	Dissimilarity variable has merit in urban jurisdictions. PDCs 8, 9, and 16 (Northern Virginia, Rappahannock Rapidan, and George Washington) should be treated as single PDC as was done in Figure 8.
5	Repeat step 4 but add new variable reflecting change in proportion of commuters working outside their jurisdiction of residence. This new variable, shown in Eq. 5, accounts for fact that potential for jobs and housing to be balanced does not guarantee commuting behavior will reflect such balance.[a]	High R^2 (0.94). All 4 variables are significant: commute time (p = 0.00), dissimilarity (p = 0.00), jobs/labor force disparity (p = 0.04), and change in proportion of persons commuting outside their jurisdiction of residence (p = 0.04).	Inclusion of a variable reflecting persons commuting outside their jurisdiction of residence enhances approach for urban areas.
6	Repeat step 5 except use 1980-1990 data in lieu of 1990-2000 data.	Respectable R^2 (0.88) but only commute time is significant; dissimilarity is not significant (p = 0.10) and with the wrong sign.	In 1980 some of these jurisdictions were not urbanized or characteristics differed substantially between 1980 and 1990.
7	Calibrate Eq. 5 based on all jurisdictions, not just those in PDCs 8, 9, 15, 16, and 23.	High R^2 (0.92). Commute time is significant (p = 0.00), and change in proportion of persons commuting outside their jurisdiction of residence is not significant (p = 0.06); other variables are not significant.	Eq. 5 is valid only for urban areas.
8	Remove dissimilarity variable and disparity variable from Eq. 5 and calibrate based on only urban jurisdictions (those in PDCs 8, 9, 15, 16, and 23).	High R^2 (0.91). Commute time remains significant (p = 0.00), and proportion of persons commuting outside their jurisdiction of residence is not significant (p = 0.08).	All 4 terms in Eq. 5 are necessary. Note that correlation among 3 jobs/housing balance variables is never above 0.32.

[a]Computed from U.S. Census Bureau (undated [c], 1999, 2003).

Two variables in Equation 5 evaluate similar concepts: the change in dissimilarity from 1990 to 2000 and the change in the proportion of persons commuting outside their jurisdiction of residence over the same time period. To some extent, one might expect that as a PDC's dissimilarity rises so will the proportion of persons commuting outside their jurisdiction of residence. However, the correlation between these two variables for the dataset used in step 5 (the jurisdictions in the urban PDCs) is negligible (-0.03), suggesting there is a difference between the potential for jobs/housing balance (reflected by the dissimilarity variable) and the actual jobs/housing balance (reflected by the proportion variable).

The calibrated model is of the form

Jurisdiction commute time in 2000 = 0.79 (Jurisdiction commute time in 1990)
+ 101.07 (PDC dissimilarity in 2000 – PDC dissimilarity in 1990)
– 1.07 (Jurisdiction jobs/labor force disparity in 2000)
+ 7.09 (Proportion commuting outside their jurisdiction of residence in 2000 - Proportion commuting outside their jurisdiction of residence in 1990)
+ 11.58 [Eq. 6]

Examination of the model shows that most of the variation in the year 2000 commute time is explained by the 1990 commute time. (Removing the 1990 jurisdiction commute time from Equation 6 and recalibrating the model based on the remaining variables would reduce the R^2 value from 0.94 to 0.65; by contrast, removing the other three variables and keeping only the 1990 commute time reduces the R^2 value from 0.94 to 0.91.)

Sensitivity Analysis

The practical impact of a change in each variable shown in Equation 6 may be compared by measuring the change in travel time that results from changing each of the four independent variables by 20% of the difference between the maximum and minimum value in the dataset. For example, from 1990 to 2000, the maximum change in proportion of persons commuting outside their jurisdiction of residence was 0.25 (an increase in Williamsburg) whereas the smallest change was -0.31 (a decrease in James City County). The midpoint of these two values (-0.03) serves as a baseline against which the impact of a 20% increase in the range, e.g., -0.03 + 20% of (0.25 – [-0.31]), may be compared.

Table 7 shows the results of this sensitivity analysis. For comparison, the impact of changing the jobs/labor force disparity for the analysis used to produce Figure 7 is also shown. The combined effect of the three variables related to jobs/housing balance (2.2 minutes) is, in minutes, only about one-half the impact of the travel time variable (4.2 minutes). If the analysis had stopped with step 4 (which is Equation 4 but applied only to the urban locations with PDCs 8, 9, and 16 represented as a single PDC), the two variables related to jobs/housing balance would have less than one third of the impact of the travel time variable. In sum, to the extent that the 1990 travel time reflects other factors not captured by the three jobs/housing balance variables, the impact of jobs/housing balance is at most about one-half as large as other factors.

Table 7. Impact of Twenty Percent Change in Each Variable on Commute time

Model	Change This Variable by 20%	Impact on 2000 Travel Time
Longitudinal analysis from 1990 to 2000, urban areas only[a] (Eq. 6)	Decrease 1990 jurisdiction travel time	4.2-minute decrease
	Decrease (1990 PDC dissimilarity - 2000 PDC dissimilarity)	0.5-minute decrease[b]
	Decrease jurisdiction jobs/labor force disparity	0.8-minute decrease[b]
	Decrease proportion of persons commuting outside jurisdiction of residence	0.8-minute decrease[b]
Longitudinal analysis from 1990 to 2000, all jurisdictions statewide (Eq. 4 recalibrated without variables that were not significant)	Decrease 1990 jurisdiction travel time[c]	5.6-minute decrease
Single point in time analysis at 2000, urban areas only[a]	Decrease jurisdiction jobs/labor force disparity	3.4-minute decrease
Single point in time analysis at 2000, all statewide jurisdictions (see Figure 7)	Decrease jurisdiction jobs/labor force disparity	5.3-minute decrease

[a]Includes jurisdictions in the modified Richmond Regional PDC; the Hampton Roads PDC; and the combined PDCs of Northern Virginia, Rappahannock-Rapidan, and George Washington.
[b]The true summation of these impacts without rounding is 2.2 minutes.
[c]No other variables were significant in the model.

Clearly, these data show that the impact of jobs/housing balance on commute time depends on how the impact is measured. *At a single point in time,* a simple examination of Virginia jurisdictions shows that a 20% improvement in jobs/housing balance decreases commute times by 3.4 minutes (if urban areas only are considered) or 5.3 minutes (if all jurisdictions statewide are considered). However, such an analysis does not prove jobs/housing balance caused a drop in travel time. Although it is possible that balance may have caused such a decrease, it is also possible that other factors associated with the balance (e.g., transit service, compact development, etc.) may have been the result. In other words, if jurisdiction *x* has a 20% better jobs/housing balance than jurisdiction *y*, then (when all jurisdictions in Virginia are considered) jurisdiction *x* has a commute time that is 5.3 minutes below that of jurisdiction *y* (if both jurisdictions are the same region).

A question decision makers might face, therefore, is: What will be the impact *over time if a particular jurisdiction's jobs/housing balance changes?* That is, over a 10-year period, what happens if jurisdiction *x* changes its jobs/housing balance by 20%? The longitudinal analysis (Eq. 6) attempts to control partially for these factors by incorporating the existing travel time for each jurisdiction. In the urban areas, over a 10-year period, the model shows more modest impacts than those shown at a single point in time: a 20% increase in jobs/housing balance decreases commute time by 2.2 minutes. No impact is detected when all jurisdictions are considered.

There are some practical difficulties with comparing the importance of jobs/housing relationships based on these data with those from other studies. The Virginia data are at the jurisdictional level (compared to some studies that examined data at a more microscopic scale of analysis). That said, the Virginia relationship appears to be within the bounds of previous work. On the one hand, Equation 6 suggests a statistically significant relationship between jobs/housing balance and commute time. Although jobs/housing balance may be correlated with a variety of other factors that themselves influence commute time, Equation 6 at least measures the impact of changing jobs/housing balance. On the other hand, Equation 6 does not show as strong an impact as some other studies in the literature. For example, for Prince William County, with a below-average jobs/labor force ratio (0.51, compared to an average value of 0.92 for the Northern Virginia / Rappahannock Rapidan / George Washington region), according to Equation 6, a 10% increase in Prince William County's employment directly affects the dissimilarity and disparity variables and reduces the expected commute time from 42.3 minutes to 41.7 minutes—a decrease of 1.4%. By contrast, with the understanding that VMT and commute time are not directly comparable, Cervero and Duncan (2006) found that a 10% increase in employment reduced VMT by 3%.

It should also be noted that according to the linear dissimilarity index (Eq. 2 and Figure 5), jobs/housing balance improved slightly for the period 1990 through 2006 without an explicit policy intervention. Note also that Giuliano (1991) reported that it appeared jobs/housing balance could improve in Los Angeles without a policy intervention. If Virginia takes steps in the future to encourage stronger jobs/housing balance, it would be informative to compare the change in balance from the past (1990 through 2006) to the future.

CONCLUSIONS

- *Jobs/housing balance may be defined as an equivalence of the numbers of an area's jobs and area residents seeking those jobs. A variety of policies related to jobs/housing balance have been proposed; fewer have been implemented.* Implemented policies include redirecting future land development (either for individual site proposals or comprehensive plan amendments) and offering private incentives (to increase residential housing in areas where it is needed) or public incentives (to grant residential building permits in areas where residential development is needed). Other policies, such as identifying local land use regulations that hinder achievement of balance, have been proposed but not necessarily implemented. Some literature specifically advises against using jobs/housing balance to reduce congestion, citing either other approaches that are more effective for congestion reduction (e.g., Downs, 2004) or the fact that imbalances are temporary (e.g., Giuliano, 1991).

- *Although the concept of jobs/housing balance has been used in several parts of the United States to make policy decisions, there is no single numerical criterion that is a universal standard for defining good balance*. The most common performance measure is the ratio of jobs to housing in one location relative to adjacent areas, and such balanced ratios have been characterized as about 1.25; 0.8 to 1.2; or 1.2 to 2.8. Other performance measures include the ratio of employment to population, the dissimilarity index, and the imbalance indicator.

- *Jobs/housing balance may be measured in at least two ways using Virginia data at the jurisdiction level.* To assess a jurisdiction's balance relative to the region at a given instant in time, the ratio of the jurisdiction's employment and labor force is compared to the regional ratio of employment to labor force. Positive values mean a surplus of jobs to labor force;

negative values mean a jobs-poor area. To assess how a region's jobs/housing balance changes over time, the linear dissimilarity index is computed at two points in time; this index is based on employment and labor force values for the various jurisdictions that comprise the region. An increase in the index means jobs/housing balance is decreasing; a decrease in the index means the balance is increasing.

- *At a given point in time, above-average jurisdiction commute times are correlated with below-average jurisdiction jobs/labor force ratios after controlling for the region in which these jurisdictions are located.* This correlation exceeded -0.7 for all time periods examined: 1980, 1990, 2000, and 2006. The 2000 data suggested that for two jurisdictions in the same region, a jurisdiction with a 20% higher jobs/labor force disparity will have a 3.4-minute lower commute time (when only urban jurisdictions are considered) or a 5.3-minute lower commute time (when all jurisdictions are considered). This does not prove that jobs/housing balances alone reduces travel time; rather, it shows that some factor associated with jobs/housing balance reduces travel time.

- *Longitudinally, Virginia data showed that jobs/housing balance has a statistically significant impact on a jurisdiction's average commute time, but this impact is evident only when other factors are carefully controlled.* For the urban jurisdictions where the final model was tested, a 20% change in the range of observed values for variables designed to capture jobs/housing balance affected average commute times by about 2.2 minutes. By contrast, a corresponding 20% change for the variable that accounts for other factors affected commutes by about 4.2 minutes.

- *The impact of jobs/housing balance on commuting, according to the longitudinal model used for Virginia urban areas, is within the wide range of findings of other studies. Some literature indicated no impact on commuting; other sources indicated a 28% reduction in VMT or a 13.3% reduction in travel time.* Although a statistically significant relationship between commuting behavior and jobs/housing balance was shown for Virginia data, the longitudinal impact was somewhat modest. For example, according to the model described in Equation 6, a 10% increase in employment in one jobs-poor jurisdiction within a large congested urban region reduced travel time by about 1.4%.

- *The failure to account for mismatches between housing prices and job types does not render jobs/housing balance meaningless based on the studies reviewed.* Giuliano (1995) predicted commute lengths in Baltimore based on travel costs and found that the predicted commute was about one-half as long as the actual commute—but inclusion of housing types in the model still raised the predicted commute by about 20%, leading Giuliano to conclude that mismatches did not explain why predicted and actual commutes differed. Cervero and Duncan (2006) found that a certain increase in employment reduced VMT by 2.99%; matching jobs and employment changed this value to 3.29%. Yang and Ferreira (2005) computed the correlation between predicted and average commute time for Boston; the correlation was 0.33 (without matching job types and resident skills) or 0.35 (when matching did take place).

OPTIONS FOR INCORPORATING JOBS/HOUSING BALANCE INTO THE DEVELOPMENT OF THE STATEWIDE TRANSPORTATION PLAN OR THE SIX-YEAR IMPROVEMENT PROGRAM

Although jurisdictions with higher jobs/housing ratios had measurably shorter commutes than did jurisdictions (in the same region) with lower jobs/housing ratios, this report showed that improving jobs/housing balance for a given jurisdiction had only a modest impact on commute time and only under certain circumstances, such as when regions were carefully defined and when only urban regions were included. This suggests the need to define carefully how jobs/housing balance should be used.

The *Code of Virginia* clearly requires such use, however, as stated in § 33.1-23.03:

> The Statewide Transportation Plan shall establish goals, objectives, and priorities that cover at least a 20-year planning horizon, in accordance with federal transportation planning requirements. The plan shall include *quantifiable measures* and *achievable goals* relating to, but not limited to, congestion reduction and safety, transit and high-occupancy vehicle facility use, *job-to-housing ratios*, job and housing access to transit and pedestrian facilities, air quality, movement of freight by rail, and per capita vehicle miles traveled. The Board shall consider such goals in evaluating and selecting transportation improvement projects for inclusion in the Six-Year Improvement Program pursuant to § 33.1-12 (emphasis added).

As shown in this report, there is a variety of ways to develop measures and goals relating to jobs/housing balance within the context of the STP and/or SYIP. Two options, either of which should satisfy the requirements of the *Code* (§ 33.1-23.03), are (1) use the jobs/labor force ratio, or (2) use the exponential dissimilarity index.

Option 1: Use the Jobs/Labor Force Ratio

Recognizing that jobs/housing balance has a moderate impact on commute time, for select projects in an urban region, determine whether a transportation project connects a jurisdiction with a high jobs/labor force ratio to a jurisdiction that has a low jobs/labor force ratio, relative to the region. Then, use this determination as one of many factors when considering potential projects.

For example, if a project is proposed that will provide greater service between two jurisdictions, the factor for jobs/housing balance may be determined by computing the jobs/labor force ratio for the region and then determining the difference between this average value and the jobs/labor force ratios for each of the two jurisdictions affected by the project. If one jurisdiction had a high jobs/labor force ratio and one had a low jobs/labor force ratio, this project could be deemed a qualifying project. In the language of the *Code* (§ 33.1-23.03), the following are noted:

- The *quantifiable measure* is the number of projects selected that connect a jurisdiction with a high jobs/labor force ratio to a jurisdiction with a low jobs/labor force ratio.

- The *achievable goal* is to increase the percentage of qualifying projects.

As the *Code* (§ 33.1-23.03) specifies "job-to-housing ratios," it is noted that such ratios were found to be highly correlated with the ratios of jobs to labor force, with correlations of 0.95, 0.95, 0.95, and 0.93 for years 1980, 1990, 2000, and 2006, respectively. When implementing option 1, the following choices may be made by staff:

- whether the region should be defined by the PDC boundaries (as was done in this report) or whether some other boundary should be used

- whether the urban regions that use this option are Hampton Roads, Northern Virginia, and Richmond (as was done in this report) or whether fewer or additional urban regions should be included

- whether a single ratio should be computed as all jobs divided by all labor force (as was done in this report) or whether multiple ratios should be computed that incorporate home price and employment income; although it is indeed logical to consider socioeconomic status to ensure residents are connected with the types of jobs they are likely able to obtain, the extra effort of obtaining such data is a relevant consideration; Cervero and Duncan (2006) showed that although matching jobs and labor force improved the efficacy of this ratio, failure to make such matching did not prevent the computed ratio from being useful.

Option 2. Use the Exponential Dissimilarity Index

Although a strength of the jobs/labor force ratio is its simplicity of computation, a weakness is that it does not explicitly include a transportation impact in its computations. Accordingly, an alternative approach is to calibrate and use the exponential dissimilarity index (Eq. 3) for a given urban region. Then, one can use a project's impact on the index as one of several factors in project selection.

For example, if a region comparable to that shown in Figure 1 was being used, using the same project from option 1, the impact of the project on travel time before and after the project would be recorded. (This impact could be estimated from the regional travel demand model.) The difference in the index for this before and after case would be used. For example, if the project reduced the index from, say, 0.081 to 0.080, that would be an improvement of 0.001 in jobs/housing balance for the region. In the language of the *Code*, the following are noted:

- The *quantifiable measure* is the forecast change in the region's exponential dissimilarity index.

- The *achievable goal* is to reduce this index from its previous value.

If option 2 is implemented, staff have the same three choices noted for option 1: the manner in which the regional boundaries are chosen, which urban regions are chosen, and whether socioeconomic status is considered. In addition, staff have two other choices to make:

- whether the parameter β is calibrated based on travel distance (as was done in this report) or whether some other method, such as travel time, is used

- whether data for this metric are obtained directly by staff (as was done in this report) or whether information from the appropriate regional travel demand model is used.

Other Options

If Virginia encourages stronger jobs/housing balance as per options 1 and 2, a subsequent question that will arise is whether balance improves at a greater rate than it did for the period 1990 through 2006 when no such policy interventions were in place.

Because this report examined data only at the jurisdiction level rather than the more detailed census tract level, a third option not discussed here is to encourage metropolitan planning organizations (MPOs) to examine, as part of their Constrained Long-Range Regional Plan (CLRP), the impact of prospective projects on jobs/housing balance using, as a geographical unit of analysis, the transportation analysis zone (TAZ). The state could then use as a factor in project selection those projects that favorably affect balance based on such TAZs. This option would require further study and is one of several further research questions noted in Table A3 of Appendix A.

FEASIBILITY OF IMPLEMENTATION OF OPTIONS

Option 1 can be implemented at present. Option 2 requires additional effort. A productive starting point is examination of the MPO's regional travel demand model.

Regardless of which option is chosen, the *Code* (§ 33.1-23.03) does not specify which staff are responsible for implementing the "quantifiable measures and achievable goals" relating to jobs/housing balance. Rather, the language assigns these duties to the CTB with the assistance of the Office of Intermodal Planning and Investment:

> The Commonwealth Transportation Board shall, with the assistance of the Office of Intermodal Planning and Investment, conduct a comprehensive review of statewide transportation needs in a Statewide Transportation Plan . . . .
>
> This Statewide Transportation Plan shall be updated as needed, but no less than once every five years . . . .

Thus, in practice, the staff who would compute these measures could presumably be any of the following:

- staff who support the Office of Intermodal Planning and Investment to the extent that such staff are responsible for developing the STP

- planning or programming staff of the Virginia Department of Transportation to the extent that such staff are responsible for providing the information necessary for the

CTB to “consider such goals in evaluating and selecting transportation improvement projects for inclusion in the Six-Year Improvement Program” (§ 33.1-23.03)

- local or MPO planning staff to the extent that such staff may have computed such metrics for various projects being discussed in the STP or SYIP that are also being considered as part of the MPO’s CLRP or subsequent Transportation Improvement Program (TIP).

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APPENDIX A

CREATION OF A CONSISTENT LONGITUDINAL DATASET

At the outset of this project, it was not clear which data should be used to assess jobs/housing relationships. Consequently, three steps were taken to develop a dataset that could be used to assess such relationships for the period 1980-2008.

1. Examine available Virginia data.
2. Select appropriate data elements.
3. Modify individual records to make the data consistent over time.

Examine Available Virginia Data

Table A1 summarizes available Virginia datasets for estimating jobs/housing balance from the Bureau of Economic Analysis (BEA), the U.S. Census Bureau, the Weldon Cooper Center for Public Service, and the Minnesota Population Center. Table A1 shows there are multiple data options for estimating the "jobs" and the "housing" component for jobs/housing balance.

Table A1. Summary of Available Data for Jobs/Housing Balance

Data Element	Source	Temporal Coverage	Spatial Coverage
Population	Weldon Cooper	Annually 1960-2008	Every jurisdiction (134 cities and counties)
Employment[a]	BEA	Annually 1969-2007	Every area, where an area is comprised of one, two, or three jurisdictions (105 areas).
	VEC	Annually 1990-2008 (electronic)	Every jurisdiction
	VEC	Annually 1942-1989 (not electronic)	Every jurisdiction
Labor force	Census	1980, 1990, and 2000	Every jurisdiction
	VEC	Annually 1990-2008	Every jurisdiction
Total housing units	Census	1980, 1990, and annually 2000-2007	Every jurisdiction
	Weldon Cooper	Annually 1990-2007, but estimate only[b]	Every jurisdiction
Occupied housing units	Census	1980, 1990, 2000	Every jurisdiction
	Census	Single estimate for 2005-2007	Jurisdictions with population >20,000
	Census	2007[c]	Jurisdictions with population >65,000
Travel time to work and place of employment	Census, Minnesota, Spar	1980, 1990, 2000	Every jurisdiction
		Single estimate for 2005-2007	Jurisdictions with population >20,000

Weldon Cooper = Weldon Cooper Center for Public Service; BEA = Bureau of Economic Analysis; VEC = Virginia Employment Commission; Census = U.S. Census Bureau; Minnesota = Minnesota Population Center.
[a]VEC employment estimates are typically lower than those of BEA, in part because the Bureau of Labor Statistics data, upon which VEC data are based, do not include certain employment categories such as forestry, fishing, hunting, the military, "other" (BEA, 2008), and domestic workers (Bureau of Labor Statistics, 2007).
[b]Total housing units may be estimated by adding the annual building permits, available through Weldon Cooper, to the total housing units available from the decennial census.
[c]For years 2004-2006, census data are available for selected areas with a population of 65,000 or more.

The “jobs” in jobs/housing balance is captured by employment. Employment data are available electronically for every jurisdiction from 1990 on from VEC and are described as “Quarterly Census of Employment and Wages, Sector (2 digit) data for Total, All Industries (00) for Every County/City, Aggregate of all types” (VEC, undated). Although BEA data are available going back to 1969, they are combined for some jurisdictions (e.g., the City of Charlottesville and Albemarle County). BEA employment estimates are higher than VEC employment estimates (e.g., in 2005, Virginia wage and salary employment data reported by the Bureau of Labor Statistics (BLS) were about 7% lower than those reported by BEA), because some categories (e.g., forestry, fishing, and domestic workers) are not included in the BLS data upon which the VEC data are based.

The “housing” in jobs/housing balance is captured by housing, labor force, or population. Occupied housing units (households) have historically been available only as part of the decennial census, although the U.S. Census Bureau’s American Community Survey has begun to track these data for some jurisdictions. Total housing units are available on an annual basis. Labor force data are available from VEC in electronic format for every jurisdiction going back to 1990 and are described as “Annual Not Seasonally Adjusted Labor Force, Employment and Unemployment data in Every County/City” (VEC, undated). Population data are readily available as noted. In terms of temporal and spatial coverage, the best dataset is population, which is available for every year and every jurisdiction, going back at least as far as 1960 in electronic format.

Select Appropriate Data Elements

Figure 1 suggested that for the Richmond region, similar indications of jobs/housing balance might be obtained regardless of whether “housing” was represented by total housing units, occupied housing units (households), population, or labor force. Figure A1 shows a similar finding statewide, based on data from the 2005-2007 American Community Survey, which represents the 79 Virginia jurisdictions with a population in excess of 20,000. The correlation among these four variables exceeded 0.99. Because of the possibility that more heavily populated jurisdictions might obscure variation in the less populated areas, the correlations were also assessed for those jurisdictions with a population between 20,000 and 65,000. The lowest correlations were between labor force and total housing units (0.88) and between labor force and occupied housing units (0.93); all other correlations were relatively high (0.94 to 0.98).

Although the high correlations suggest all four metrics are feasible for the denominator of a jobs/housing balance, Table A1 suggests that the use of labor force or population might be preferred. Unlike occupied housing data, the labor force data are available on an annual basis even before the year 2000, which facilitates some historical analysis, and labor force does not require the additional step of incorporating building permits, which would be required to obtain annual estimates of total housing units before 2000. Because it is possible that some jurisdictions in Virginia may have disparate proportions of workers in their population, *labor force* was chosen as the denominator of jobs/housing balance.

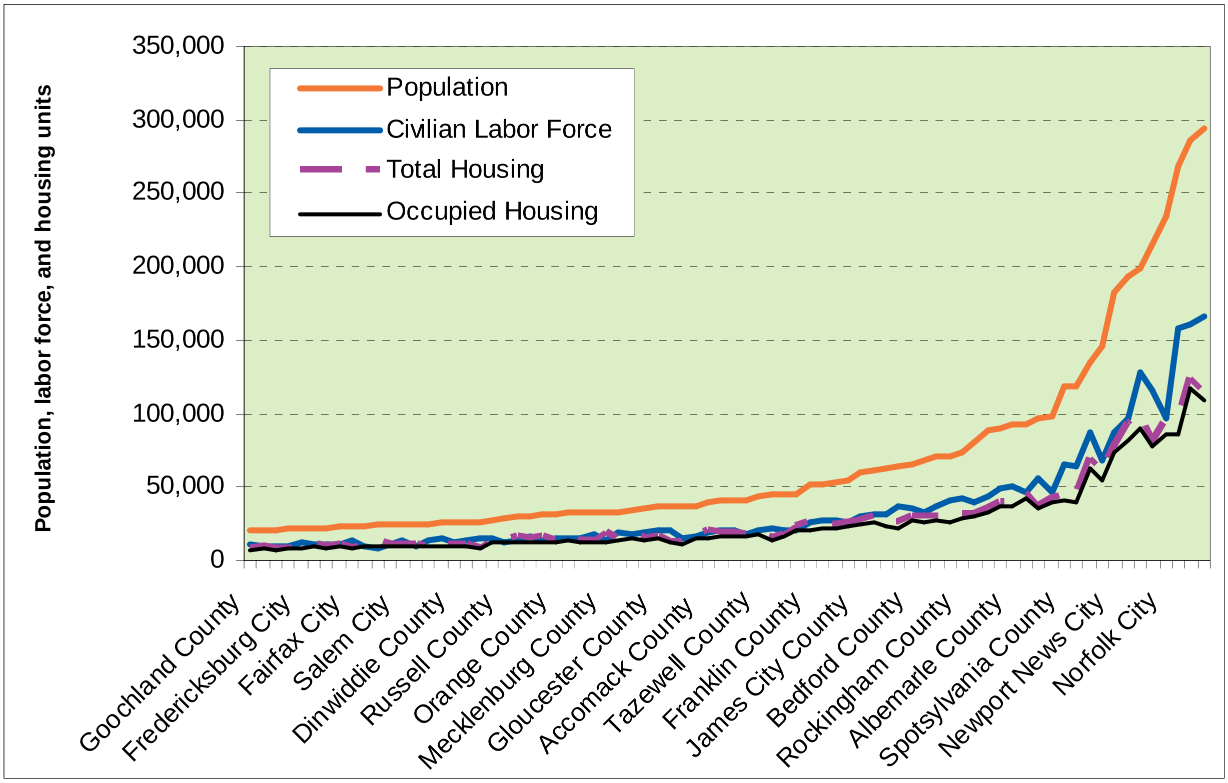

Figure A1. Correlation Among Population, Labor Force, Total Housing Units, and Occupied Housing Units Based on the 2005-2007 American Community Survey, Virginia Jurisdictions Over 20,000 in Population. Data sources are population (Weldon Cooper Center for Public Service, 2009); employment and labor force (Virginia Employment Commission, undated), and housing (U.S. Census Bureau, 2008a). Excludes the largest jurisdictions of Prince William, Virginia Beach, and Fairfax County; including them would show an even greater correlation.

Modify Individual Records to Make the Data Consistent Over Time

Several adjustments were made to develop a longitudinally feasible dataset that stored data by jurisdiction and by region.

Population data are available for every year and every county and city in Virginia (Weldon Cooper Center, 2009a). Two changes were made regarding how historical data are grouped to make the population data by jurisdiction directly comparable across years: 1960-1994 populations for the City of South Boston were added to the total for Halifax County for those years (because in 1995 the city reverted to a town and hence was included within the Halifax County population) and populations for the City of Clifton Forge and Alleghany County were combined (because after 2000 the city reverted to a town and hence its population was included within the Alleghany County population). A similar approach was followed for the other data elements.

It appears that the 1980 travel time and the 1980 number of households for Charlotte County and Charles City County were reversed, and thus what appeared to be the correct values were used in the dataset.

Although labor force data for 1980 are available from the *Virginia Statistical Abstract* (Spar, 1987), these data did not appear consistent with hardcopy data from VEC. For example, the civilian labor force for the city of Alexandria (61,243) was larger than the VEC estimate (53,151). Consequently labor force data were transcribed from VEC files entitled "Local Area Unemployment Statistics from 8001 to 8012, and 80 Annual Average."

Employment data for 1980 were obtained by summing two sources. The primary source was VEC hardcopy files entitled "Covered Employment and Wages—Second Quarter, 1980." However, these files noted: "State and local government, while included in U.I. [Unemployment Insurance] Coverage, are not included in this publication." Starting in the second quarter of 1983, VEC employment data included state, local, and federal government employment; these files were entitled "Covered Employment and Wages in Virginia By 2-Digit SIC [Standard Industrial Classification] Industry for Quarter Ending June 30, 1983." Examination of King George County's data in particular (which has a large federal employment component) strongly suggested that the 1980 VEC employment also excluded federal employment; thus, the 1983 state, federal, and local employment values were added to the 1980 private employment values to estimate the 1980 total employment. (Although it would have been possible to adjust 1983 government employment by the ratio of 1980 total employment to 1983 total employment, the existence of the recession of 1981-1982 and the relative stability of government employment suggest this was not necessary.)

Note also that for 1980, the employment was available only by quarter rather than by year, and VEC staff suggested that the second quarter could be used as a surrogate for average annual employment since second quarter figures are generally stable (D. Tysinger, personal communication, December 15, 2009). A comparison of the second quarter and the average annual employment values for 1980 for a few jurisdictions supported this hypothesis: the differences were 0.20% (for the entire state, Charlottesville, and Richmond City), 1.0% (for Fairfax County), and 1.5% (for Virginia Beach City). These percentages are lower than the 2.1% of total employment for which a specific jurisdiction is not given.

Table A2. Bins and Corresponding Midpoints for the 1980, 1990, 2000, and 2006 Census

1980[a]		1990, 2000, and 2006[b]	
Bin	**Midpoint**	**Bin**	**Midpoint**
Less than 5 minutes	2	Less than 5 minutes	2
5 to 9 minutes	7	5 to 9 minutes	7
10 to 14 minutes	12	10 to 14 minutes	12
15 to 19 minutes	17	15 to 19 minutes	17
20 to 29 minutes	24.5	20 to 24 minutes	22
		25 to 29 minutes	27
30 to 44 minutes	37	30 to 34 minutes	32
		35 to 39 minutes	37
		40 to 44 minutes	42
45 to 59 minutes	52	45 to 59 minutes	52
60 or more minutes	75	60 to 89 minutes	74.5
		90 or more minutes	105

[a]Minnesota Population Center (2004b).
[b]Minnesota Population Center (2004c); U.S. Census Bureau (undated [a], 2002).

The 1980, 1990, 2000, and 2006 census give the number of commuters by bin (e.g., 5 to 9 minutes, 10 to 14 minutes, etc.). Thus, an average travel time can be estimated by using the midpoint value for each bin. However, the bins differed between the 1980 and the 1990 census. Table A2 shows these bins and their corresponding midpoints, but it is recognized that this variation may affect the comparability of 1980 and 1990 travel times.

Other Data Elements

The data elements in Table A1 are not the only ones necessary to address future research questions related to jobs-housing balance. Table A3 lists additional research questions and associated data elements that could be required by future studies.

Table A3. Additional Approaches to Address Related Research Questions

No.	Potential Research Question	Approach and Data Element Required
1	Because employees may commute across PDC boundaries, how would results be affected by redefining regions based on some other criterion?	Examine origin-destination flows (e.g., Census [2003]) and redefine regions based on these flows.
2	Is it the case that the change in some other transportation-related factor, such as transit quality or highway level of service, is affecting the change in commute times from 1990-2000 (see Eq. 6)?	In the Hampton Roads, Northern Virginia, and Richmond regions, collect transportation performance information such as the number of unlinked transit trips and traffic volumes.
3	How would performing this analysis with smaller geographical units affect the quantified impact of jobs/housing balance?	Pick a single urban region and measure population (or households) and employment opportunities at the TAZ level based on the regional urban travel demand model.
4	How would the results be affected if extremely long commutes rather than “average commutes” had been studied?	Study the impact of jobs/housing balance on commutes greater than 60 minutes (see data elements in Table A2).
5	What is the proper value of β in the exponential dissimilarity index (see Eq. 3)?	Although Marion and Horner (2008) offer some guidance, this would entail looking at actual origin-destination flows for the region (see question 1) and examining the combined impedance between zones based on the regional demand model (see question 3).
6	To what extent are housing prices, relative to income, contributing to a jobs/housing disparity?	• A sketch level approach is to incorporate average housing prices, average incomes, and average wages for various jurisdictions into a model comparable to Eq. 6. • A better (but more detailed) approach is to obtain such information for individual commuters. See also Levine (1998).
7	How would the results be affected if specific job types (e.g., clerical) were aligned with specific elements of the labor force (e.g., clerical workers)?	By jurisdiction, VEC (undated) provides different types of employment categories and average weekly wages for these categories. This could be coupled with survey data (e.g., see Cervero and Duncan [2006]) to examine how matching job and labor force types affects the results.
8	How are non-commute trips affected by jobs/housing balance?	Non-work related trips may be studied. Peng (1997) reported that “Work trips and non-work trips have very similar patterns” based on a review of Portland (Oregon) travel behavior.

Census = U.S. Census Bureau; TAZ = Transportation Analysis Zone; VEC = Virginia Employment Commission.

APPENDIX B

MEASURES BASED ON THEORETICAL COMMUTING DISTANCES

Several studies (Horner 2006, 2008, 2009; Horner and Murray, 2003; Scott et al., 2007) have considered the concept of the *minimum commute,* which is the distance that would result if each resident worked at the nearest employment location. Giuliano (1995) and Song (1992) considered a related concept, which is the commute distance as predicted by urban economic theory (Giuliano, 1995) or the polycentric model (Song, 1992).

These theoretical commuting distances, based on the minimum commute, urban economic theory, or the polycentric model, have been used to suggest three statements:

1. Jobs/housing policies have the potential to reduce commute distance.
2. Jobs/housing policies have little potential to reduce commute distance.
3. The theoretical commute is related to the actual commute.

Jobs/housing policies have the potential to reduce commute distance.

A review of Horner (2008, 2009); Horner and Murray (2003); and Song (1992) suggests that jobs/housing balance has the potential to reduce commuting distances because the variables in these studies (e.g., minimum commute time [Horner and Murray, 2003] were shown be susceptible to changes in jobs or housing locations.

Horner (2009) distinguished the region's total actual commute time (T_{actual}) and the minimum commute time ($T_{minimum}$). In practice, T_{actual} is the sum of all travel time by all commuters in a region, whereas $T_{minimum}$ is the sum of all travel times that could be achieved if each person worked at the employment location closest to his or her home. The difference between total and actual commute time is referred to as excess commuting, and as shown in Equation A1, may be expressed as a percentage (Horner, 2009).

$$\text{Excess commuting time percentage} = 100\left[\frac{T_{actual} - T_{minimum}}{T_{actual}}\right] \qquad \text{[Eq. A1]}$$

The spatial structure of the zones that comprise a given region will influence these calculations; for example, Song (1992) suggested that larger zones will tend to give smaller estimates of excess commuting than smaller zones. Horner and Murray (2003) found that, based on an analysis of the Atlanta region, an 82% reduction in the minimum commute time could be achieved when only workers were relocated whereas a smaller reduction of 75% was achieved when only jobs were relocated. The authors also found that relocating a small number of workers could have a substantial impact: relocating slightly more than 7% of workers reduced the minimum commute by more than one-third.

Based on data from Tallahassee (Florida), Horner (2008) noted that the minimum commute distance was 3.10 miles presuming job and residential locations were fixed. However, changing the location of new commercial and residential development between 1990 and 2000 (e.g., have more workers [who come after 1990] live in the jobs-rich CBD and have more jobs [created after 1990] be located in the jobs-poor outlying areas) reduced the minimum commute time to 1.90 miles (Horner, 2008).

Song (1992) examined 1980 Orange County (California) commuting data and found that the polycentric model—which predicts resident worker density and employment density as a function of distance from multiple employment centers—explained actual commuting distance better than the monocentric model (which predicts worker density and employment density as a function of distance from a single employment center located at the center of the region). This finding led Song to suggest that households do, in fact, attempt to reduce their commuting cost (provided one recognizes that the cost minimization may be in reference to a nearby employment center and not necessarily the CBD). Song also cited another dataset for another region that showed that the mean observed commuting distance was less than the distance that would arise if residential and employment locations were randomly chosen. Song concluded that jobs housing policies "may have the potential to succeed."

Jobs/housing policies have little potential to reduce commute distance.

Two studies (Giuliano, 1995; Scott et al., 1997) used the difference between theoretical commutes and actual data to suggest that other factors explain commute distance such that jobs/housing policies are not likely to affect commute distance.

Scott et al. (1997) explicitly compared the theoretical minimum commute to the actual commute for eight municipalities within Canada's Hamilton Census Metropolitan Area. The authors reported an average excess commute time (23.64 minutes) that was almost 4 times as large as the minimum commute time (6.35 minutes). The regional average was 1.00 jobs per resident worker, with two municipalities being jobs rich (values of 1.16 and 1.111 jobs/resident worker) and the remaining six being jobs poor (with values ranging from 0.02 to 0.77 jobs per resident worker). Yet in all eight cases the observed commute was at least 3 times longer than the regional minimum commute. The authors concluded that (1) workers consider other factors besides the cost of commuting in their decisions regarding where to live, and that (2) "policies advocating jobs-housing balance as the principal strategy for facilitating more efficient commuting are unlikely to meet the expectations of policy-makers."

A review of Giuliano (1995) suggests that a mismatch between housing and employment (e.g., the lack of adjacent housing that can be afforded by persons at a given employment center, which can result from economic growth or exclusionary zoning) may affect commute length or distance but not as dramatically as one might suspect. Giuliano noted two datasets from Baltimore and Los Angeles that compared the actual commute with the commute predicted based on elements of urban economic theory (e.g., that households consider the monetary and time cost of travel when choosing a location, that employment is located at the CBD because that location has the highest value of land, and that each household has one worker). The author noted that the predicted commute was substantially less than the actual commute (e.g., in Baltimore, the predicted commute was 4.39 miles for homeowners compared to an actual commute of 10.2 miles). When constraints, such as the type of housing, were incorporated into the prediction, the predicted commute rose by only about 20% (e.g., the predicted commute for Baltimore homeowners rose from 4.39 to 5.04 miles, which was still about one-half the actual commute of 10.2 miles). Giuliano thus concluded that "mismatches between jobs and workers do not account for a substantial part of observed commuting patterns."

The theoretical commute is related to the actual commute.

Several studies (Horner, 2006, 2008; Yang and Ferreira, 2005) and data from Scott et al. (1997) show some degree of correlation between minimum commuting distance and actual commuting distance, suggesting that the former can be used to predict the latter. To be clear, all of these sources indicate that actual commuting distance is multiple times larger than the minimum commuting distance: correlation indicates that changes in one may be related to changes in the other, thereby providing some predictive power.

Horner (2008) related the minimum commuting distance and the actual commuting distance based on data from Leon County (Florida), which saw its actual commuting distance increase from 5.54 miles in 1990 to 6.00 miles in 2000. At the same time, its theoretical minimum commuting distance increased from 3.01 to 3.10 miles. An earlier work (Horner, 2006) extracted data from Leon County at the TAZ level (e.g., 483 zones in 1990 and 594 zones in 2000) and identified for each zone two values: the actual average commuting distance for workers living in each zone and the minimum average commute distance for those workers. (This latter measure, the minimum average commute distance, was estimated by linking jobs with workers such that each zone's total workers and total jobs matched reality but such that total commute time was minimized.) A high degree of correlation (0.808 in 1990 and 0.747 in 2000) was found.

Using census tract data from Boston (for 1980, 1990, and 2000) and Atlanta (2000), Yang and Ferreira (2005) found that the correlation between minimum average commute time (by place of residence) and actual commute time range from 0.33 (Boston in 1990) and 0.41 (Boston in 1980), when no attempt was made to match job types and resident skills. The range of observed correlations rose to between 0.35 (Boston in 1990) and 0.45 (Boston in 1980) when jobs and residents were matched based on placing each into one of two groups: low skills and high skills.

Finally, a strong correlation (0.80) may be calculated from data from Scott et al. (1997) reflecting minimum and observed commutes for eight municipalities in Canada's Hamilton Census Metropolitan Area.