EVEN SMARTER GROWTH? LAND USE POLICY IMPACT ON TRANSPORTATION AND EMISSIONS IN MARYLAND

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Abstract

Urban form studies have generally used regional density vs. sprawl land use scenarios to assess travel behavior outcomes. The more nuanced but nonetheless important allocation of jobs and housing and their relationship to each other as a factor in travel behavior has received much less attention. That relationship is explored in this statewide urban form study for Maryland. This is a state where county land use has a long tradition of growth management, but one whose regional and statewide implications have not been evaluated. How does a continuation of the County level smart growth regime play out statewide compared to other scenarios of job and housing distribution that are driven by higher driving costs or transit oriented development goals or local zoning rather than local policy-driven projections? Answers are provided through the application of a statewide travel demand model, the Maryland Statewide Transportation Model (MSTM). The findings suggest that the debate should move beyond walkability, density and compact growth and towards a more productive dialog about how we organize whole cities and regions.

Keywords: Land use, transit oriented development, travel behavior, smart growth, greenhouse gases, VMT

Introduction

This paper adds to the body of research around the interaction of land use, transportation and greenhouse gases (GHG). It does so by testing projected scenarios that vary future land use and travel costs to assess their impacts on travel behavior and GHG. Beyond adding to the metropolitan urban form studies that address this issue *(1, 2)* this study is of interest for several other reasons:

- The analysis is conducted at a statewide level using a statewide travel demand model, a scale where there are few such research efforts
- Maryland, has a well-established, growth managed, land use pattern in place and this study thus looks at the marginal effects of further adjustments
- The scenarios developed go beyond the typical Sprawl vs. Smart Growth dualities and provide nuanced results that emphasize employment location as a key variable
- The findings shed an interesting light on transit-supportive land use patterns
- Findings are reported by type of area – Rural, Suburban and Urban – and by urbanized and non-urbanized geographies

The study projects forward over 23 years (2007-2030) and assumes moderate growth in households (just over 1% p.a.) and stronger growth in employment (1.7% p.a.) over this timeframe.

Even with a broad array of local and statewide Smart Growth type policies and tools, Maryland continues to push for still more compact and dense urban areas[i] to also yield greater emissions reductions as part of its latest Long Range Transportation Plan and Climate Action Plan.

Against this background the National Center for Smart Growth Research and Education (NCSG) has built and tested various land use, transportation and environmental scenarios to explore statewide policy options and outcomes. These scenarios reported here include, as the baseline, continuing the current policy-driven land use patterns or assuming more job decentralization or increasing the costs of travel, or supporting transit via land use. This study holds the officially committed and modest future transportation facility improvements constant across scenarios.

We proceed with a literature review, and then describe the physical and policy context of the study, the travel model used and the scenarios to which the model is applied. We present and discuss our findings and conclude with their implications for statewide land use/transportation/emissions planning.

Literature Review

A significant amount of research has been conducted on the relationship between the built environment and travel behavior. The earliest focus on the relationship was on the effect of transportation investment on land use and location *(3–5)*. A strong focus has been on the effect of changes in land use patterns and development, specifically density, on the choice of mode and number of vehicle miles traveled (VMT). Cervero *(6)*has extensively studied the relationship, finding positive, but small impacts from higher density, transit oriented development. Similarly, Crane *(7–9)*studies new urbanism and transit oriented development and its effect on travel behavior; finding generally little or no impact from land use or street design on travel behavior. A theme from many similar studies that use a variety of methods, both empirical and models, show that mixing land uses tends to have a measureable impact *(10)* on travel behavior but the effect from density, one of the major tenets of new urbanism and smart growth, is negligible *(11)*.

The results of a significant portion of the research show that VMT is generally inelastic with density; mixed use is more elastic and the factor that has the greatest impact on travel is accessibility to jobs and downtowns. Schimek *(12)* using the 1990 NHTS found density had a measurable, but very small impact on travel that was far outweighed by other socioeconomic (SE) variables. Boarnet and Sarmiento *(13)* found virtually no effect on travel behavior from density, using a variety of models. A study by Kitamura et, al. *(14)* of five San Francisco neighborhoods found travel was reduced in denser neighborhoods, but there was a stronger correlation between travel and individual attitudes than with the underlying land use. Bento et, al. *(15)* studied a comprehensive set of built environment variables and found little correlation between density and travel behavior, but some explanatory power when a large group of built environment variables were present in an area. Næss *(16)* has a similar finding about accessibility in a study of Copenhagen, but also found that self-selection bias likely plays a role in the relationship, an effect not commonly controlled for in previous studies.

Badoe and Miller *(17)* reviewed much of the earlier empirical literature and concluded that where sound methodology was employed, land use had a minor or non-existent effect on travel behavior, while accessibility had a larger, though still small role. Another review *(18),* is critical of a majority of the literature, but finds credible evidence that little relationship exists between density and travel behavior and plausible evidence that a small but slightly more significant relationship with diversity and travel behavior.

Most of these findings were generally confirmed in many more studies and synthesized into relative elasticities by Ewing and Cervero *(19)* who conducted a meta-analysis of 60 studies measuring the impact of density, diversity and design on VMT. The most significant findings showed the greatest elasticity comes with accessibility to jobs, far outweighing other land use effects including density, diversity and design.

The above reviews report on *empirical* studies or reviews. Another group of studies use integrated land use and travel demand models to estimate the transport-land use relationship. Anderson et, al. *(20)*; Scott, Kanaroglou, & Anderson *(21)*; Behan and Farber et al., *(22)* all applied the IMULATE model, which simulates a single hour of morning rush hour traffic, calibrated with 1986 Census of Canada and the 1986 Transportation Tomorrow Survey, to measure the impact of urban form on emissions and air quality. In all of these papers, the same model was applied to the same study area (Hamilton, Ontario) and the same time period with significantly different emission reduction results from similar land use specifications. Reductions ranged from a high of nearly 62 percent to a low of 3 percent. The results indicate that changes in emissions from land use patterns are likely driven more by changes to the modeling environment then effects from urban form.

In 2004 the voluminous Propolis report was released *(23)* that tested numerous transportation and land-use (tr/lu) scenarios both individually and in combination in 8 European metropolises using several integrated tr/lu modeling frameworks. The results of the study demonstrated that combination scenarios might provide significant emission reductions, showing a 15-20% reduction in CO_2 emissions from the most effective combination scenario, which included pricing. Bartholomew and Ewing *(2)* conducted a meta-analysis of results from metropolitan scale scenario planning exercises. The results of the analysis indicate that compact development could reduce VMT by 7.6% on average compared to projected non-compact development.

Studies that have applied other integrated models find little or no impact from higher densities. A notable group of papers are those that use MEPLAN. Rodier et al. *(24)* used MEPLAN in part to measure the relationship between land use and transportation outcomes in the Sacramento area finding a modest reduction in VMT (in the order of 5 percent) attributable to land use. Echenique et al. *(1)* recently applied MEPLAN and other models to growth scenarios in Britain to measure change in multiple planning-related indictors. The study results indicate that land use and transportation investments indicative of compact development have little impact on most indicators or led to potentially undesirable trade-off between socio-economic consequences and environmental benefits, for example. Rodier *(25)* provides a comprehensive summary of international modeling exercises that measure VMT and emission reductions. The results indicate that land use policies alone have little impact on VMT, in the order of three percent, while pricing strategies reduce VMT by 12 percent on average over 30 years.

A significant amount of research confirms that density has a relatively small overall impact on travel, particularly as it relates to VMT. An important area that has received much less attention is how changes in the future location of jobs or housing affects travel outcomes. This paper contributes significantly to the literature by decomposing these two land use variables to measure their individual combined effects on travel.

Context

Maryland is a small and elongated state sandwiched between Pennsylvania and Virginia that nevertheless encompasses a spectrum of land use settings from very rural to very suburban/urban. Almost 19% of its total land area is defined as being in urban areas, making it the 6th most urban state. At 2,529 people per square mile Maryland is 13th in density. Central Maryland is anchored to the job-rich national capital region of DC and to the Baltimore region.

This seemingly urban and dense statewide picture masks a much more variegated land use pattern. In this study we define three categories of land use – Urban, Suburban and Rural – and apply them to the 1151 transportation zones used in our statewide travel demand model. The three land use categories are based on a combination of residential and employment density and reveal the land use nuances alluded to. We apply these subareas to 4 geographies that correspond to the two metros and the rural western and eastern bookends of the state. In our schema, more restrictively defined than in the Census, only 1.9% of the State's total acreage is classified as Urban, 5.8% is Suburban and 92.3% is Rural. The most developed geographic subarea – the Baltimore metro - is just under 20% Urban/Suburban and is double that of the Washington metro. The rather limited amount of urban and suburban land use resulting from our schema can be attributed to a longstanding legacy to county growth management, evident in Figure 2, and which has resulted in the Urban Growth Boundaries (UGBs) evident in most of the counties' comprehensive plans.

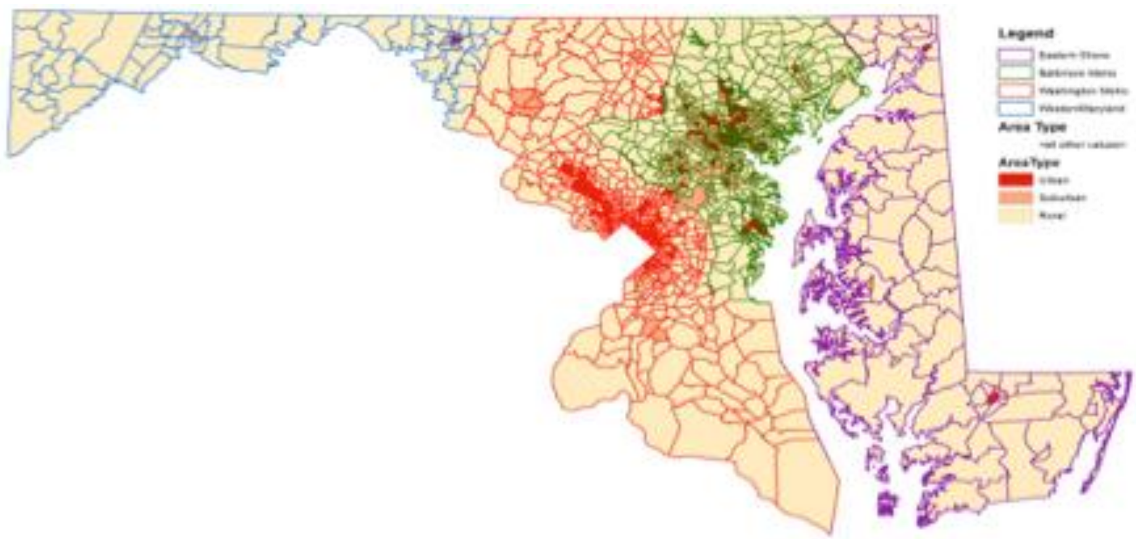

Figure 1. Spatial distribution of the four geographies and three area types

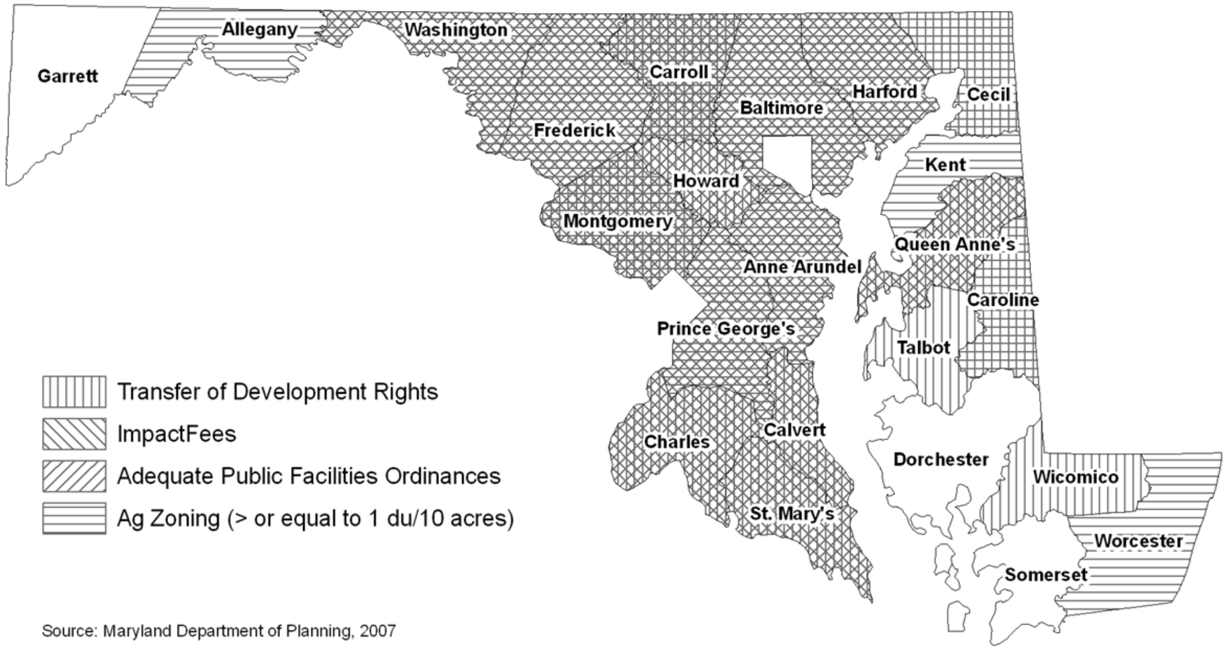

Figure 2. Maryland Growth Management, 2007

To this pre-existing county pattern the state has added its own growth management framework, consisting mainly of Priority Funding Areas (PFAs) which specify minimum densities and public sewer and water service among other classification standards as the basis for any state-funding of roads, schools and other financial incentive programs.

Travel Modeling Framework

Transportation outcomes are produced by the four-step statewide travel demand model referred to as the Maryland Statewide Transportation Model (MSTM). The MSTM's first layer consists of national travel and freight patterns (Figure 3). The second layer is a multistate layer representing more detailed travel patterns including local travel. The multi-layer modeling approach allows for better representation of multiple trip types including short-distance trips, mode split using urban transit and long-distance trips that have at least one trip end outside the state.

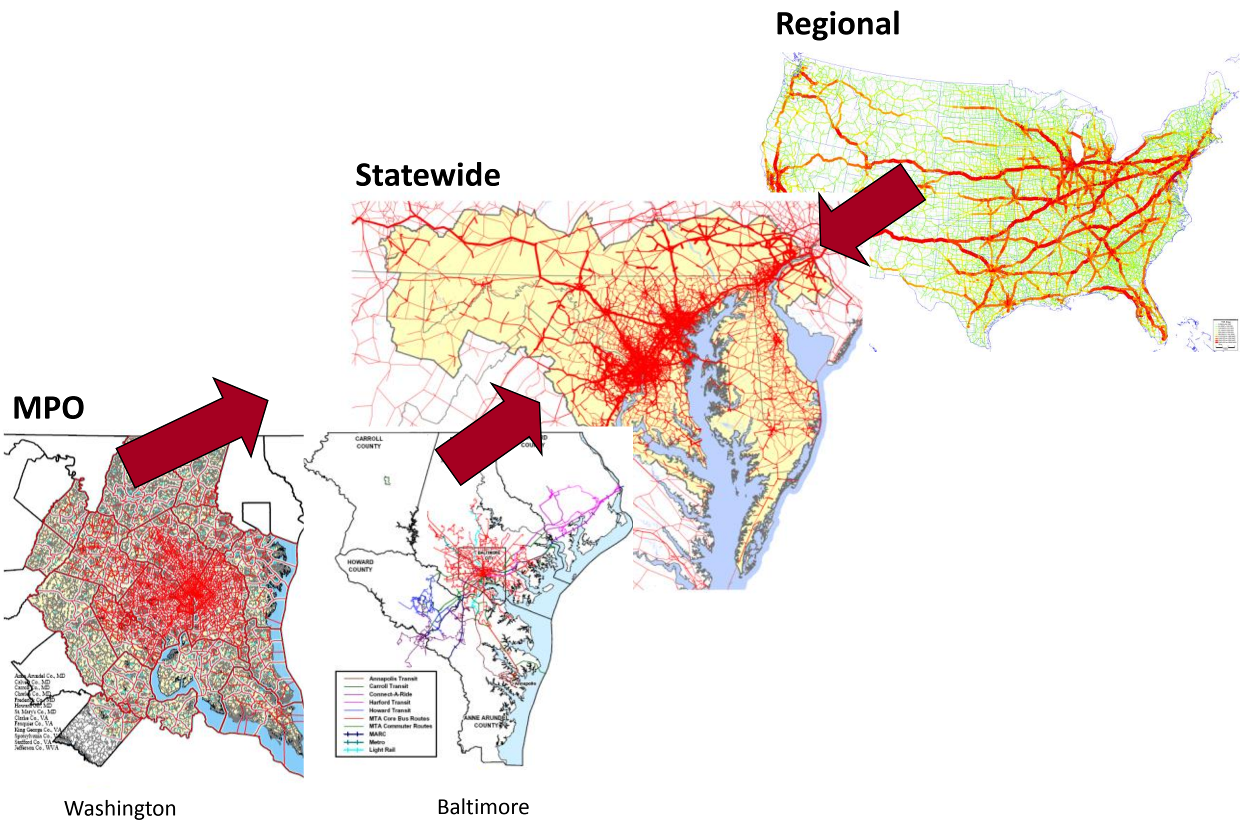

Figure 3. Multi-layer model structure

Figure 4 summarizes the MSTM model components within the multistate and national levels. Economic and Land Use assumptions drive the model. On the person travel side, the national model includes a person long-distance travel model for all long-distance trips of 50 miles or more, including through trips with neither trip end within Maryland. These trips are combined with multistate level short-distance person trips classified by study area residents, produced by using trip generation, trip distribution, and mode choice components. On the freight side, the national model includes a long-distance commodity-flow based freight model of truck trips that are 50 miles or longer.

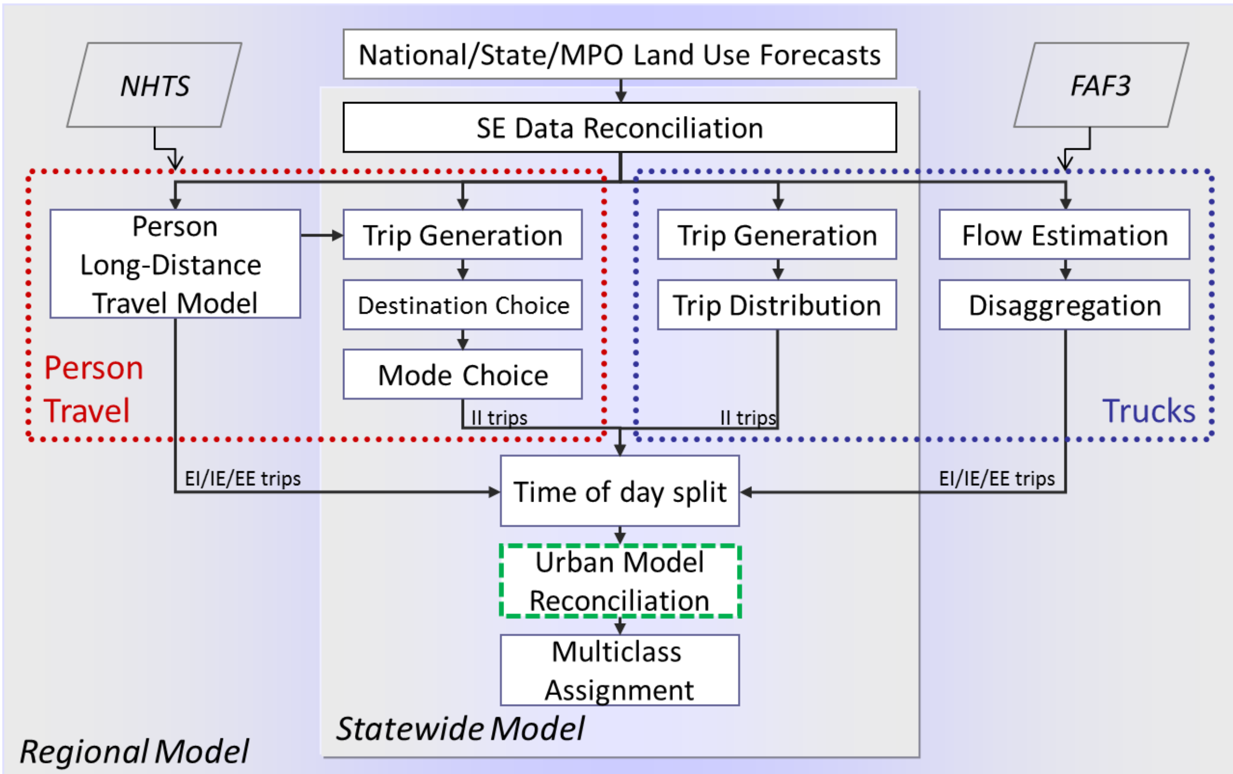

Figure 4. Overview of methodology of the land use travel demand model

Socio-economic data for the MSTM is collected from a number of national, state, and local agencies. In addition to socio-economic data, various datasets are used for model development, calibration and validation. The model includes the entire state of Maryland and selected counties of surrounding states, including Washington D.C. since travel patterns in Maryland are affected by the neighboring states.

The network also contains all built and CLRP (Constrained Long Range Plan)-planned transit facilities in the region including metro rail, light rail transit (LRT), bus, and commuter rail (both MARC and AMTRAK). Proper linkages have been established between highway and transit in the form of park-and-ride, access, and transfer links.

The Mobile Emissions Model (MEM) used in this study integrates emission rates generated by the MOVES2010a EPA model with the loaded transportation network. The MOVES model uses generalized national data such as vehicle fleet age distributions with localized county-level data such as average hourly temperatures and fuel formulation to produce emissions rates (factors) that are then applied at the highway link level in the transportation model. The emission rates (emissions per unit of distance for running emissions or per vehicle for starts, extended idle and resting evaporative emissions) are created in a look-up table format that are applied to the loaded MSTM network.

The GHG reductions presented are for on-road transportation below the 2030 baseline CLRP scenario. Reductions in GHG are presented for 2030 and not cumulatively over time and thus they do not show the immediate impacts of changes in travel behavior verses the long-term effects of land use changes. Fleet-wide vehicle efficiency for Maryland in 2007 is 24.46mpg and assumptions in 2030 incorporate CAFE standards (with a 2025 requirement that low duty vehicles achieve 54.5mpg) for a fleet-wide average of 49.05mpg. The carbon intensity of fuels (based on the current fleet mix of gasoline, diesel, ethanol and other alterative fuels) in 2007 is held constant for 2030. Further we provide an abbreviated discussion of specific emission results, as they are nearly coterminous with changes in VMT. Greater detail on emissions results is provided in Tables 8 and 9.

In sum, the land use interventions are more aggressive than the transportation and technological parameters. In this sense, the work most clearly reflects the potential for additional land use strategies to further influence transportation outcomes in a smart growth state that is growing at a moderate rate.

Scenario Descriptions

The reference or baseline scenario is the officially-sanctioned set of housing and employment projections that drive the Constrained Long Range Plan for the MPOs and State, called the CLRP. Three other scenarios for 2030 are developed. These are called Buildout (BO), High Energy Price (HEP) and Transit Located Growth (TLG). Two additional combinations of these are created for sensitivity analysis.

In our descriptions, we detail the differences between scenarios in terms of their geography and area (U, S and R) characteristics and for households and employment because these are important to the results and findings.

Statewide totals are the same for all scenarios except for HEP which has lower household but higher job growth, a function of the fact that HEP was a modeled scenario while the other two are rule-based allocations. We control for these differences in reporting results. Detailed scenario characteristics in numbers and percentages are presented in Table 1. This same data is converted to household densities and employment intensities in Table 2. Note that numbers greater than the CLRP 2030 reference case are shown in red bold and less than 15% in black bold.
Figure 5 (a and b) shows household and employment allocations (i.e. land use) in 2030 with the BO, HEP and TLG scenarios shown as the differences in housing and employment allocations from CLRP respectively.

Table 1. Number of household and employment in 2007 base year and 2030 horizon year

Indicator	Land Use Scenario*	Western Maryland				Washington Metro				Baltimore Metro				Eastern Shore				Total
		U•	S	R	T	U	S	R	T	U	S	R	T	U	S	R	T	
Number of HH	2007	9,392	17,951	67,948	95,291	190,495	336,369	320,670	847,534	297,103	413,922	303,663	1,014,688	9,282	10,718	150,529	170,529	2,128,042
	2030	12,670	21,526	82,119	116,314	264,880	396,484	442,321	1,103,685	335,466	465,182	386,504	1,187,152	12,612	13,928	235,372	261,912	2,669,061
	BO	6,942	24,958	93,468	125,369	252,905	377,535	452,736	1,083,176	390,870	428,109	378,807	1,197,787	12,902	16,856	232,973	262,732	2,669,063
	HEP	5,415	20,003	79,843	105,262	264,588	383,167	416,905	1,064,661	411,097	439,617	383,314	1,234,028	11,689	16,386	198,365	226,441	2,630,391
	TLG	12,670	21,526	82,119	116,314	286,135	402,151	415,399	1,103,685	360,030	463,143	363,979	1,187,152	12,612	13,928	235,372	261,912	2,669,063
Number of EMP	2007	13,322	32,957	69,989	116,268	540,021	324,352	228,542	1,092,915	644,851	476,187	259,660	1,380,698	25,646	29,834	128,868	184,348	2,774,229
	2030	16,545	38,847	80,895	136,287	675,518	472,122	346,043	1,493,683	846,233	716,679	398,488	1,961,400	33,501	36,088	174,289	243,878	3,835,248
	BO	9,021	33,027	118,201	160,250	379,379	548,558	599,364	1,527,301	638,942	682,564	535,074	1,856,579	18,169	25,797	247,150	291,116	3,835,246
	HEP	7,158	27,230	101,894	136,282	431,683	603,812	590,522	1,626,017	685,079	733,227	562,245	1,980,550	17,425	25,099	214,904	257,429	4,000,278
	TLG	16,545	38,847	80,895	136,287	689,480	471,887	332,314	1,493,681	871,288	714,472	375,640	1,961,400	33,501	36,088	174,289	243,878	3,835,246
PCT.CHG. HH	BO	-45.2%	15.9%	13.8%	7.8%	-4.5%	-4.8%	2.4%	-1.9%	16.5%	-8.0%	-2.0%	0.9%	2.3%	21.0%	-1.0%	0.3%	0.0%
	HEP	-57.3%	-7.1%	-2.8%	-9.5%	-0.1%	-3.4%	-5.7%	-3.5%	22.5%	-5.5%	-0.8%	3.9%	-7.3%	17.6%	-15.7%	-13.5%	-1.4%
	TLG	0.0%	0.0%	0.0%	0.0%	8.0%	1.4%	-6.1%	0.0%	7.3%	-0.4%	-5.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PCT.CHG EMP	BO	-45.5%	-15.0%	46.1%	17.6%	-43.8%	16.2%	73.2%	2.3%	-24.5%	-4.8%	34.3%	-5.3%	-45.8%	-28.5%	41.8%	19.4%	0.0%
	HEP	-56.7%	-29.9%	26.0%	0.0%	-36.1%	27.9%	70.6%	8.9%	-19.0%	2.3%	41.1%	1.0%	-48.0%	-30.4%	23.3%	5.6%	4.3%
	TLG	0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	-4.0%	0.0%	3.0%	-0.3%	-5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

• U – Urban; S – Suburban; R – Rural; T – Total

* BO – Build Out; HEP – High Energy Price; TLG – Transit Located Growth

PCT.CHG.HH – Percent change in household; PCT.CHG.EMP – Percent change in employment

Table 2. Land Use Characteristics of the Scenarios

Indicator	Land Use Scenario*	Western Maryland				Washington Metro				Baltimore Metro				Eastern Shore				State-wide
(1)	(2)	U* (3)	S (4)	R (5)	T (6)	U (7)	S (8)	R (9)	T (10)	U (11)	S (12)	R (13)	T (14)	U (15)	S (16)	R (17)	T (18)	(19)
Household (HH) Density	2007	4.69	1.61	0.07	0.10	3.37	2.11	0.16	0.39	4.44	1.97	0.26	0.71	2.40	1.20	0.07	0.08	0.31
	2030	6.33	1.94	0.08	0.12	4.68	2.48	0.22	0.50	5.01	2.21	0.33	0.83	3.27	1.56	0.11	0.12	0.39
	BO	**3.47**	**2.24**	**0.10**	0.13	4.47	2.37	0.23	0.49	**5.84**	2.04	0.33	0.84	3.34	**1.89**	0.11	0.12	0.39
	HEP	**2.70**	1.80	0.08	0.11	4.67	2.40	0.21	0.49	**6.14**	2.09	0.33	0.86	3.03	**1.83**	**0.09**	**0.10**	0.39
	TLG	6.33	1.94	0.08	0.12	5.05	2.52	0.21	0.50	5.38	2.20	0.31	0.83	3.27	1.56	0.11	0.12	0.39
Employment Density	2007	6.65	2.96	0.07	0.12	9.54	2.03	0.12	0.50	9.63	2.26	0.22	0.96	6.64	3.34	0.06	0.09	0.41
	2030	8.26	3.49	0.08	0.14	11.9	2.96	0.18	0.68	12.6	3.41	0.34	1.37	8.68	4.04	0.08	0.11	0.57
	BO	**4.51**	**2.97**	**0.12**	0.16	**6.70**	**3.44**	**0.30**	0.70	**9.54**	3.25	**0.46**	1.29	**4.71**	**2.89**	**0.12**	**0.13**	0.57
	HEP	**3.57**	**2.45**	**0.10**	0.14	**7.63**	**3.78**	**0.30**	0.74	**10.2**	3.49	**0.49**	1.38	**4.51**	**2.81**	**0.10**	0.12	0.59
	TLG	8.26	3.49	0.08	0.14	12.1	2.96	0.17	0.68	13.0	3.40	0.32	1.37	8.68	4.04	0.08	0.11	0.57
Job Housing Balance	2007	1.42	1.84	1.03	1.22	2.83	0.96	0.71	1.29	2.17	1.15	0.86	1.36	2.76	2.78	0.86	1.08	1.30
	2030	1.31	1.80	0.99	1.17	2.55	1.19	0.78	1.35	2.52	1.54	1.03	1.65	2.66	2.59	0.74	0.93	1.44
	BO	1.30	**1.32**	**1.26**	1.28	**1.50**	**1.45**	**1.32**	1.41	**1.63**	1.59	**1.41**	1.55	**1.41**	**1.53**	**1.06**	**1.11**	1.44
	HEP	1.32	**1.36**	**1.28**	1.29	**1.63**	**1.58**	**1.42**	1.53	**1.67**	1.67	**1.47**	1.60	**1.49**	**1.53**	**1.08**	**1.14**	1.52
	TLG	1.31	1.80	0.99	1.17	2.41	1.17	0.80	1.35	2.42	1.54	1.03	1.65	2.66	2.59	0.74	0.93	1.44

- U – Urban; S – Suburban; R – Rural; T – Total
- BO – Build Out; HEP – High Energy Price; TLG – Transit Located Growth

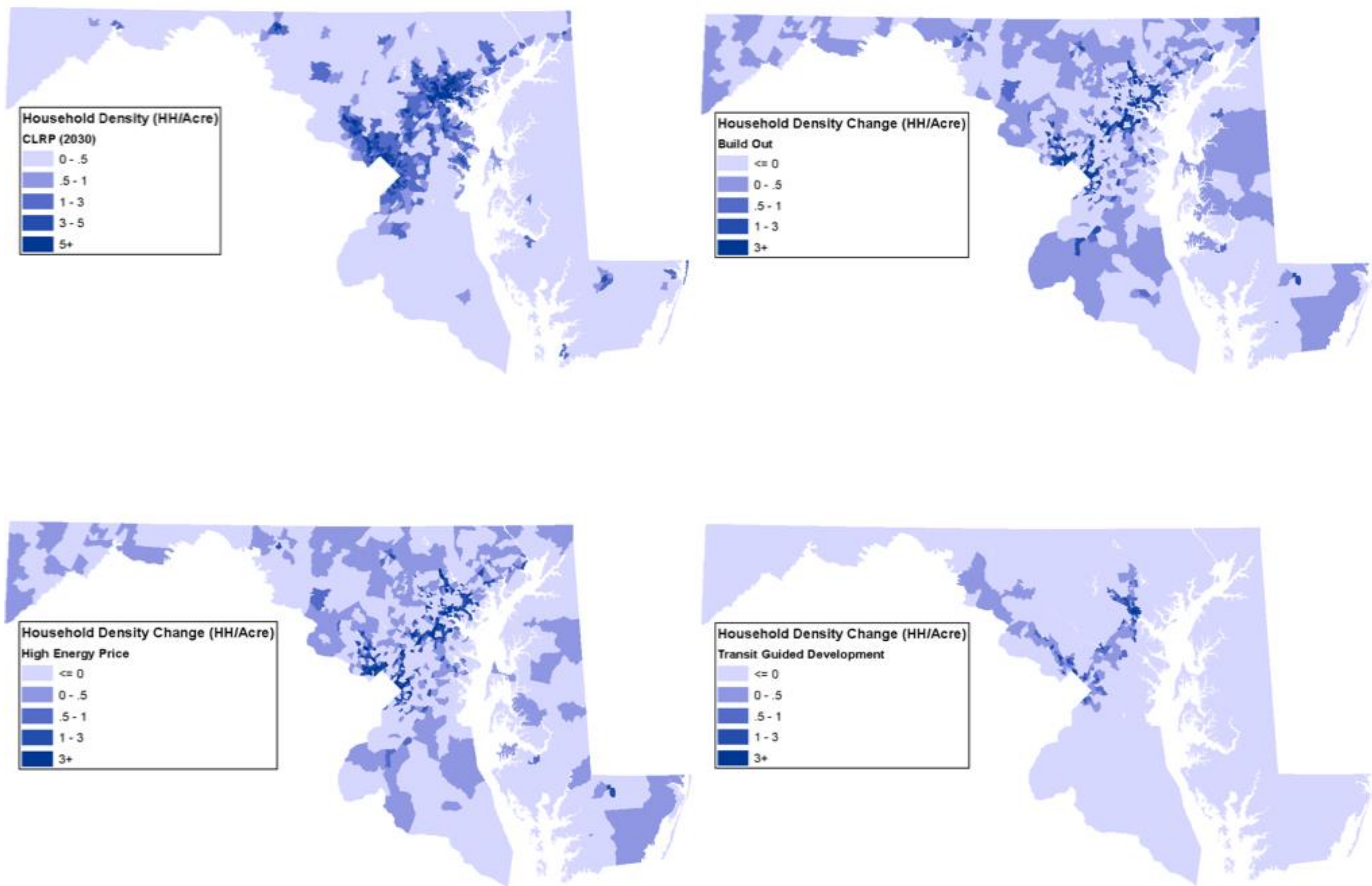

Figure 5a. Changes in household density (households/acre)

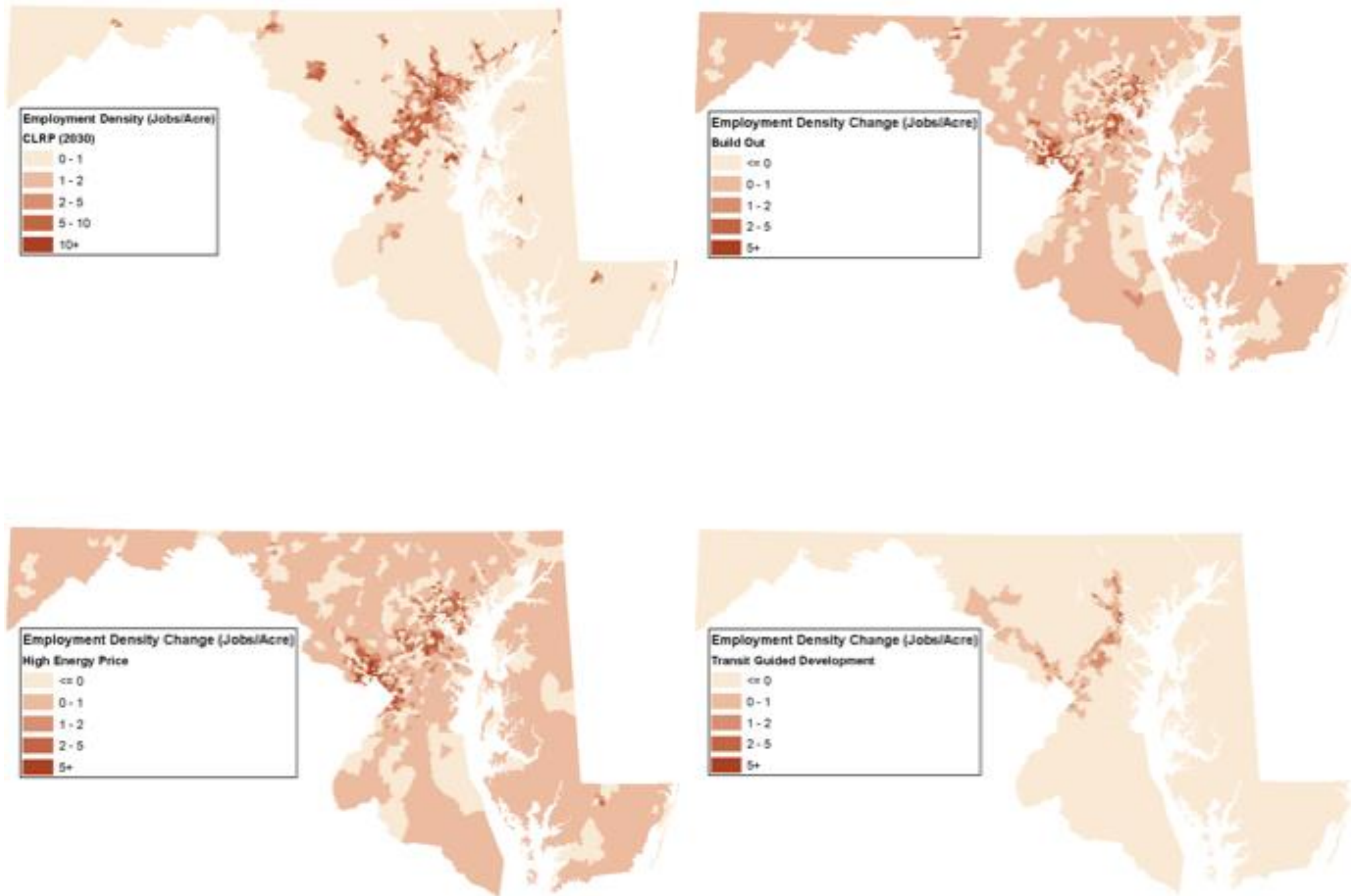

Figure 5b. Changes in employment density (jobs/acre)

2030 Constrained Long Range Plan (CLRP)

Local jurisdictions disaggregate county totals to the TAZ level based on local trends, plans and policies. These projections implement local policies to maximize growth inside UGBs. They are strongly policy-influenced and can be viewed as more normative than market-driven. The CLRP scenario incorporates all significant transportation projects and programs that are planned in the region between the base and future year. The CLRP scenario is fiscally constrained; projects are selected based on funding availability. This same set of future transportation projects is used for all the scenarios. The land use pattern of CLRP (figures 5a and 5b) shows all development in 2030, not just that of the growth increment, and clearly mirrors the current comprehensive plans and statewide PFA (Priority Funding Areas) maps.

Build Out (BO)

While CLRP allocates most growth to areas within UGBs and PFAs, the existing pattern of zoning does not necessarily mirror this allocation. Rural lands have significant household and employment capacity that is not used up in the CLRP allocation. In BO new development is allocated according to existing zoning until all vacant, buildable land is developed and then the total allocation is reduced across the board until it matches the 2030 control totals across all SMZs. The resultant land use pattern of BO, more evident in the tables than the maps, is mostly a job sprawl scenario. Household allocations are not much different in Rural areas than in CLRP. The real differences are in jobs. In terms of geographies, many more jobs go to Western and Eastern MD than in CLRP and HEP; in terms of areas, there are more jobs in Rural areas, many fewer in Urban areas than in CLRP and HEP and fewer in Suburban areas jobs (except in the Washington metro where there are more suburban jobs than CLRP). This pattern is reflected in dramatic reductions in jobs/housing (j/h) balance vs. CLRP.

High Energy Price (HEP priced)

The HEP scenario explores the effects of high energy prices on development patterns and travel behavior. This scenario derives population and employment from national forecasts of economic activity and these forecasts are then disaggregated to individual states, counties, and SMZs. Under the HEP scenario, travel costs, which include the cost of fuel and the non-gas related expenses are quadrupled. The land use pattern of HEP (see Figures 5 a and b) results in a more concentrated redistribution of activity than in BO, with population and employment centers closer together but also more decentralized into more Suburban and Rural locations. In terms of geographies, there are fewer households in western and eastern geographies than in CLRP and BO and fewer jobs in Western and Eastern MD than in BO but more than in CLRP (except for the Baltimore Metro). In terms of areas, there are fewer Rural households than CLRP and BO in all geographies. There are more Urban households in the Baltimore Metro than in BO and CLRP but fewer Urban households in Western and Eastern MD than in BO and CLRP. Job-wise, there are fewer jobs in Rural areas than in BO but more jobs in Urban areas than in BO, though fewer than in CLRP; there is also greater suburbanization of jobs in Washington and Baltimore metros than BO or CLRP; as with BO, there are dramatic reductions in j/h balance vs. CLRP BUT they are more co-located with households than in BO because of the travel penalties built into the land use outcomes.

In order to conduct some sensitivity analysis, two variants of HEP were added to the analysis: *CLRP Priced* keeps the travel cost constraint but substitutes CLRP land use for HEP land use; *HEP Unpriced* maintains HEP land use but without the quadrupled auto travel cost.

Transit Located Growth (TLG)

The TLG scenario explores the effects of development patterns on travel behavior, especially transit ridership. TLG aggressively (and without regard to feasibility or impacts other than travel-related) allocates more development to areas served by transit, specifically rail transit (Figure 6). A quarter of all future household and employment growth under CLRP is shifted to state-designated TOD station areas and then another quarter of growth is shifted to other transit areas. To offset the increased growth in transit areas, growth in the non-transit areas was reduced by a corresponding amount across the board. The land use maps for TLG reflects this very corridor-focused pattern (see Figures 5a and 5b).

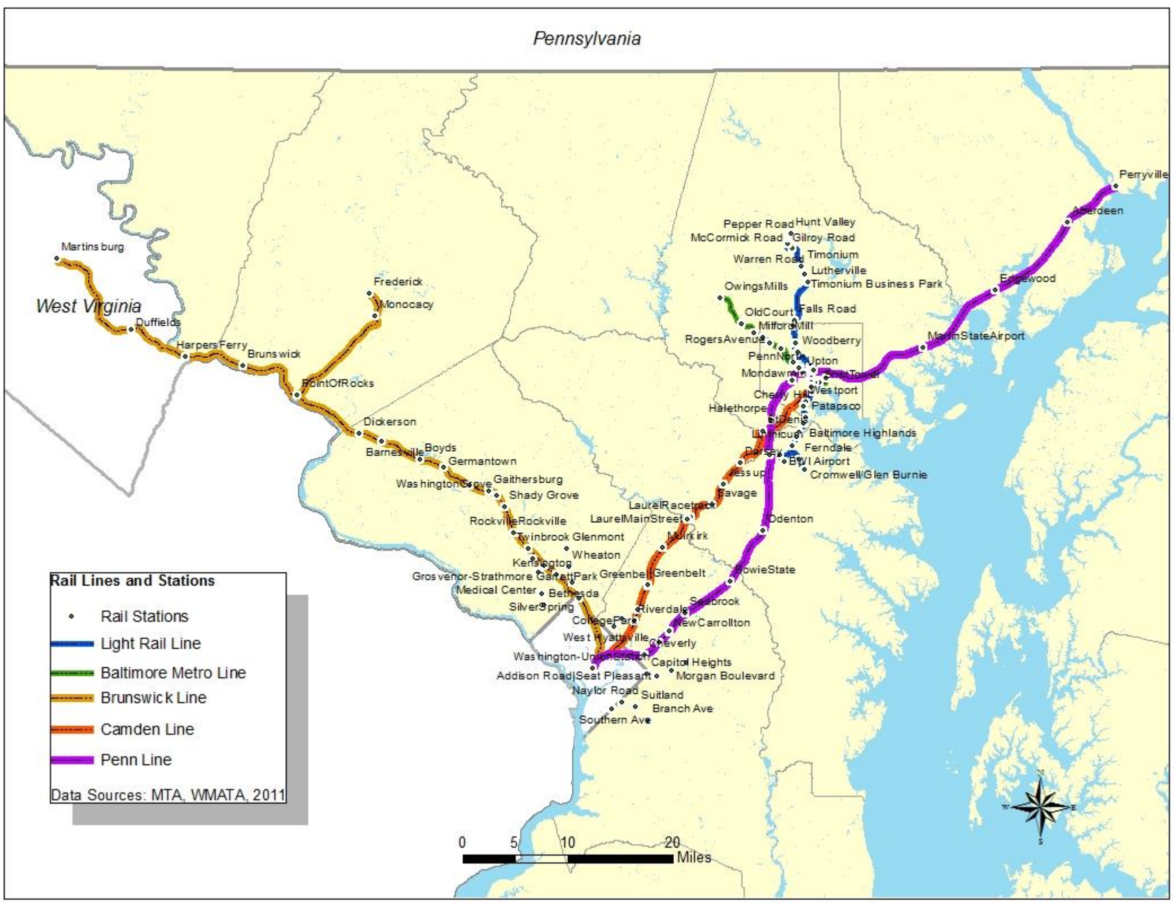

Figure 6. Rail system in Maryland

Results and Discussion

Table 3 presents the transportation results for the AM peak hour for VMT, vehicle hours of travel (VHT), vehicle hours of delay (VHD), congested lane miles (CLM) and travel time index (TTI) in absolute terms. Numbers greater than the CLRP 2030 reference case are shown in red bold and less than 15% in black bold.

Table 3. Empirical results of transportation indicators

Indicators	Land Use Scenario*	Western Maryland				Washington Metro				Baltimore Metro				Eastern Shore				State-wide
		U	S	R	T	U	S	R	T	U	S	R	T	U	S	R	T	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
VMT (millions)	2007	0.22	0.85	7.17	8.25	10.88	19.64	28.84	59.36	12.06	24.66	33.02	69.74	0.4	0.49	14.15	15.03	152.4
	2030	0.29	1.09	9.26	10.64	14.52	26.05	44.52	85.08	14.28	31.36	45.45	91.08	0.55	0.74	21.34	22.63	209.4
	BO	**0.39**	**1.31**	**11.1**	**12.81**	16.01	29.25	**53.87**	**99.13**	16.07	34.82	50.74	101.6	**0.63**	**0.91**	**24.96**	**26.5**	**240.1**
	HEP	**0.24**	**0.92**	8.01	9.16	**12.2**	**21.47**	**35.46**	**69.13**	12.61	27.53	**37.79**	**77.93**	0.49	**0.63**	**16.96**	**18.08**	**174.3**
	HEPb	**0.25**	**0.92**	**7.61**	**8.78**	**11.17**	**19.57**	**31.16**	**61.9**	**11.28**	**24.35**	**33.17**	**68.8**	0.48	**0.56**	**16.4**	**17.43**	**156.9**
	HEPc	0.26	1	8.93	10.19	14.55	25.74	43.77	84.06	14.53	31.57	44.83	90.93	0.52	0.72	19.58	20.82	206
	TLG	0.29	1.09	9.27	10.65	14.64	25.96	43.3	83.89	14.39	31.03	43.64	89.06	0.55	0.74	21.29	22.58	206.2
VHT (millions)	2007	0.01	0.03	0.17	0.21	0.47	0.83	1.03	2.32	0.59	0.87	0.99	2.45	0.06	0.02	0.43	0.51	5.49
	2030	0.02	0.04	0.22	0.28	0.79	1.52	2.11	4.42	0.67	1.3	1.66	3.63	0.1	0.04	0.75	0.9	9.22
	BO	0.02	**0.05**	**0.28**	**0.36**	**0.93**	**1.84**	**3.39**	**6.16**	**0.83**	**1.5**	**1.93**	**4.26**	0.1	0.06	1.11	1.28	12.06
	HEP	**0.01**	**0.03**	0.19	**0.23**	**0.56**	**0.85**	**1.26**	**2.66**	**0.57**	**0.96**	**1.15**	**2.68**	**0.06**	**0.03**	**0.56**	**0.65**	**6.22**
	HEPb	**0.01**	**0.03**	**0.18**	**0.22**	**0.51**	**0.96**	**1.01**	**2.48**	**0.49**	**0.85**	**1.01**	**2.36**	0.09	**0.03**	**0.53**	**0.65**	**5.71**
	HEPc	**0.01**	**0.03**	0.21	0.26	0.74	**1.21**	1.94	3.89	0.7	1.21	1.49	3.41	**0.07**	0.04	0.67	0.78	8.34
	TLG	0.02	0.04	0.22	0.28	0.84	1.6	1.99	4.43	0.68	1.34	1.63	3.65	0.11	0.04	0.75	0.91	9.28
VHD (thousands)	2007	0.27	0.32	1.52	2.12	13.51	17.64	25.6	56.75	30.96	29.36	32.52	92.84	0.59	0.36	7.44	8.39	160.1
	2030	0.41	0.37	1.67	2.45	13.43	21.23	33.87	68.52	29.04	31.09	38.16	98.29	0.76	0.36	9.28	10.4	179.7
	BO	0.43	0.39	1.72	2.55	14.2	22.98	37.01	74.18	29.32	32.82	39.99	102.1	0.84	**0.42**	9.71	10.97	189.8
	HEP	**0.34**	**0.31**	1.51	2.16	**10.72**	**15.31**	**23.96**	**49.98**	25.86	**25.09**	**29.25**	**80.2**	0.67	0.33	**7.65**	**8.65**	**141**
	HEPb	0.36	0.32	1.5	2.17	**10.17**	**14.91**	**22.56**	**47.65**	**24.81**	**22.95**	**27.27**	**75.03**	0.66	**0.3**	**7.64**	**8.6**	**133.4**
	HEPc	0.36	0.33	1.56	2.24	12.77	19.37	30.29	62.42	27.89	29.35	35.1	92.34	0.72	0.35	8.25	9.32	166.3
	TLG	0.39	0.35	1.57	2.31	12.7	20.23	31.6	64.53	27.64	29.37	34.85	91.86	0.75	0.35	8.76	9.86	168.6
CLM	2007	1.19	0.34	4.43	5.96	96.36	260.1	376.1	732.5	84.39	235.8	370.7	690.9	15.06	4.94	61.27	81.27	1511
	2030	2.37	9.1	13.31	24.78	165.9	392.9	865.9	1425	138.3	415.7	813.7	1368	17.49	10.03	266.9	294.4	3112
	BO	**6.34**	**11.6**	**34.62**	**52.57**	217.4	509.6	1186	1913	177.3	498.4	1063	1739	**26.47**	**15.94**	**363**	**405.4**	**4110**
	HEP	**1.25**	**1.56**	**11.62**	**14.43**	**97.13**	**218.7**	**370.1**	**685.9**	**88.05**	**264.3**	**400.6**	**752.9**	**21.1**	9.63	**169.9**	**200.6**	**1654**
	HEPb	**1.34**	**0.95**	**5.91**	**8.2**	**71.45**	**182.6**	**279.3**	**533.3**	**63.13**	**177.6**	**266.2**	**507**	17.21	**6.95**	**128.9**	**153.1**	**1202**
	HEPc	**1.4**	7.9	**18.93**	28.23	179.2	385.4	757.4	1322	138.8	405.7	770.7	1315	**22.1**	9.63	233.4	265.2	2931
	TLG	**3.09**	7.9	**16**	26.99	164.6	387.7	847.5	1400	137.1	401.9	715.4	1254	17.52	12.13	279.3	309	2990
TTI	2007	0.46	0.39	0.21	0.23	0.61	0.66	0.54	0.59	0.52	0.6	0.56	0.57	0.78	0.42	0.36	0.38	0.54
	2030	0.57	0.54	0.28	0.31	0.7	0.76	0.67	0.71	0.59	0.7	0.65	0.66	0.95	0.6	0.52	0.54	0.65
	BO	**0.68**	0.61	0.32	**0.36**	0.76	0.81	0.75	0.77	0.64	0.73	0.7	0.7	1	**0.71**	0.59	0.6	0.7
	HEP	**0.48**	**0.46**	0.24	0.27	**0.6**	**0.64**	**0.55**	**0.58**	0.54	0.61	**0.55**	0.57	0.88	0.56	0.46	0.47	**0.55**
	HEPb	0.5	**0.44**	**0.23**	**0.26**	**0.56**	**0.61**	**0.51**	**0.55**	**0.47**	**0.55**	**0.49**	**0.51**	0.9	**0.5**	**0.44**	**0.46**	**0.5**
	HEPc	0.53	0.51	0.27	0.3	0.71	0.74	0.65	0.69	0.61	0.69	0.64	0.65	0.9	0.6	0.5	0.51	0.64
	TLG	0.57	0.53	0.28	0.31	0.71	0.76	0.67	0.71	0.6	0.7	0.64	0.66	0.98	0.61	0.53	0.54	0.65

♣ U – Urban; S – Suburban; R – Rural; T – Total

* BO – Build Out; HEP – High Energy Price; HEPb – High Energy Price, unpriced; HEPc – High Energy Price, priced; HEPTLG – Transit Located Growth

Table 4 provides the environmental indicators in absolute and percentage terms, which consists of emissions of NOx, VOc, and CO2. Though many factors affect vehicle emissions estimated in the model including the county (which changes meteorology and fuel formulation), vehicle and road type and speed, the level of pollutants emitted from a vehicle is directly proportional to VMT. It is also significantly affected by congestion, which exacerbates emissions, though our analysis does not explicitly report emissions caused by congestion effects, it is implicit in the modeling framework as it accounts for differences in emissions at varying travel speeds. VMT is nonetheless the predominate driver of emissions. Thus, the changes of those emission indicators across scenarios are very consistent with the VMT changes.

1

Table 4. Empirical results of environmental indicators

Indicators	Land Use Scenario*	Western Maryland				Washington Metro				Baltimore Metro				Eastern Shore				State-wide
		U*	S	R	T	U	S	R	T	U	S	R	T	U	S	R	T	
Nox (in tons)	2007	0.4	2	16.6	19	29.4	46.4	54.3	130.1	34.8	52.7	68.6	156.1	0.6	0.8	22.1	23.5	329
	2030	0.5	2.6	21	24.1	37.2	59.5	79.7	176.3	40.9	63.2	91.3	195.4	0.8	1.1	30.7	32.5	428
	BO	0.7	2.9	23.5	27.1	40.5	65.9	93.7	200.1	46.3	69.6	99.9	215.7	0.9	1.3	34.9	37.2	480
	HEP	0.4	2.1	18.8	21.3	31.5	49.2	64.1	144.8	36.9	56.7	76.3	169.9	0.7	0.9	25.8	27.5	363
	HEPb	0.4	2.1	18	20.5	29.1	45.3	57.6	131.9	32.5	49.8	67.2	149.5	0.7	0.8	24.7	26.2	328
	HEPc	0.5	2.3	20.3	23.1	37.3	58.6	78.2	174.1	42.3	64.2	89.8	196.3	0.8	1	29	30.8	424
	TLG	0.5	2.5	21.1	24.1	37.3	59.3	78	174.6	41.5	62.7	88.7	192.8	0.8	1.1	30.6	32.4	424
VOC (in tons)	2007	0.1	0.3	2.2	2.6	4.7	7.2	8.9	20.8	5.8	8.3	10.1	24.2	0.2	0.2	4	4	52
	2030	0.1	0.4	2.6	3.1	5.8	8.8	12.3	26.9	6.4	9.5	12.3	28.5	0.2	0.2	5.4	5.8	64
	BO	0.2	0.4	3	3.6	6.3	9.7	14.8	30.9	7.2	10.4	14	31.6	0.2	0.3	6.2	6.7	73
	HEP	0.1	0.3	2.3	2.7	4.9	7.2	9.9	22	5.7	8.4	10.7	24.8	0.2	0.2	4.4	4.8	54
	HEPb	0.1	0.3	2.2	2.7	4.6	6.8	9	20.3	5.2	7.6	9.5	22.3	0.2	0.2	4.3	4.6	50
	HEPc	0.1	0.3	2.5	3	5.8	8.6	12.1	26.4	6.6	9.5	12.5	28.5	0.2	0.2	5	5.4	63
	TLG	0.1	0.4	2.6	3.1	5.8	8.8	12	26.6	6.5	9.4	12.2	28	0.2	0.2	5.4	5.8	63
Co2 (in tons)	2007	112	548	4494	5154	7505	12292	15118	34916	8807	14226	18248	41281	201	242	6611	7053	88403
	2030	145	657	5419	6221	9119	14917	20974	45010	9808	16256	22929	48993	237	309	8705	9252	1094766
	BO	193	748	6074	7016	9914	16408	24776	51098	11030	17842	25145	54016	274	372	9909	10555	122685
	HEP	120	561	4877	5558	7762	12374	17061	37198	8825	14523	19402	42750	217	264	7269	7749	93255
	HEPb	123	559	4701	5383	7237	11565	15473	34276	7907	12988	17307	38203	209	237	7014	7460	85322
	HEPc	131	610	5258	5999	9106	14578	20583	44267	10065	16402	22608	49075	231	297	8162	8690	108032
	TLG	145	656	5428	6230	9177	14928	20512	44617	9917	16125	22212	48255	238	309	8682	9229	108330

Overall Findings

The priced scenarios display large differences in outcomes compared to the baseline and unpriced scenarios. The unpriced scenarios show much smaller differences when compared to the baseline scenario and each other. This is generally consistent with prior research and expectations. However, some scenario-specific findings are unexpected and suggestive.

In the two scenarios that quadruple auto travel costs, the reductions in transportation and emission indicators are significant compared to the baseline statewide. These reductions range between -15% and -61% and apply to almost all the transportation indicators, geographies and subareas. We see, for example, reductions statewide of 25% for statewide VMT and 38% for VHT. Interestingly and importantly, it seems to be the travel costs are the major reason for these reductions while the impact of land use shifts are not as pronounced. The CLRP priced scenario (HEP?) slightly outperforms the HEP priced scenario (HEPc) by between 4% and 14% on most transportation and emissions indicators.

When we remove the cost-influenced scenarios from consideration, the differences between the remaining scenarios shrink dramatically. The land use only scenarios (BO, HEP unpriced (HEPb) and TLG) show less significant impacts on VMT and related measures compared to the baseline scenario. The only scenario that shows changes approaching or exceeding 15% above the baseline is the Buildout Scenario (BO). This is true statewide (+14.6% in VMT for example), for the Washington Metro area and the two rural bookends of the state. For VHT, the difference is more striking with BO at 31% more than the baseline. These results can be explained by the heavy re-allocation of new employment growth in the BO scenario out of the urban areas and into the rural areas, where allowed by zoning, and the consequent reorientation and lengthening of trips from housing that was much more modestly reallocated to suburban and rural areas. These new trips are mostly made on roads with less capacity, ones that were not originally designed for such diffuse development, and consequently result in a very large increase in congestion. Because this reallocation occurs without any expansion in transportation capacity beyond those in the base case CLRP or any efforts to better coordinate decentralizing jobs and housing, as in the HEP scenarios, the quality of transportation suffers.

The significant land use shifts from the baseline CLRP in the other scenarios do not move any any indicators more than 10% statewide or more than 14% for any geography. In both the Western and Eastern geographies there are much larger swings. The one exception is the Washington Metro where VHT in HEP unpriced is 12% less than in CLRP (and 6% less than TLG). In HEP unpriced in this metro region, the j/h balance is much improved in suburban and rural areas compared to CLRP, but without the congestion that accompanied the BO scenario.

This overall similarity in outcomes is unexpected and sobering. We believe there are two related explanations for these findings:

(1) So much of the development and transportation patterns are already well established in the state that adding another 24% in households and 38% in jobs and dispersing them widely, while maintaining travel facilities and travel costs constant, should not be expected to change travel outcomes much. Perhaps a 40 year time horizon rather than our 23 year one, which could massage more growth, would better differentiate these scenario outcomes.

(2) While the locational shifts made in the scenarios are significant, in this longtime, growth-managed state with UGBs in place in so many central counties, the land use shifts represented in the 3 scenarios under discussion, while significant, are still minor tweaks in the scheme of things and thus yield only minor differences.

This said, however, the minor differences are not in the expected direction and call into question some accepted assumptions about smart growth interventions.

The further decentralization of many jobs and some households outside currently designated growth areas in the HEP unpriced scenario marginally *improves* all travel outcomes compared to the smart growth land use patterns of CLRP. "Marginally" in this instance means reductions in all the transportation related indicators of between 1% and 7%. This more decentralized balancing of jobs and housing statewide produces slightly better transportation benefits for all geographies and for all subareas, except in Western Maryland where land use patterns are already more concentrated and the road network may have less absorptive capacity than in the more spread out Eastern shore. These benefits are most pronounced in the Washington Metro area, particularly in its suburban and rural portions, which are relatively well served by an existing, underutilized road network. This is most clearly reflected in the lowest congested lane miles of the three scenarios under consideration here (6.5% less than CLRP in the Washington Metro area, for example).

The TLG scenario, which concentrates half of all future growth around transit served areas, might be expected to perform better than the official projections (CLRP) and the decentralized j/h balance of HEP unpriced. TLG, however, does only a little better than CLRP while HEP unpriced does a little better than TLG, but these differences are typically small (See Figure 7). The reasons for TLG results are not significantly different than CLRP are as follows: (1) with the TLG scenario, the changes in household and employment densities are made only in the Baltimore/Washington area, Eastern Shore and Western Maryland do not receive any movement, thus the changes in transportation and emissions indicators are not as pronounced, (2) in the TLG scenario, only half of the growth is relocated to rail transit served areas, the other half of the growth and the base case does not change leading to only an incremental improvement over baseline CLRP, (3) for activities that are moved to rail transit served areas, auto travel is still and option, however, the travel distances are reduced thus the modest improvements in transportation and emissions indicators are observed. (4) In the TLG scenario there is no change to transit service, i.e. no service extension or improvement. However, in another study done by the NCSG for the Maryland Department of Transportation (*27*), the same land use change was accompanied by a doubling of service frequency and a halving of fares. These significant interventions increased rail transit trips from 13% in the only TLG compared to CLRP baseline to 35% in the TLG with transit improvements. While this previous study results also found that TLG does not result in significant increases in transit use, it presented the impacts one would expect from a transit oriented development policy given limited parameters of the scenario analysis. For example, the TLG scenario reduces total number of vehicle trips in the region by 5.97% from CLRP. This reduction results from increased use of transit due to the increased accessibility. The TLG scenario also reduces average trip length in the designated areas. Reduced average trip distances may also have encouraged some trips to shift to non-motorized modes for which our model is not sensitive to. Under this scenario, transit share increases for all income groups and purposes. The increase is higher for rail transit. This maybe because the TLG scenario is designated around rail stations.

Moreover, TLG reduces both SOV and HOV trips but the reduction is not very significant (up to 3%). The decline in SOV is greater than HOV and the greatest reduction is observed for work trips.

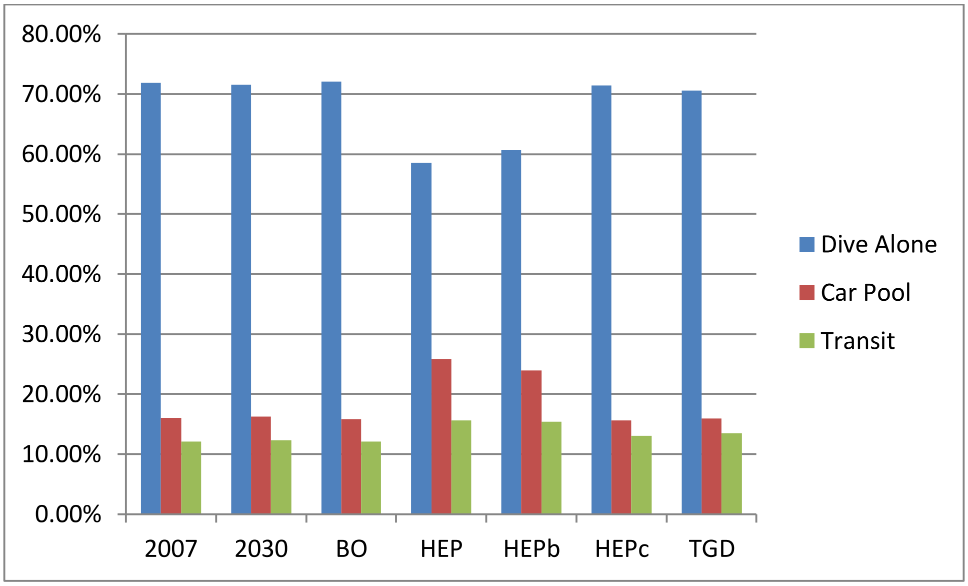

Figure 7. Statewide transit mode shifts by scenario

In this work study, while more drive-alone work trips are siphoned off by transit opportunities in this scenario, these only increase peak hour transit usage 1.3% (from 12.2% in CLRP to 13.5% in TLG). This is less than half the increase in HEP priced transit usage of 3.4% which was not directed at transit enhancements but at live-work proximity. The effect of new growth around all transit stations may be to lengthen other non-transit commute and other trips, which make up the great majority of trip-making. It is also the case that some transit stations are more far flung and less central to population and job centers than others (e.g. MARC station locations and some of the existing and proposed light rail stations). HEP priced is also the only scenario that significantly increases carpooling, which goes from 16.1% in CLRP to 25.8% in HEP priced.

The scenario implications for the more rural, low density geographies are worth pondering. So too are the differences between the urban metros, since the Washington Metro region has many more and more dispersed urban employment centers and corridors than the more monocentric Baltimore Metro. We also want to tease out suggestive findings at the U, S, and R subarea level by scenario.

Rural geographies and subareas

Western Maryland and the Eastern Shore have very different development patterns. The mountainous, wooded terrain and sparse transportation networks of Western MD have helped produce a town and village settlement pattern and much less rural housing and job spread than the level, agrarian Eastern Shore, as reflected in Table 2. This pre-existing pattern affects the reallocation of households and jobs from their distribution in the 2007 and the baseline CLRP of 2030, which are fairly similar to each other proportionately.

Both the BO and HEP move relatively large numbers of jobs out of urban and suburban areas and into rural areas (see Table 1); this is not the case in the two Metro areas which move jobs out of urban areas and into both the suburban and the rural areas. The BO scenario, driven by available zoning capacities, moves many more jobs into rural areas than the HEP one, which is more sensitive to travel costs (See Table 1). On the household front, Western Maryland moves a significant number of households out of Urban areas in both scenarios but this is much less pronounced on the Eastern shore where housing is already spread out. It would seem that both the zoning and the travel shortening influences drive similar allocation outcomes except that the travel shortening effect on household relocation of HEP is much more pronounced in both rural geographies than of BO. HEP moves fewer jobs but more housing into rural areas than BO as it tries to better balance the two (see Table 2 showing the j/h balance shifts). Both scenarios have a much better j/h balance than the 2007 and 2030 CLRP land use outcomes. For VMT, HEP unpriced shows larger increases across the region (4-8%) in the rural regions while having virtually no impact on VMT the two metropolitan regions. The effect is similar in pattern, but different in magnitude for the other transportation indicators.

What is the effect of all these shifts on transportation indicators? BO, with its greater job and housing sprawl, fares much worse on all transport indicators than CLRP, especially in congested lane miles, the highest single shift (+112%) in all the indicators calculated. HEP is much better on all indicators, as expected, and CLRP unpriced performs even better than the HEP priced land use, as noted in our general discussion earlier. But HEP unpriced still fares much better than the officially endorsed CLRP pattern. The greater job decentralization patterns clearly help a lot. This set of outcomes is considerably more pronounced in the more spread- out Eastern Shore, where HEP land use tightens housing reallocations more than in Western Maryland.

<u>Metro geographies and subareas</u>

A different set of land use shifts is at work in and between the two Metro geographies that account for so much of the state's transportation and GHG outcomes. In the currently more urban Baltimore region, the BO and HEP scenarios move more households into Urban areas than in CLRP and these being taken mostly out of Suburban areas (the least so in TLG). The converse holds for jobs which are moved out of Urban areas and into Rural areas, except for TLG, which mirrors the CLRP allocations (See table 1). In the less urban Washington Metro, in the BO and HEP scenarios, there is little household shifting but much more pronounced job shifting out of Urban areas and into Suburban and, even more strongly, Rural areas. TLG, by contrast, mirrors the official CLRP job allocation with their stronger Urban and weaker Suburban emphases.

As noted earlier, these shifts seem to benefit the Washington Metro somewhat more than the Baltimore region; in the Washington region the difference between BO and HEP outcomes are very large for all transportation indicators, more so than in the Baltimore region. As elsewhere, the sensitivity testing of CLRP priced performs better than the HEP land use. HEP unpriced performs on a par with CLRP. TLG outcomes are better than HEP unpriced for VMT and Congested Lane Miles (the presumed effects of some mode shifts), but not on VHT or VHD. HEP unpriced in the Washington Metro does just over 5% better on CLM than TLG, perhaps a function of its greater redistribution of jobs into its rural areas where the existing road network is able to absorb this traffic. These results are reversed in the Baltimore Metro, where CLM performance is worse under HEP unpriced than under TLG by over 4%, perhaps due to the stronger mode shift benefits of transit oriented urban jobs in this more urban region.

Conclusions

This study confirms findings from others that, at the metropolitan scale and beyond, changes in land use variables alone will have a small effect on travel behavior and emissions. Table 5 samples the findings of several such prominent studies. Even *Growing Cooler*, with its very aggressive land use and assumptions and a 43- year timeframe, is only able to generate VMT reductions of 3.5% to 5%. On the other hand, we found, as do others, that pricing interventions have a major effect on travel behavior. In our case, we quadrupled the cost of auto travel and found reductions in travel indicators like VMT, VHT and VHD in the 13% to 30% range and CO2 emissions reductions almost as high. Reductions in Congested Lane Miles were even higher, exceeding 60%. While the land use outcomes from our unpriced scenarios display relatively small differences among themselves, these differences are instructive for what they tell about the importance of shifts in employment location and in their relation to housing accessibility. Because our baseline trend case is a smart growth one, rather than the typical sprawl one, our findings also shed light on growth management policies.

Table 5. LU/VMT relationships from other similar studies (imply urban on-road GHG reductions)

Study	Key features of Studies	Findings
NCSG (2013) Maryland model Reduction from 2030 baseline	From land use alone in year 23 From land use plus severe pricing	-17-24% w/pricing -1-3% wo/pricing
Rodier (2009) International modeling literature review	From land use alone in year 20 From different forms of pricing alone From land use plus pricing	- 0-3% - 1-17% - 14-22%
Echenique (2012) Metro London, greater Cambridge and a more rural subregion,	3 case studies modeling compaction, **dispersion** and **expansion** vs. Trend, in year 20 or 34 yrs; very growth managed	- 5% for compaction + 5% for dispersion Elasticity: 0.10
Bartholomew and Ewing (2009); Review of 63 studies Reduction from trend	Density increases and VMT reductions over diff. timeframes in diff. contexts	Av.: - 7.6% Elasticity: 0.075
ULI/CS "Growing Cooler" (2009)	Land use compaction changes very aggressive; results in year 43 year	- 3.5-5%
TRB (2009) "Driving and the Built Environment"	Doubling residential density across a metropolitan area	- 5-12% Elasticity: 0.05-0.12
PROPOLIS (2004)Seven European regions tested via 3 different integrated tr/lu models	Individual and packaged policies tested; land use policies included residential core densification; auto pricing and transit packages combined did best	-15%-20% CO2 for combined maximum package; land use effect minimal

Transit supportive land use that allocated half of future household and employment growth to rail station areas yielded very small ridership benefits. The effects of these transit supportive land use shifts on auto travel outcomes, moreover, were mildly positive but considerably less so than those of other scenarios.

Very significant job sprawl (our BO scenario) without concomitant housing decentralization causes major deterioration in transportation and emission s performance. To the degree that such low density job sprawl is likely, beyond service and retail functions but also for office land uses, as suggested in Lang's *Edgeless Cities (26)*, this is a problematic pattern from a transportation perspective. Counties or regions that long and zone for job growth without concomitant, proximate housing growth will thus likely see deterioration in both mobility and accessibility. Conversely, counties, regions and small states that encourage the colocation of employment and residences, even if in a more dispersed pattern, outside of existing denser, compact areas, may see no deterioration in travel outcomes and even some small benefits. This was true in our study in all performance measures and in almost all geographies and in most areas. This pattern performed slightly better than the current smart growth trajectory, showing reductions ranging from about 1% (on VMT in the Baltimore region) to about 12% (Washington region VHT).

Our findings resonate with those of Echenique et al (2012) whose geographies and land use scenarios have similarities with ours as do the longstanding, very stringent British land use policies of containment.

The variation in our outcomes from the job shifts in the various geographies and areas support the notion that growth management policies should not be a one-size-fits all prescription, a conclusion echoed in the exhaustive PROPOLIS study of sustainability in 7 European metros. The location of residential development, where there is generalized demand and limited supply, is easier to influence via planning and zoning decisions than employment decisions. The latter depend on a more complex set of market factors that are less susceptible to local or regional planning and zoning decisions. Most scenario-driven regional plans gain their VMT and other indicator reductions from planners and the public visioning desired futures and moving households and jobs around accordingly, typically without the benefits of either market studies to support their plausibility or fiscal impact analyses to support their political viability. In addition, there is rarely an effort to estimate the effect of such movements on the cost of housing, which could be substantially increased. Such regional plans also tend towards a proliferation of mixed use centers in the expectation that their presumed regional multi-modal traffic benefits will offset increases in local congestion (Levine 2013) but such designations are also typically made without the benefit of market feasibility. Given the centrality of employment locations to transportation benefits and their complex relationships to grain, colocation and scale, this aspect of regional and statewide growth management warrants much more scrutiny, as our sobering findings suggest.

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