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The role of VMT reduction in meeting climate change policy goals

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ABSTRACT

This article evaluates the case for vehicle miles traveled (VMT) reduction as a core policy goal for reducing greenhouse gases (GHGs), concluding the economic impacts and social consequences would be too severe given the modest potential environmental benefits. Attempts to reduce VMT typically rely on very blunt policy instruments, such as increasing urban densities, and run the risk of reducing mobility, reducing access to jobs, and narrowing the range of housing choice. VMT reduction, in fact, is an inherently blunt policy instrument because it relies almost exclusively on changing human behavior and settlement patterns to increase transit use and reduce automobile travel rather than directly target GHGs. It also uses long-term strategies with highly uncertain effects on GHGs based on current research. Not surprisingly, VMT reduction strategies often rank among the most costly and least efficient options. In contrast, less intrusive policy approaches such as improved fuel efficiency and traffic signal optimization are more likely to directly reduce GHGs than behavioral approaches such as increasing urban densities to promote higher public transit usage. As a general principle, policymakers should begin addressing policy concerns using the least intrusive and costly approaches first. Climate change policy should focus on directly targeting greenhouse gas emissions (e.g., through a carbon tax) rather than using the blunt instrument of VMT reduction to preserve the economic and social benefits of mobility in modern, service-based economies. Targeted responses are also more cost effective, implying that the social welfare costs of climate change policy will be smaller than using broad-brushed approaches that directly attempt to influence living patterns and travel behavior.

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1. Introduction

Climate change has been pushed to the forefront of public policy consideration, and legitimate questions about the appropriate responses have become central to international discussions. Transportation policy is important in these discussions since current technology relies heavily on oil as a source of energy. Not surprisingly, some have recently proposed policies that explicitly discourage vehicle travel in order to reduce oil consumption and thus limit greenhouse gas (GHG) emissions (particularly carbon dioxide). We believe this strategy is counterproductive on practical grounds.

Urban economists have long recognized the importance of reducing generalized transportation costs as a means of increasing productivity and enhancing human welfare. The goal of reducing transportation costs is a core principle underlying fundamental theories explaining why cities exist, the size and scope of market areas, firm clustering, density gradients, and bid rent in mainstream urban economics texts (O'Sullivan, 2009, pp. 22–30, 45–53; McDonald, 1997, pp. 168–169; Blair, 1995). Indeed, this is one reason economists consider traffic congestion an external cost (O'Sullivan, 2009, pp. 254–266; McDonald, 1997, pp. 168–194). Recent research has also found a statistically significant empirical link between higher travel

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speeds, increased productivity and higher income (Broersma and van Dijik, 2007; Cervero, 2001; Graham, 2007; Hartgen and Fields, 2009; Pozdena, 2009; Prud'homme and Lee, 1999; Prud'homme, 2000). Rising traffic congestion (and its associated longer travel times and higher transportation costs) is an external cost that offset the productivity benefits of agglomeration economies that make cities wealth generators and growth centers for national economies. We believe this research highlights the importance of mobility, the ability to move from point to point more quickly and easily, to urban development (and by extension national economic growth and productivity).

Public policies that curtail vehicle travel will often lengthen travel times (and thus increase generalized transportation costs) and imply a non-pareto optimal shift in travel consumption that reduces human welfare, income, and the ability of societies to address environmental problems and other externalities. Public policy would enhance both effectiveness and welfare if it focused on incentives, transparent marginal-cost pricing for travel, and direct internalization of externalities. While these strategies might have the effect of lowering vehicle miles traveled (VMT), this outcome is not an explicit goal and would be the result of consumers voluntarily readjusting their preferences in a more transparent market place.

The next section frames what we believe is the core policy question in the context of the current debate over transportation and climate change. The third section examines in depth the tradeoffs involved with some key policies proposed for reducing transportation GHG emissions. The final section sets forth how we think policies should proceed.

2. Climate change, greenhouse gases and transportation

We accept that the earth is warming, CO_2 is the major component to greenhouse gases, and anthropogenic sources are a significant concern. But determining which policy responses are most appropriate and necessary is far from settled. In fact, this discussion is just beginning. We will return to this question, which is central to our position on VMT reduction as a policy goal, in subsequent sections of this article.

Given the potential of many climate change policy proposals to reduce freedom and wealth, any policy discussion must also recognize the inherent uncertainties surrounding climate science and the implications for social welfare. Here, we make four observations that inform our policy framework.

First, climate models are extraordinarily imprecise, because they attempt to extrapolate from a century (or less) of detailed data phenomena that take centuries and millennia to unfold (Idso and Singer, 2009, pp. 9–22; Wielicki et al., 2002). Moreover, the primary drivers of climate change are not particularly well understood and modeling the effects of clouds, precipitation, light, and other factors is difficult at best with high levels of uncertainty. Thus, the apparent policy goal of attempting to achieve an 80% reduction in carbon dioxide emissions by 2050 is at best a rule of thumb, not an objective conclusion grounded in hard scientific evidence.

For example, many climate change policy proposals are based on climate models that tie rapidly-growing concentrations of CO_2 in the atmosphere to rapidly rising temperatures (IPCC, 2007, pp. 2–4). These links are extrapolated through climate models that predict with "virtual certainty" continued temperature increases, weather variability, and other environmental impacts in the 21st century (IPCC, 2007, Table SPM-2, p. 9). Indeed, the controversy over the so-called "hockey stick" graph (see Mann, Bradley and Hughes, 1998) showing a dramatic rise in temperatures since 1910 is also cited as corroborating evidence for the role of carbon dioxide (IPCC, 2007; see also the critique of the hockey stick in McIntyre and McKittrick, 2003). Yet, the earth has not experienced statistically significant warming for more than a decade, and global temperatures appear to have declined. In testimony before the US Congress, climatologist John Christy (2009) reported actual temperature changes had fallen during the first decade of the 21st century, contrary to predictions from mainstream simulations of climate change (see also the review in Idso and Singer (2009), pp. 63–134).

Even if global warming is progressing as many climate scientists predict, this brief respite may well provide the breathing room necessary to develop more effective technological solutions to the challenges presented by rising temperatures in the future. Ten years in the context of global temperature changes is small, but can be quite dramatic in the context of recent human history. The variance and imprecision of current climate models strongly suggests that draconian policy proposals that severely limit transportation, land use, and housing choices may not be necessary or even the most appropriate. A decade in the course of human history allows for a reasonably wide window for innovation and technical progress through less intrusive policies and organic market forces. For example, automobiles fully powered by electricity generated by nuclear power plants is feasible within a twenty or 40-year window for most high-income nations as the price of gasoline increases and technology advances. France generated 76% of its electrical power from nuclear sources in 2008 according to the World Nuclear Association (an international trade association for the nuclear industry). Some rapidly growing emerging nations have more potential to use this technology. China for example, has 11 nuclear reactors in operation, 18 under construction, and 90 planned, according to the NWA.

Second, controlling emissions in one country may have little impact on the larger goal of limiting global GHGs. The US, for example, accounted for 20.3% of global *man-made* carbon emissions in 2006, and is projected to contribute 18.7% in 2010 (DOE, 2009, Table A10). Burning US gas and diesel fuel accounts for about 8.9% of world wide man-made carbon emissions in 2006 and 7.7% in 2010 (DOE, 2009, Tables A10 and A11). On a per capita basis, increasing energy efficiency has slowed the growth of carbon dioxide emissions in the US, which have even fallen since 2006 (DOE, 2006, Table H.1cco2; Staley and Moore, 2008, p. 200). But, while the US and Europe remain the largest overall emitters of GHGs, the real pressure on future emissions will come from growing countries such as India, China, Brazil and even continents such as Africa, as they become

wealthier and consume more. The US Energy Information Agency reports that China exceeded the US in overall carbon emissions in 2006 (DOE, 2009). Moreover, China alone, with more than 1.3 billion people, is on track to produce 29% of the world's anthropogenic carbon emissions and 14.5% of worldwide carbon emissions from liquid fuels by 2030 (DOE, 2009, Tables A10 and A11).

Thus, regardless of what the US accomplishes, even joined by wealthy nations within Western Europe, future global emissions will be determined largely by other nations. Policies that reduce productivity, such as reducing mobility by reducing VMT, will do little more than reduce our economic competitiveness while failing to achieve broader environmental goals. Moreover, wealth-reducing strategies likely compromise our ability to address environmental concerns because higher wealth implies greater capacity to mitigate the environmental consequences of human activity (summarized in Kahn, 2006).

Third, too many of the policy proposals addressing transportation sector GHG emissions are sweeping, draconian changes that severely limit housing choice, transportation options and, in our view, substantially reduce economic productivity, competitiveness, and the wealth creation necessary to meet environment protection and mitigation goals. For example, the US Department of Transportation has combined with the US Environmental Protection Agency and the US Department of Housing and Urban Development under a Livable Communities initiative with the explicit goal of promoting higher housing densities and transit ridership. Achieving goals of significantly increasing transit ridership would require a significant reordering of the urban landscape in the US. Commuting data, for example, shows that transit market shares do not rise above 10% until census tract densities reach 10,000 people per square mile (Pisarski, 2006, figure 3-61), about four times the density of the average American suburb (Balaker and Staley, 2006, pp. 46–47). The more rigorous development controls implied in land-use planning that direct housing into higher densities tends to reduce the supply of housing, placing further upward pressure on housing prices (Green and Malpezzi, 2003, pp. 146–151). Thus, higher housing densities also often imply higher housing costs (measured per square foot).

Importantly, we believe that even though the US cannot alone have substantial directly impact GHG build-up, the moral, ethical and economic value of reducing CO_2 remains. We believe CO_2 emissions from man-made activities is an externality. As such it represents a social cost that should be internalized, primarily through pricing and incentive-based strategies, to ensure efficient social and economic outcomes are achieved. This is the core of our policy approach to climate change in the transport sector.

3. Transportation, VMT reduction and climate change

There are many paths by which to approach reducing the GHG emissions from transportation. In the policy and research community, serious discussion and debate over the potential costs and benefits, tradeoffs, unintended consequences, and other aspects of these paths has only just begun. Unfortunately policies are promoted without the benefit of a thorough examination of the tradeoffs implied in these approaches. Again, the public transit/automobile trade off may rank among the most prominent. Advocates of public transit emphasize the out of pocket costs, which are subsidized, but typically omit that public transit commuting trip times can be double those for automobile users (Pisarski, 2006, pp. 109–110). Similarly, costs and lifestyle impacts of the quadrupling of density necessary to achieve the increase in public transit market shares are not calculated. Thus, we believe too many people are quick to leap to conclusions that some particular policy is the silver bullet to reduce GHG emissions from transportation, when in fact these policies imply significant social, economic, and cultural tradeoffs.

In the short and intermediate term, reducing VMT would increase generalized transportation costs and negatively impact economic productivity. Many urban regions in the US, Australia, and Europe, for example, have adapted to the availability and widespread use of the automobile. Dramatic shifts to non-automobile transportation modes would imply significant shifts in urban land-use patterns to much higher-density living and toward the use of mass transit. Both of these shifts imply increases in housing costs (likely reducing both the quality and quantity of housing consumed) and longer travel times. Higher residential densities are correlated with less affordable housing (for similar housing types and characteristics), reflecting greater competition for land in less space. While absolute housing price levels have moderated in some places, housing supply has been allowed to increase with demand even though the types of housing have changed significantly. For example, in an effort to increase residential densities, Portland, Oregon uses a growth boundary to restrict development in rural areas. Absolute price increases have been mitigated by an increase in multifamily housing units as a substitute for single-family detached housing although land as a share of the home prices have increased dramatically (Phillips and Goostein, 2000; Staley and Mildner, 1999, pp. 5–8). Longer travel times also restrict accessibility to employment and housing, and urban areas will be less able to "sort" workers based on jobs skills and productivity. In short, the "opportunity circle" for workers and firms will fall, reducing the productivity, wealth, and income (Hartgen and Fields, 2009; Staley and Moore, 2008). Thus, policy strategies that reduce wealth and income are likely to be "second best" options, and the outcomes would be sub-optimal. (This would be particularly important if the reduction in wealth also compromised a community's (or nation's) ability to invest in environmental mitigation.)

In principle, policy approaches that emphasize technological innovation over behavioral shifts have tended to produce more cost-effective outcomes. This may be most dramatically illustrated by the striking and broad-based reduction in air pollution in almost all major US urban areas as a result of increased fuel efficiency standards and pollution-control devices on passenger vehicles in the US. VMT in the US has increased by 155% since 1970 yet the emissions from the six major

pollutants (excluding carbon) tracked by the US Environmental Protection Agency have fallen by 48% (Balaker and Staley, 2006, pp. 54–55). Indeed, average vehicle emissions are falling by about 7–9% per year. Technology has dramatically reduced the ecological footprint of industry as well. In 1700, for example, a city of 15,000 supported 10 factories of efficient scale whereas a modern city of 200,000 now supports 10 factories (Staley, 2005, pp. 116–117).

Policy approaches to reducing GHGs are rich and diverse, suggesting that emissions reduction needs to be considered on a nation-by-nation, region-by-region, and perhaps city by city bases. For example, a partial list of strategies includes:

- Improved land-use planning (transit-oriented development, mixed-use development, etc.).
- Technological improvements to vehicles (hybrid vehicles, electric vehicles, etc.).
- Simple shift of the vehicle fleet to smaller cars.
- New CAFE standards.
- Improved traffic signal timing and synchronization.
- Increased telecommuting.
- Increased transit use.
- Applying road pricing.
- Applying parking restrictions.
- Increased walking and bicycling.
- Increased ridesharing by subsidizing implementation.
- Increased use of roundabouts (in place of traffic signals).
- Increased advanced traffic management on highways (ramp metering, use of shoulders as a traffic lane during peak periods, etc.).
- Adding road capacity sufficient to reduce congestion.
- Expanding HOV and HOT lanes.
- Increased carpooling.
- Decreased average speeds on higher speed roads.

There are certainly many more not listed here. Reason Foundation is collaborating with the Hartgen Group in Charlotte, North Carolina on a detailed examination of the possible GHG reductions and their costs from some of these strategies for US urban areas. While the results have not yet been published (we anticipate a 2010 release), we share here results from analysis of four of the strategies to provide useful insight into the complexities, relative costs and tradeoffs associated with addressing climate change as well as the inherent risks of generalized, one-size-fits all approaches.

3.1. Vehicle fuel efficiency

New CAFE standards require new cars and light trucks to get 35 miles per gallon by 2020 (US Congress, 2007). This will require an increase in average fuel economy of about 27% for cars and about 58% for light trucks, and these changes will have substantial effects on vehicle CO_2 emissions.

Even with the new standards, the fleet will continue to include older, less fuel-efficient vehicles, and people's ordinary driving is generally less efficient than CAFE tests, so actual fleet fuel efficiency averages will be lower. In 2006 the ratio of CAFE standard to real world fleet efficiency averages was 1.36. Extrapolating from that we apply the 1.36 ratio to the 35 mpg 2030 standard to estimate an actual fuel efficiency of the auto fleet of 25.71 mpg. A similar estimate (assuming some improvement in efficiency) for trucks gives 11.93 mpg for single-unit trucks and 7.42 mpg for combination trucks.

Assuming VMT continues its long-run growth trend (more on this below), the new CAFE standards will reduce fuel consumption and CO_2 emissions 31.2% below what they would be with current vehicle fleet efficiency by 2030. That is about a 4.4% increase over 2005 emission levels. In other words, the new CAFE standards will hold CO_2 emissions from vehicles close to current levels even if travel as measured by VMT increases 52%.

The US Congressional Budget Office (CBO, 2003, 2004, 2008) attempted to quantify the costs of the new CAFE standards, including vehicle costs net of fuel cost savings for consumers. The estimates varied substantially, from $230 per vehicle to nearly $900 for autos. Using the highest cost in the range, incremental costs are $900 per vehicle for passenger cars and light trucks, $1500 for single-unit commercial trucks, and $3000 for combination trucks. Applying these costs to anticipated fleet changes through 2030, the average cost will be $51.77 per ton of CO_2 emissions reduced by 2030.[1]

Two caveats are in order. On the emission reduction side, more efficient vehicles will lower the relative cost per mile to drive and might lead people to drive more—the 'VMT rebound' effect. NHTSA (2008, pp. VIII-5-VIII-8, VIII-11) assumes −0.15 for the rebound elasticity effect in its 2008 statistical report. A survey of the literature by the California Climate Change Center at UC Berkeley (Auffhammer, Haneman and Szambelan, 2006, pp. 8-20–8-27) examined seven studies between 1992 and 2004 and found a range between 5% and 23% that diminished over time. More recently Small and Van Dender (2007) accounted for real income effects and changes in gas prices and estimated a short-run effect of 3.1% and a long-run rebound effect of 15.3%, concluding that the effect is "considerably smaller than values typically assumed for policy analysis." That

[1] See Hartgen et al., pp. 34–35 and Table 9 for details behind this calculation.

said, there could be some slight VMT rebound effect by 2030 and beyond that would reduce the GHG emission savings from more efficient vehicles. But at the same time, our cost estimates did not include the money consumers save from buying less fuel with more efficient vehicles. So the total cost per ton of emission reductions is actually somewhat lower than estimated.

3.2. Improved timing of urban traffic signals

Signal timing improvements may be one of the most cost-effective ITS applications and can save fuel by reducing vehicle idling, minimizing stops, and increasing overall travel speeds (Staley and Moore, 2008, pp. 145–146). Fuel economy varies by speed in a well-known inverted U-shaped fashion, with maximum fuel economy generally around 45 mph (Small and Verhoef, 2007, pp. 72–76). So improving speeds on urban arterials to be steadier and closer to 45 mph can reduce fuel consumption and GHG emissions. Improving a traffic signal may seem insignificant, but it influences both peak and off-peak travel because of the wide scope of the arterial network in most urban areas, so those improved signals add up. About 27% of urban weekday traffic (measured by VMT) in urban areas is on arterials and collectors (FHWA, 2005). A recent review of the status of signals nationwide indicated that over 75% of the 300,000 traffic signals currently in use could easily be improved in flow characteristics either by updating equipment or adjusting their timing (Chin et al., 2004, p. 67). FHWA's Arterial Management Benefits database indicates that basic signal improvements can achieve a 15–20% reduction in delay (Chin et al., 2004, p. 68). More advanced improvements, such as automated signal controls, can reduce delay by up to 40% (Chin et al., 2004, p. 68). Barth and Barbooonsomsin (2008, p. 10) evaluated traffic conditions in Southern California and found that increasing arterial speeds by 2.5 mph, 5 mph, and 10 mph could reduce CO_2 emissions by up to 25%, 45% and 70%, respectively.

Taking the lower bound of the FHWA's estimates, Hartgen and Fields (2009) forecast a 15% reduction in delay on arterial road systems during peak periods by 2030, and a 10% reduction during off peak. CO_2 emissions in urban areas would fall by 2.3% in 2030, or nearly 13 million tons per year.[2]

Traffic signal timing improvements are relatively inexpensive according to the 2007 National Traffic Signal Report Card (NTOC, 2007). Including the capital costs of installing the signals themselves, the costs of timing the signals (which must be rechecked/retimed every 3–5 years), and the costs of maintaining the signals (one technician per 60 signals), comes to $13,500 every 10 years for intersection controllers, $3000 every 3 years per intersection for timing, and a $60,000/year technician for every 60 traffic signals (NTOC, 2007, p. D-1). This amounts to about $112 per ton of CO_2 saved.[3] But improved flow saves motorists time and fuel as well, accumulating benefits of reducing CO_2 by an average cost of $2307 per ton based on detailed estimates of travel in 48 large cities in the US (Hartgen and Fields, 2009).

3.3. Reducing VMT through smart growth

If people drive fewer miles, they will use less fuel and emit fewer GHGs. Reducing VMT by means of "smart growth" policies has rapidly become the central focus of reducing transportation GHG emissions. The argument is that denser, compact, mixed-use development will change people's travel behavior, and those changes will lead to fewer GHG emissions (Ewing et al., 2008; TRB, 2009). A typical approach is to use integrated land-use/traffic-assignment models to estimate how much VMT might be saved by generic but location-specific changes in land use density or land use mix. A useful survey in *Transportation* examined the different scenario growth policies of about 50 regions and found that their models show focusing most new development into "compact" (central area and TOD-like) locations would reduce regional VMT by a median of 2.3% versus the "trend" forecast (Bartholomew, 2007, pp. 397–412). This implies, by our estimates, about a 50% increase in VMT over 20 years and a 5% reduction in the rate of VMT growth. A subsequent meta-analysis encompassing 85 scenarios in 23 separate studies found substantial variation in estimates. Alternative scenarios averaged 7.9% less than regional trend forecasts among all studies, but the average variation ranged from 5.2% *above* trend VMT to 31.7% below trend (Bartholomew and Ewing, 2009, pp. 18–19).

Notably, these scenario studies are not observations of travel. Rather they are computer models of the impact of an assumed (and often quite extreme) change in land-use pattern on VMT, compared with a trend forecast. The whole exercise depends on the hidden assumptions between travel behavior and land use or travel prices. And the studies typically do not price the cost of undertaking the action or consider the probabilities of their success. Scenario analysis, or transportation demand forecasting, does not consider implementation costs or transaction costs involved in achieving difference scenarios, nor do they calculate the net social costs and benefits of pursuing different land use and transportation options. Indeed, most transportation-land use scenarios are developed without significant public comment. Bartholomew (2007), for example, notes that 61% of scenario project sponsors in his study "indicated concern" about future land supply, increased automobile

[2] First, Hartgen et al. forecasted CO_2 for 2030 assuming no changes in signalization based on forecasted daily vehicle miles traveled and regional travel time indexes using speed curves from the Transportation Energy Data Book. Second, they forecasted CO_2 emissions for 2030 assuming a 15% improvement in travel flow for peak hours (based on Chin et al. (2004)) and 10% improvement for off-peak hours. Third, they included a 10% adjustment factor to account for the effects of CAFÉ changing. Traffic flow improvements were limited principal arterials and minor arterials since these roads include most of major urban intersections and signals

[3] Hartgen et al. calculated the number of signalized intersections in each of 48 urbanized areas using arterial signal data from the Chin et al., and extended it based on the city shares of arterials from FHWA data (FHWA, 2005). See details of methodology in Hartgen et al., pp. 115–118.

use and continuing urban sprawl as a motivation for undertaking the scenario planning process. Planning ideology aside, estimating the incremental cost of urban densification is very difficult on purely pragmatic grounds since it would require a thorough understanding of the relationship between land development costs and benefits as well as quantifying (and presumably objectively scoring) household and consumer preferences.

A 5% reduction in 2030 car/light truck VMT—in the middle of the range, but twice the median, of the 50 regions examined in Bartholomew's *Transportation* survey—would reduce their CO_2 emissions in 2030 about 4%, which would essentially hold them at 2005 levels, assuming no significant changes in vehicle technology, shifts to different types of vehicles, or improvements in vehicle efficiency.

The costs of achieving the densities that lead to that 5% reduction in VMT through smart growth policies are difficult to estimate, but they appear to be nontrivial. Ewing et al. (2008, p. 8), for example, point out to achieve reductions of VMT in the range of 25–30% by 2050, at least 60% of new residential would have to average about 13 units per acre, effectively removing the single-family detached home from the menu of choices since the average lot would be about 3385 square feet. In contrast, the US Census Bureau (2009) reports that the median lot size for a new detached one-family housing unit sold in 2008 was 9070 square feet while the average was 19,482 square feet. Most new housing units would need to be multifamily units to meet the density targets necessary to achieve the policy objectives of reducing travel. The land use shifts implied by Ewing et al. would represent a substantial departure from previous trends where *new* development has occurred at lower than average densities (TRB, 2009, p. 116).

In addition, compared to changes in vehicle fuel efficiency or improved roadway operations, smart growth policies focused on changing land use to influence travel behavior are a very indirect means of reducing GHG emissions. These scenario and forecast-driven policy recommendations also make significant assumptions about implementation that really amount to assertions without significant empirical support, including:

- Land-use policies directly determine land-use patterns. Often, they do not (Staley, 2001). Planning boards often fail to implement formal growth-control policies (Holcombe, 2001; Fulton et al., 2002, 2003). Planning commissions also often follow market trends rather than dictate market outcomes (Pogodzinski and Sass, 1994). Planning commissions, as representatives of local community values, also tend to respond local political concerns rather than national or global policy goals (McMillan and McDonald, 1991).
- Denser, more walkable, better designed development reduces the amount people drive. Sometimes it does, but often it does not (Boarnet and Crane, 2001).
- Reducing the amount people drive reduces GHG emissions. It might, but if they use a transit system with low ridership or fail to buy a newer, more efficient vehicle for the remaining driving they do, their GHG emissions could increase. In fact, on a per passenger mile basis, most bus and light-rail transit systems in the US emit as much or more carbon as conventional automobiles (O'Toole, 2008, pp. 10–11).

In our view, all three steps in this policy chain would have to build on each other and be effectively implemented for land-use policies to reduce GHG emissions significantly. Yet, each step is far from a sure thing, and most of them hinge on political decisions on the local level. Even if each step has a modest chance of failure, the cumulative chance of failure in the chain can be substantial.

As a UCLA climate center told the California Air Resources Board: "VMT is an inadequate proxy for vehicle greenhouse gas emissions" (Lewis Center, 2009). Meanwhile, according to the Federal Highway Administration, between 1990 and 2007 overall US travel (VMT) increased about 41.3% (FHWA, 2007, Table VM-202), but fuel use (including diesel) increased just 33.7%, reflecting the already improving fuel economy of the vehicle fleet (FHWA, 2007, Tables MF-2 and MF-221).

We must consider the radical transformation of living and traveling we would all have to undergo to achieve the VMT reductions necessary to dramatically reduce vehicle GHG emission. A US Department of Transportation report (2004, Appendix D, page 5) concluded that: "The threshold value at which density seems to have a meaningful effect upon VMT, or trips, is somewhere probably between 6000 and 7000 persons per square mile." Among US urbanized areas, only Los Angeles, New Orleans and San Francisco currently have average densities in excess of 5000 people per square mile (Cox, 2009).

Even this threshold is misleading. In order to maximize transit usage, users must be within walking distance of a transit stop and the rule of thumb in the transit community is that travel splits are most favorable toward transit when users live within one-third to a half mile of a transit stop (Staley and Moore, 2008, pp. 155–160). Even in these cases, transit mode capture rates are often significantly less than 30%. Proximity to transit stations is a well recognized constraint on ridership, and surveys consistently show maximum market penetration is within one-third of a mile (Bernick and Cervero, 1997, pp. 124–129). To achieve significant transit capture rates, transit-oriented development residential densities are expected by experts to approach 12–15 net housing units per acre or more (Calthorpe, 1993, p. 83), implying population densities approaching 20,000 people or more per square mile and densities about six times the typical US suburb. Thus, while Manhattan borough-level densities of 70,000 people per square mile are not necessary to achieve significant market penetration for transit, urban land-use patterns need to resemble Brooklyn and the Bronx, and to a lesser extent Queens if broad-based changes in travel favoring transit have a plausible likelihood of being accomplished.

Moreover, higher density increases congestion, even if some people shift to other travel modes. One study estimates that congestion leads to typical 30-min commute trips that are 28% shorter in distance than they would be in uncongested conditions. But that reduction in distance only decreases CO_2 emissions by 10% due to the lower fuel efficiency of vehicles in

congestion (Treiber et al., 2008). Put another way, this indicates that with density and congestion, a 1% reduction in VMT produces only a 0.36% reduction in GHGs.

3.4. Increasing the use of transit

Transit can carry many more people per gallon of fuel than can autos. Substantially increasing transit use might significantly reduce GHG emissions. What if we could increase transit commuting shares in the nation's urbanized areas by 50%? In the New York-Newark urbanized region, with a 30% transit work share at present, this would mean increasing the transit work share to 45%. For most other cities, however, it means a 1–3 percentage-point increase in the transit share (American Community Survey, 2005). Such an increase would likely be possible only with dramatic policy shifts such as a very large expansion of transit service or the elimination of transit fares.

Assuming that *all* of the shift to transit would come from solo-driver commuting is generous. For the New York region, Hartgen et al. (2010) calculate that would mean reducing the drive-alone share 17.2 percentage points, from 50.4% to 33.2%, but for most other cities, again, it would only be a change of a few percent. Since work travel is about 35% of all urban private-car VMT, and single-axle truck and combo truck VMT would not be affected, the reduction in VMT of cars and light trucks would be the reduction in the drive-alone share *times 0.35.* For New York, this is −6.0%, for other cities less than 1%, so even a fairly large increase in transit commuting share would have a relatively small effect on VMT in most regions.

Again, using detailed data from 48 urban areas in the US, Hartgen et al. (2010) estimate that a 50% increase in the transit commuting share would reduce overall 2030 CO_2 emissions from transportation in those urban areas by about 16,000 tons of CO_2 daily, or about 1.09%.

However, this does not take into account that additional transit service—more trains and buses—emit more GHGs as well. The choices of technology, local geography, the service mix, weather, and many other factors would determine the net local effects. Given the small reduction in auto emissions from the increase in transit, we doubt it would not take much increase in transit emissions to consume the benefits. Consider the following. According to the *Transportation Energy Data Book* (Table 2.12) the energy efficiency of cars is about 5489 BTU per vehicle mile (using conventional fuels), compared with 37,498 BTUs per vehicle mile for transit buses and 70,170 BTU for rail transit. Using average vehicle loads from the 48 cities' long range transportation plans, per passenger-mile, cars use about 3496 BTU, buses 4318 BTU, and rail transit 2750 BTU, suggesting that cars are actually more energy-efficient, both as vehicles and in operational practice in the US. To say it another way, the 'average' bus would have to carry about 10.7 persons, and the 'average' rail transit vehicle about 20.1 persons, to be as energy-efficient as the 'average' car with 1.6 passengers. Achieving those averages would require considerable growth in transit ridership beyond the rate of service expansion and current trends even with recent increases in gasoline prices. Indeed, public transit ridership has fallen in 2009 (APTA, 2009a) even after steady growth since 2003 (APTA, 2009b, Table 5, p. 10).

We doubt changes in services levels high enough to make an meaningful impact on travel can be achieved. Hartgen et al. (2010, pp. 70–73) used data on costs per revenue vehicle mile for transit service in 48 US urban areas from the National Transit Database (2006) to examine ways to increase ridership and conclude that the most cost-effective means would be to offer fare-free service at about $1398 per ton of CO_2 saved. Aside from several year-long demonstrations in the 1980s and 1990s, however, free-fare transit service has not been implemented on any large US transit system for both cost and policy reasons (Perone and Volinksi, 2002).

A potentially more viable way to increase ridership may be service improvements. A TCRP study reports that travelers' response to scheduling and frequency changes of transit has an average service elasticity of +0.5, an average service expansion elasticity of +0.7–+0.8, and bus routing and coverage increases have an elasticity of +0.6–+1.0 (Evans et al., 2004, Chapter 10). Hartgen et al. (2010) used a conservative transit service elasticity of 0.60, meaning that a 100% increase in service yield a 60% increase in ridership, to estimate potential increases in transit ridership from investments in service coverage and quality. Achieving a 50% increase in ridership would require an average 83% increase in service levels. In short, many transit agencies would be faced with a near doubling of existing service capacity. That increase in service is expensive and extraordinarily hard to manage. Using 2006 operating cost per vehicle mile for the 48 urban area's transit systems, Hartgen et al. (2010) estimate the average cost of per ton of CO_2 saved by increasing transit service is $4257, but ranging widely from a low of $472 for Bridgeport, CT (served by rail service to New York-Newark) to a high of $11,899 for Salem, OR.

4. Conclusion

Given how VMT reduction compares to alternative technologies and policy strategies such as improved CAFÉ standards and traffic signal optimization, it seems clear we should not be starting our approach to reducing transportation GHG emission with a VMT reduction strategy. VMT is a proxy for mobility in high-income nations and reflects prevailing transportation technology that maximizes choice and flexibility, is resilient to obstacles to travel mobility and allows individuals to customize travel. As a result, the customized mobility afforded by the automobile reduces generalized travel costs and enhances productivity. In short, the inherent efficiencies of the automobile expand the opportunity circle—the jobs and workers accessible within a specific travel time—and generate higher incomes as a result of the access to more diverse employment and housing options (Staley and Moore, 2008, p. 42). The automobile, as a mode of travel, is unrivaled in its

ability to allow individuals to optimize their travel choices. Virtually all dominant forms of mass transit, in contrast, require fixed routes, schedules, or dependency on third parties (or all three) to be cost-effective. As a consequence, they represent an economically and socially inferior mechanism of travel absent offsetting, usually urban amenities. To compensate for the loss of privacy provided by detached homes, open space provided by large yards, or quiet provided by low densities, transit-supportive urban areas provide public parks, neighborhood shops within walking distance (mixed uses), and, presumably, proximity to public transit that takes travelers to their intended destinations. These are the principles of smart growth and transit-oriented development (Calthorpe, 1993; Bernick and Cervero, 1997). As a practical matter, preferences for these urban amenities tend to be concentrated in a relatively small segment of the general population—singles, young professionals, and households without (and not anticipating) children. Thus, policies that shift households from automobiles to high density urban settings that limit mobility, promote mass transit, and reduce overall consumption will likely reduce human welfare by limiting access to preferred housing and transportation options.

A more cost-effective and socially beneficial approach to climate change would be to adopt policies that directly target GHG emissions and internalize the externalities of the byproducts of human activity such as anthropogenic carbon emissions. A VMT-based strategy does not accomplish this goal.

In our view, a focus on reducing VMT as a core policy goal assumes a static technology for powering personal vehicles and reveals a value-driven policy agenda more focused on limiting urban sprawl and automobility than meaningful mitigation of environmental harms. Advances in fuel efficiency and other technologies (e.g., plug-in hybrid, electric vehicles) are well within a 50-year window for adopting technologies to mitigate carbon emissions. CAFÉ standards have already been put in place to facilitate this transition on fuel efficiency, and many experts expect increases in oil prices to accelerate this transition once the world economy recovers from the recession and economic growth picks up in China, India, and other emerging economies. In fact, China is expected to sell more than 10 million automobiles in 2009, achieving levels only reached by Japan and the US in previous years (BBC, 2009). Notably, China's growth if fueled by domestic demand, not exports. Sales of the all electric Tesla sports car began in 2008, and 700 vehicles have been delivered to customers in the US and Europe (Tesla Motor Sports, 2009). A scenario by which most travel using personal vehicles will be powered by electricity generated from a non-carbon emitting nuclear power sources by 2050 is not just technically possible. It's plausible.

In addition, the transportation policy community will likely be embracing a wide range of policy innovations from the list in the beginning of Section 3 above. Policymakers should begin addressing environmental concerns by starting with the least costly and intrusive measures, and consider more complex strategies as our level of certainty about their impacts and how they will work increases. Some measures will have the effect of reducing VMT as a secondary impact. For example, the primary goal of variable rate road pricing is to optimize traffic flow and speed in real time, and is already common practice on High Occupancy Toll lanes in Southern California, San Diego, Denver, and Minneapolis (Staley and Moore, 2008, pp. 138–142). More transparent pricing to manage traffic efficiently may well have the secondary effect of encouraging alternative modes (a substitution effect), but that would not be the primary goal. Technological advances in electronic tolling are also expediting the transition from manual toll collection to boothless, high speed charging in many high-income countries and some fast growing low-income countries. As nations such as the US begin to transition away from fuel-based funding mechanisms to various forms of real-time electronic road pricing over the entire road network, technological advances able to incorporate the costs of externalities such as carbon emissions for individual vehicles will likely become more cost-effective. We have no reason to expect tolling or other transportation management technologies will be more resistant to innovation than other sectors of the economy. These strategies, like the air pollution-control devices of the 1970s and 1980s, do not imply reductions in mobility or VMT.

Thus, although carbon emission represent an externality that can justifiably be mitigated through public policy, public policy can take a less intrusive approach that does not constrain the organic, innovation inducing characteristics of freedom of choice and markets. These policies would avoid high cost, low gain approaches such expensive and intrusive policies that aim to induce changes in behavior such as mandatory land-use planning that explicitly induces congestion, in the words of US Department of Transportation Secretary Ray LaHood, to "coerce" people out of their cars (CNSnews, 2009).

A general principle of welfare economics is that shifts in resources should be "pareto optimal" where the new outcomes do not make anyone worse off. We believe a policy focused on VMT reduction is not pareto optimal. Curtailing mobility reduces the tangible welfare of individuals and households by limiting housing and transportation choice, increasing travel times, reducing productivity, and subsequently household incomes. Moreover, these costs are not balanced with commensurate social benefits. The impacts of costly carbon reduction strategies in the US will not materially or significantly influence the levels of global carbon emissions given the rapid pace of growth in major competing nations, including the BRIC nations (Brazil, Russia, India and China). We doubt that reductions in anthropogenic emissions will significantly alter the current course of climate change given the relatively small proportion of emissions created by human.

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