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**Review of U.S. and European Regional Modeling Studies of Policies
Intended to Reduce Transportation Greenhouse Gas Emissions**

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Abstract

With the enactment of a new federal transportation law in 2005, State and regional transportation plans and programs are for the first time required to achieve the objectives of the SAFETEA-LU planning process, which focus on enhancing mobility and supporting economic development, while minimizing conventional emissions and greenhouse gas emissions. In 2007, the U.S. Supreme Court held that greenhouse gases are a pollutant and so are covered by the Clean Air Act and, consequently, the USEPA can regulate them. California and 13 other states are now attempting to regulate the emissions of greenhouse gases from vehicles.

The results from over 40 long-range regional scenario exercises performed in the U.S. and Europe demonstrate that substantial reductions in vehicle-miles of travel (VMT), fuel use, and emissions of both criteria pollutants and greenhouse gases are possible using transportation pricing policies and investment priorities that have been demonstrated as acceptable and effective in a modest but growing number of metropolitan areas and regions around the world.

Summary

VMT (vehicle-miles of travel) reductions in 20 years range from 10% to 30%, compared to the future trend scenario, are achievable with reductions in emissions and fuel use roughly proportionate to the decrease in VMT, while supporting the same level of future job and housing growth. In most studies, the highway levels-of-service are the same as, or better than, the trend scenario.

The studies reviewed also suggest that these reduced-VMT scenarios generally produce higher transportation system productivity, positive net user economic benefits, greater equity in the distribution of transportation system benefits, reduced congestion delays, and a reduction in other adverse environmental impacts.

The most-effective policy sets combine land use policies, such as compact growth, with strong transit provision and not expanding highway capacity. The addition of auto pricing policies, such as fuel taxes, worktrip parking charges, or all-day tolls increases the effectiveness of the land use and transit policies. Peak-period tolls, by themselves, increase travel. Expanding road capacity, along with transit capacity, but without changing market incentives to encourage more efficient use of existing roads and parking, results in expensive transit systems with low ridership.

The U.S. Studies

The following is excerpted from:

Bartholomew, Keith, *Integrating Land Use Issues into Transportation Planning, Summary Report, DOT Cooperative Agreement No. DTFH61-03-H-00134. 2005. Dept. of Architecture, University of Utah.*
http://faculty.arch.utah.edu/bartholomew/SP_SummaryRpt_Web.pdf

Bartholomew surveyed members of the National Association of Regional Councils (NARC) in 2003-04 for examples of scenario planning using land use, transit, and other policies to reduce travel. Land use policies typically included density increases, clustering development in transit corridors or around rail stations, and urban limit lines. Both travel models and geographic information system (GIS) evaluation tools were used in the scenario evaluations. The median reduction in VMT in the 20-year scenarios for 31 exercises with adequate data was 2.3% but 11 scenarios resulted in reductions of 5% or more.

Five scenarios resulted in reductions of 10% or more. These studies generally evaluated modest growth management policies and did not employ the pricing of parking or fuels or roadways. So, these results may be viewed as lower bounds on what VMT reductions could occur in scenario exercises.

Example data from the projects are:

1. Arizona, Maricopa Association of Governments. ~ 3% VMT reduction in 20 years.
2. San Francisco Bay Area Alliance for Sustainable Development. 4.6% reduction in VMT by 2020. Most of the growth in this scenario is located in the existing urban cores of the region.
3. Georgia Regional Transportation Authority. 7% VMT reduction.
4. Baltimore Regional Transportation Board. 8.2% VMT reduction. Redevelopment was emphasized, road capacity maintained at current levels, and transit capacity moderately expanded.
5. Portland Metro. ~8.8% VMT reduction in 20 years (17.6% VMT reduction in 40 yrs). Growth contained within urban growth boundary, plus auto pricing, transit investment, and pedestrian improvements.
6. Southern California Association of Governments. ~10% VMT reduction in 25 years. Housing and jobs focused in existing centers and corridors.
7. Denver Regional Council of Governments. 12.5% VMT reduction in 25 years. Most growth would locate in infill development sites within the central city and existing suburbs.
8. Envision Central Texas. ~17% VMT reduction compared to current trend. New growth in existing developed areas, which would accommodate 1/3rd of anticipated new households and 2/3rds of new jobs.

9. Contra Costa County, CA. 17.3% reduction in VMT in 20 yrs. Growth placed in existing urbanized areas, and along rail transit routes.
10. EPA, Atlanta, GA. ~38% difference in VMT between worst and best scenarios.

The European Studies

For many years, the European Commission has performed sophisticated studies of policies to reduce pollution, traffic accidents, noise, and greenhouse gas emissions. We review the four main reports here. In these studies, urban models were used, which are state-of-the-practice methods representing both travel and land development and use. These model sets are composed primarily of discrete choice models based on microeconomics and so give elasticities of demand with respect to price. These statistics permit comparisons across regions and validation of most model components.

Quite significant policies were evaluated, including higher taxation of fuels, larger auto purchase and registration fees, and tolling of roadways (both all-day and for peak periods), as well as urban limit lines, and density increases. So, we may view these projections as the upper bounds of what could be achieved in most regions in the U.S. As these are the most-complete and best-designed studies ever done, this review gives some detail about the policies and results.

F.V. Webster, P.H. Bly, and N.J. Paulley, eds., Urban Land-use and Transport Interaction, Avebury (Brookfield, MA), 1988.

Seven urban models were run on seven cities around the world on the same policy sets, intended to reduce VMT and emissions. Each region ran a 20-year Future Base Case, different for each region, but basically a trend scenario plus any major investments already programmed. All results are reported as differences from the future base case.

The results were reasonably coherent and showed that only urban limit lines reduce residential sprawl. Such controls did not raise housing prices, however, due to increased density.

Increasing land use density is effective in reducing VMT, especially if the walk and bike modes are well-provided for. Parking charges in the central business district (CBD) decentralize employment, whereas vehicle purchase and registration taxes (or fuel taxes) reduce auto ownership and VMT. The vehicle taxes are much more effective, if supported by good transit service, especially to the CBD and other employment centers. Land use and transit policies have little effect, unless supported by pricing.

Faster radial travel by freeway or rail increases the decentralization of upper-income households, thereby increasing segregation by income. Increasing the cost of both auto travel and transit by 50% decreases travel and energy use about 10%. Increasing auto costs by 400% reduces VMT and emissions about one third. (I note that making workers pay for parking or providing cash-in-lieu-of-parking incentives in the U.S. increases

“felt” travel costs by around 400%, without actually increasing costs, as the parking costs are merely being unbundled from wages.) All pricing scenarios decreased travel delays.

I note that travel models must include an auto ownership step and the walk and bike modes in order to represent these policies accurately. Also, the peak and non-peak periods must be modeled separately.

SPARTACUS, Final Report. European Commission, Environment and Climate Research Programme. Sept., 1998. On the internet at www.ltcon.fi/spartacus or from Kari.Lautso@LTcon.fi.

This study used MEPLAN, one of the most-advanced urban models, at the time, on Helsinki, Bilbao, and Naples. A raster (grid) GIS program was added to MEPLAN to calculate impacts from noise and emissions on households and to produce maps. A user interface was also added to simplify the input of policies and also the production of output tables, maps, and graphs. Policy impacts were net from the future base case, as above.

Overall, only the travel pricing policies were found to reduce VMT substantially. For example, increasing auto costs by 50% decreased VMT by 16%. Land use policies were not very effective, except to back up the transit system. Pricing was required in order to gain large increases in transit use.

The most effective pricing policies combined congestion pricing with mileage or travel pricing (fuel tax or all-day tolls). Increasing rail service increased all travel speeds in Bilbao and Helsinki, due to some auto travelers switching to rail, while in Naples the existing transit system was made more efficient. This shows the need to not add highway capacity in long-range investment plans that are intended to reduce VMT and emissions.

Combining land use policies for intensification in transit corridors and urban limit lines with transit investments and the pricing of auto travel was found to be the most effective approach to reducing VMT. Greenhouse gases and fuel use are reduced between 13% and 24%, depending on pricing levels, with an increase in auto operating costs of about 100% being most effective. Delays were decreased significantly in all pricing scenarios.

The raster system was effective for analysis and mapping. The user interface was also very useful in aggregating the outputs in various ways. Various weighting schemes with social, economic, and environmental indicators were tried. Also, sensitivity tests were conducted on the various equity measures and on indicator weighting ranges. They also found that such studies should include surrounding rural areas, as they often receive significant impacts. The authors also recommend that studies should also be for at least 20 years, to capture counterintuitive and changing effects over time.

PROPOLIS: Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability. Final Report. European Commission, Energy, Environment, and Sustainable Development Thematic Programme. February, 2004. Available from Kari.Lautso@LTcon.fi.

This study carried on the SPARTACUS approach, modeling 7 urban regions using three advanced integrated urban models. The study was firmly embedded in the sustainable development policy analysis paradigm, using many indicators of Social, Economic, and Environmental effects. All models used a raster analysis and mapping capability and a user interface for policy inputs and for the analysis of model outputs. Policy results were net from the future base case, as in the two previous studies.

The policy results were generally the same as in the SPARTACUS study, with more variation due to differences among the urban regions. The results were generally similar across all 7 regions, though. Methodologically, the findings were also the same as in the previous study. In the future baseline (trend) scenarios, the large number of European Commission sustainability indicators deteriorated in all regions.

By applying pricing, land use, and transit investment policies, most of the indicators could be reversed. Increasing auto operating costs by 75%, adding parking charges, and decreasing transit fares by 50% was the most effective pricing policy component. It reduced greenhouse gas emissions and fuel use by 15-20% in all regions, over 20 years. Because the same policy set gave the same general results in the 7 regions, the study concluded that this policy set would likely work in most EC regions. Making workers pay for worktrip parking would increase “experienced” auto costs by 100-500% in most regions, since drivers choose modes based on out-of-pocket costs (gas, tolls, parking charges, transit fares). In the U.S., the true unbundled cost to employers of providing free parking is typically much larger than the employee’s out-of-pocket fuel costs to drive to work by auto.

The effects of the various pricing policies were found to vary by region and often had negative effects on sprawl (increased sprawl) and so all must be studied individually and in combination with other policies. Increasing transit speeds increased sprawl unless accompanied by pricing and urban limit line policies. Increases in transit service often reduced road congestion and caused more sprawl. This finding shows that highways must be allowed to become congested, while improving transit. The VMT-reducing policy sets increased economic welfare by 1,000-3,000 Euros per person (net present value over 20 years) and also reduced traffic accidents, congestion, and noise.

STEPS: Transport Strategies Under the Scarcity of Energy Supply, Andres Monzon and Adriaan Nuijten, editors. July, 2006. Bucks Consultants, International, P.O. Box 11718, NL-2502 AS, The Hague, The Netherlands. Available at www.STEPs-eu.com

This consortium was funded by the the EC and used three EC-wide models, as well as one regional travel model and four regional urban models to evaluate various policies and sets of policies intended to reduce auto travel, truck travel, and air travel. I will only report on the regional modeling results, as they are comparable to the studies summarized above. The travel model was used in Brussels and a microsimulation urban model was used in Dortmund. The aggregate (zonal) urban model MEPLAN was used in Edinburgh, Helsinki, and the South Tyrol.

The scenarios ran from 2005 to 2030, in most cases. The strongest policy set, which we summarize here, included a motor fuel tax increase of 4.7% per year, which resulted in an increase in the cost of car travel of 3.0% per year. So, this amounts to an increase in the final year of analysis of about 100%, over the No Policy case. Fuel prices rose 7% per year, however, in all scenarios, including the No Policy base case. So, these scenarios were evaluated against a strong assumption of rapidly rising fuel costs.

The land use policies focused new development strongly into inner urban areas in each region. Investment in transport facilities was focused mostly on international and regional rail and on regional bus systems, modeled as an annual rise in average speeds of 0.8%, 0.4%, and 0.3%, respectively. Road pricing was increased by 6% per year for cars and heavy trucks, while bus and train fares were reduced by 1.7% annually. Rail freight speed was increased 0.7% per year. Gasoline consumption per km in cars was reduced 0.5% per year, and with diesels 1% per year. No parking charges were represented.

In sensitivity tests, the increases in fuel prices had the greatest effects on travel and greenhouse gases. This concurs with the PROPOLIS study's findings. The price-elasticity of VKT (vehicle-km of travel) with respect to travel cost was about -0.2, somewhat lower than the empirically found -0.3, so the results may be somewhat conservative. In 2030, these regional scenarios resulted in reductions in CO₂ emissions of 30-50%, compared to the 2030 No Policy case. About a third of this reduction seems to be due to greater vehicle energy efficiency. Accidents, noise, and congestion were also substantially reduced with this policy package. The growth rates of national GDPs fell, somewhat, mainly due to rising freight costs. The authors recommend a harmonized system of rising vehicle taxes, fuel taxes, and road pricing for cars and heavy trucks, in all EC countries.

Studies by the Author

A dozen published papers simulating similar policies in the Sacramento, California region by this author have produced findings similar to those in the four EC studies. These studies used three versions of the official MPO travel model and three versions of an urban model, the last version being the official version adopted by the MPO. These were all 20-year studies, unless otherwise noted. All results are compared to the future trend scenario or to a no-build (do nothing beyond the funded 3-year Transportation Improvement Program (TIP) projects) scenario. Because SAFETEA-LU requires MPOs to include support for increased economic development as a factor in developing their adopted plans, my economic welfare findings are also presented here. These are similar to consumer surplus for travelers, calculated from the mode choice model logsums, a measure commonly used in this kind of analysis across the world.

Synthesis of Findings:

1. Expanding road capacity increases auto travel and emissions, compared to doing nothing. New HOV lanes on radial freeways increase travel and emissions. They also increase sprawl. Congestion generally becomes worse, in spite of adding highway capacity.
2. Expanding transit only decreases emissions about 1%, compared to doing nothing. It decreases travel costs for lower-income households. It can increase sprawl somewhat, due to driving to the outer rail stations.
3. Expanding transit only and supporting it with land use intensification around Light Rail stations decreases emissions about 5%. It decreases travel costs for lower-income households.
4. Expanding transit only and supporting it with land use intensification around Light Rail stations and with urban growth boundaries decreases emissions about 10%. It decreases travel costs and travel delays for all households.
5. Expanding transit only and supporting it with higher fuel taxes and with workplace parking charges (refunded in higher wages as cash-in-lieu-of-parking incentives) and shopping parking charges (refunded through lower costs for goods and services) lowers emissions about 10%. It greatly increases economic benefits to all travelers, due to better transit and faster freeways. This scenario reduces congestion significantly.
6. Expanding transit only and supporting it with land use intensification and urban limit lines and with fuel taxes and parking charges, as above, lowers emissions about 15-30%. This scenario maximizes economic welfare for the region and reduces congestion the most.

Results from the most recent study using the most advanced urban model (Johnston et al., 2005):

This analysis was performed by the author with the MEPLAN urban model, developed for the Sacramento MPO. It assumed more-ambitious transit investment levels than in previous studies. The model analysis was performed for a 50-year time horizon to enable comparison with the MPO's recent 50-year visioning study results.

1. The transit-only scenario assumed many Bus Rapid Transit (BRT) lines, in exclusive lanes within the urban areas, and on highways to the outlying cities in the region. The analysis did not include use of the California emissions model, but emissions and fuel use correlate very strongly with total travel (VMT), in our other studies. This scenario reduced VMT by 8% in 2025 and 12% in 2050.
2. The MPO's transportation plan, which assumed more freeways, more HOV lanes, more or wider freeway ramps, and more Light Rail lines, was modeled with an urban growth boundary (UGB). This scenario reduced VMT 7% in 2025 and 8% in 2050 and so performed somewhat worse than the transit-only scenario.
3. The transit-only scenario was tested with a UGB. This reduced VMT by 15% in 2025 and 20% in 2050. Congestion was also reduced.
4. The transit-only scenario was tested with an extra fuel tax of \$1.00 per gallon and parking charges for worktrips. This reduced VMT by 14% in 2025 and 18% in 2050. Congestion was reduced substantially.
5. The transit-only scenario was tested with the pricing policies and with a UGB. This reduced VMT 20% in 2025 and 25% in 2050. In this scenario, congestion was reduced the most.

Such strong results stem from the inclusion of a comprehensive transit scenario with fast BRT in exclusive lanes. Also, the urban model allows new development to complement the transportation systems.

All of the tested scenarios were found to be economically beneficial for low-income travelers. The three Urban Growth Boundary scenarios were strongly positive for all travelers together, with savings of about \$0.5 million per day. The analysis method used includes only the morning peak period, so if the results are factored to get all daily travel, the savings become about \$1.5 million per day (\$500 million per year).

These scenarios all included only moderate pricing policies and thus the results should be viewed as the middle range of what is achievable for most large regions, where such levels of transportation pricing incentives will likely become acceptable within a few years.

Including transportation investment and policy scenarios together with pricing and Smart Growth policies has a significant positive impact on system performance (congestion)

and on user satisfaction. This likely enhances the political feasibility of adopting such policies.

The studies summarized above:

Johnston, Robert A. And Raju Ceerla. 1995. Land Use and Transportation Alternatives. In D. Sperling and S. Shaheen, eds., Transportation and Energy. ICEEE.

Rodier, Caroline J. and Robert A. Johnston. 1997. Incentives for Local Governments to Implement Travel Demand Management Measures. Transp. Res.:A 31:4, pp. 295-308.

Rodier, Caroline A. and Robert A. Johnston. 1997. Travel, Emissions, and Welfare Effects of Travel Demand Management Measures. Transp. Res. Rec. 1598, pp. 18-24.

Johnston, Robert A. and Caroline J. Rodier. 1998. Regional Simulations of Highway and Transit ITS: Travel, Emissions, and Economic Welfare Effects. Mathl. Comput. Modeling, 27:9-11, pp. 143-161.

Johnston, Robert A., Caroline J. Rodier, and Melanie Choy. 1998. Transportation, Land Use, and Air Quality Modeling, pp. 306-315 in Transportation, Land Use, and Air Quality: Making the Connection, ed. by Said Easa and Donald Samdahl. American Society of Civil Engineers.

Rodier, C. J., Johnston, R. A., & Shabazian, D. R. 1998. Evaluation of advanced transit alternatives using consumer welfare. Transportation Research:C, 6:1-2, 141-156.

Johnston, R. A., & Rodier, C. J. 1999. Synergisms among land use, transit, and travel pricing policies. Transportation Research Record, 1670, 3-7.

Johnston, Robert A. and Tomas de la Barra. 2000. "Comprehensive Regional Modeling for Long-Range Planning: Integrated Urban Models and Geographic Information Systems." Transp. Res.: A, pp. 125-136

J.D. Hunt, R.A. Johnston, J.E. Abraham, C.J. Rodier, G. Garry, S.H. Putman, and T. de la Barra. 2001. "Comparison from the Sacramento Model Testbed." Transp. Res. Rec., 1780. pp. 53-63.

Johnston, Robert A., Caroline J. Rodier, John E. Abraham, and John Douglas Hunt. 2001. Applying An Integrated Model to the Evaluation of Travel Demand Management Policies in the Sacramento Region: Year Two. Mineta Transportation Institute, San Jose State University, CA. MTI Rept. 01-08.

Rodier, C. J., Johnston, R. A., & Abraham, J. E. 2002. Heuristic policy analysis of regional land use, transit, and travel pricing scenarios using two urban models. Transportation Research: D.

Johnston, Robert A., Shengyi Gao, and Michael J. Clay. 2005. "Modeling Long-Range Transportation and Land Use Scenarios for the Sacramento Region, Using Citizen-Generated Policies." *Transp. Res. Rec.*, 1902, pg. 99-106.

Conclusions

Regarding policymaking, these studies show that substantial reductions in travel and emissions of pollutants and greenhouse gases are possible (10%-30%, compared to the future base case), but only with combined transportation investment, land use, and travel pricing policies. When we consider that such reductions would be multiplied by any savings due to increased energy efficiency of vehicles, we can see that quite large reductions are possible with this wider policy set. Specifically, the STEPs study showed reductions of up to 50% with vehicle efficiency policies included.

Regarding modeling methods, the general agreement among a variety of models used by many different researchers on the impacts of a great many policy types seems to validate the basic approach of integrated urban modeling of land use and travel as an approach to this policy analysis problem.

Note to reviewers: If accepted for presentation, I will reformat the references to the TRB style.