Transit Land Use Multiplier Analysis: A Kentucky Example

Extended Abstract # 30

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INTRODUCTION

Reducing fuel use and greenhouse gas emissions can simultaneously address national economic, environmental and security concerns. Reducing automobile dependency is one method for achieving these two objectives. Public transit provides alternatives to private automobile travel, reduces traffic congestion, and facilities higher density land use. These cumulative benefits are known as transit leverage. Several studies have looked at single city or region specific transit leverage multipliers. Many of these studies used resource intensive and idiosyncratic methods to measure transit leverage. In 2009, the American Public Transportation Association (APTA) published a formula driven methodology of measuring transit leverage. This paper discusses how the U.S. Department of Transportation's National Transit Database (NTD) can be used in tandem with the APTA methodology to develop quick and cost-effective estimates of transit leverage for all transit agencies listed in the NTD. This advancement can be used by policy decision makers to estimate fuel use and greenhouse gas emissions reductions achievable through changes in transit supply policies.

LITERATURE REVIEW

One of the first studies to address transit leverage was by John Holtzclaw in 1991. He examined the scale of the multiplier in three Californian cities in the Bay Area: urban San Francisco and suburban Walnut Creek and San Ramon. He found that the transit leverage was highest in San Francisco, where each passenger mile on public transit had a corresponding displacement of 9 VMT in automobiles. Compared to San Francisco, the two suburban cities' development was more of a sprawl, with less-established public transit systems. Their transit leverage factor was far lower, with only 1.42 VMT displaced for every passenger mile on public transit. This led Holtzclaw to conclude that density was a major factor in the scale of transit leverage, as San Francisco had a gross population density 12 times higher than San Ramon and a commercial density 21 times higher. (Holtzclaw, 1991)

In Sustainability and Cities, Newman and Kenworthy further explored this multiplier and tried to find its origin. Searching for the sources of these secondary reductions, they identify four major reasons for VMT reductions beyond the primary effects of mode shifting. First, when reliable transit is available, people and businesses tend to relocate closer to the transit, reducing the length of many trips. Second, people relying on public transit tend to perform trip chaining, meaning that they combine several errands into one trip. Third, when households can access public transit, they can afford to give up a car, since they are less reliant on it for daily commuting. Finally, residents of areas with public transit become accustomed to walking or biking and tend to travel with these methods more often. Accounting for these effects, they

calculated that in the U.S. transit leverage replaces 3 to 4.5 VMT for every one VMT on public transit. This number rose from 5 to 7 in their evaluation of international cities.

APTA refers to the savings identified by Newman and Kenworthy as Land-Use Multipliers and then identifies another source of savings: congestion relief. This is based on the observation that vehicles in traffic idle more than vehicles in free flowing traffic. With public transit as an alternative, less cars will be on the road so the remaining cars save on energy costs. To quantify this effect they examined the traffic density as a function of local VMT divided by the available lanes of highway. They found that excess fuel consumed rose exponentially with linear increases to traffic density. However, this effect seems to be less significant than the land-use multiplier. A 2008 ICF report focused on savings based on reductions in gallons of petroleum. Using the National Household Travel Survey in 2001 they attempted to isolate secondary reductions. Measuring in annual petroleum consumption they found that primary savings accounted for 1.4 billion gallons of petroleum annually. However, when incorporating savings due to land-use patterns and commuter behavior, they found a total savings of 4.2 billion gallons of petroleum. Therefore the secondary effects displaced 2.8 billion gallons, double the effect of primary reductions. (Bailey and Mokhtarian, 2008)

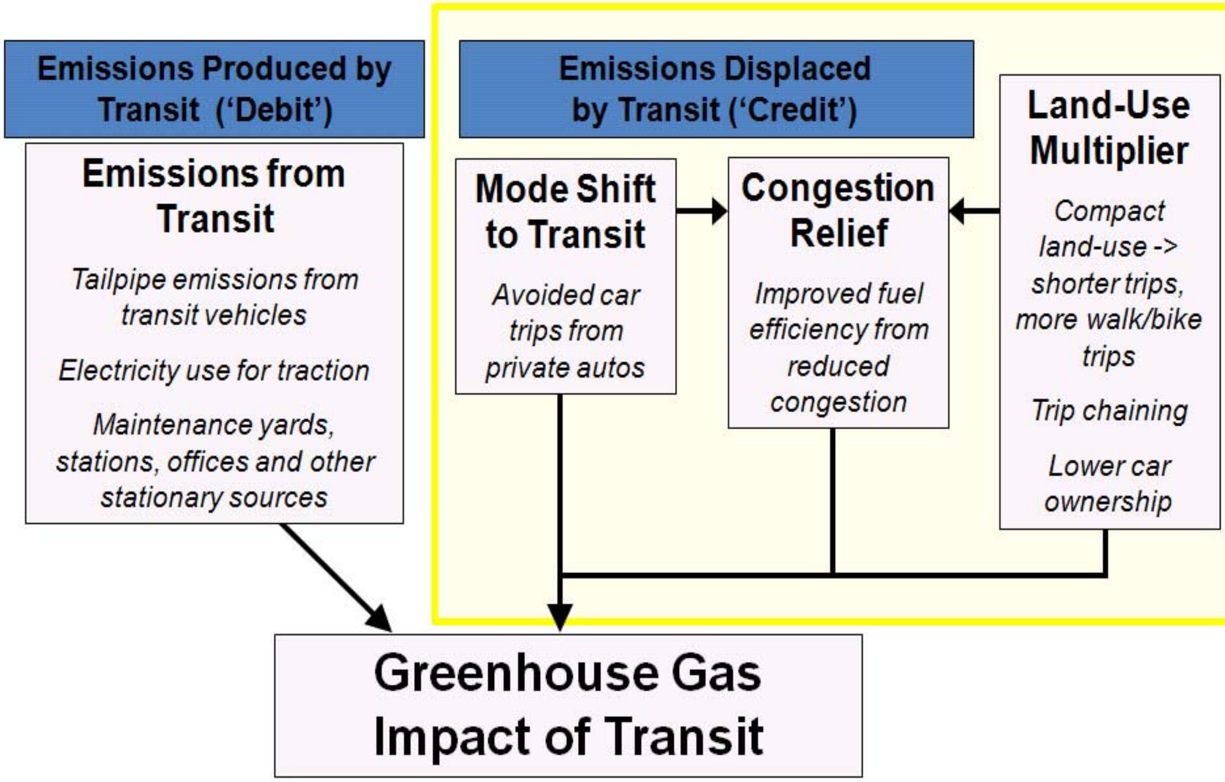
These studies suggest the transit leverage effect is the major source of reductions in VMT, fuels costs, and greenhouse gas emissions due to public transportation. These reductions were in part due to increased use of public transit, but transits facilitation of denser urban development that can be navigated without a personal automobile accounted for the majority of the reductions. Furthermore, these studies produced land use multiplier results in the same general range (2 to 9) using very different methodologies, strengthening the idea that transit leverage lies somewhere between 2 and 9.

Table 1. Summary of Land-Use Multiplier Studies

Study	Cities	Land-Use Multiplier[1]	Methodological Issues
Pushkarev & Zupan (1982)	U.S. metro areas with at least 2 million population	4	Correlation only; does not show causal relationship of transit.
Newman & Kenworthy (1999)	32 global cities	5 to 7	Correlation only; does not show causal relationship of transit.
Holtzclaw (2000)	Matched pairs in the San Francisco Bay Area	1.4 to 9	Correlation only; does not show causal relationship of transit.
Neff (1996)	U.S. urbanized areas	5.4 to 7.5	Assumes fixed travel time budgets.
Bailey et. al. (2008)	Entire U.S.	1.9	Structural equations modeling. Accounts only for land-use effects *caused* by transit.

Source: APTA. 2009. "Quantifying Greenhouse Gas Emissions from Transit."
http://www.aptastandards.com/Portals/0/SUDS/SUDSPublished/APTA_Climate_Change_Final_new.pdf

Figure 1. Overview of APTA Approach to Estimating the GHG Impacts of Public Transit



Source: APTA. 2009. "Quantifying Greenhouse Gas Emissions from Transit."

DISCUSSION OF APTA'S METHODOLOGY

The methodology of our analysis comes from APTA's 2009 report, "Quantifying Greenhouse Gas Emissions from Transit." This report outlines how to quantify the displaced greenhouse gas emissions, in metric tons of CO2-equivalent, based on mode shifting, congestion relief, and the land-use multiplier. APTA provides several different methods of calculating these displaced emissions. Some are very time and resource intensive, requiring onsite surveys and regional analysis. However, APTA also propose methods that require only basic information regarding the transit service region, such as service region population, density, and transit use. For many transit systems this information can be found in the National Transit Database (NTD). Using transit agency specific data from the NTD avoided fuel use and greenhouse gas emissions facilitated by transit can be easily estimated for hundreds of transit agencies across the country.

APTA's methodology uses population, population density, and passenger revenue miles for a given transit service region in order to assess the community-wide fuel and greenhouse gas emissions savings facilitated by transit. The estimates are calculated through a multistep process. To calculate the effect of mode shifting, a mode shift factor must be calculated. This factor, when multiplied by passenger revenue miles determines how many VMT are displaced by the transit system. To determine a mode shift factor, APTA conducted national surveys of commuters to determine how they would commute in the absence of public transportation. The mode shift factor is the percentage of people that would drive plus those that would take a taxi, divided by 2.5 times the amount of people who would ride with somebody else. These results

were then bracketed based on population into small, medium and large cities, with the mode shift factor rising from 0.34 in small cities to 0.455 in large cities. This number multiplied by the passenger revenue miles estimates the VMT reduced due to public transit use. VMT reductions can be converted to fuel savings estimates based on average fuel economy. Fuel savings can be converted to CO2-e savings estimates.

With regard to congestion relief, APTA cites a 1999 study on congestion which suggested that increased number of cars leads to exponential increases in congestion. (Mohring, 1999) This implies that linear reductions in the number of cars on the road leads to exponential increases in fuel efficiency. To quantify the amount of excess fuel consumed due to congestion, APTA uses the Texas Transportation Institute's *Urban Mobility Report*, which calculates excess fuel consumption based on traffic density. Density is defined as local VMT divided by available lanes of highway. Once the base excess fuel consumption is found, the additional VMT due to mode shifting are inserted into the equation to determine the excess fuel consumed in the absence of public transportation. With this information, we can quantify the increases in fuel consumption, and therefore greenhouse gas emissions due to increased congestion.

The final factor is the land-use multiplier. APTA recommends doing local analyses based on the region that is being examined. However, in cases where a regional analysis is too difficult or expensive to perform, they suggest the use of the national average as determined by a 2008 ICF study, 1.9. (Bailey and Mokhtarian, 2008) This multiplier is entered into an equation to determine the amount of greenhouse gas emissions avoided due to public transit use. The calculation is as follows:

Emission reductions from land-use multiplier (metric tons per year) =
Transit passenger miles / average vehicle occupancy (default 1.39)
× Emissions per vehicle mile (default 0.436 kg) × Land-Use Multiplier / 1000

The division by one thousand converts the final number from kilograms to metric tons.

DEVELOPING A TYPOLOGY

The APTA equations can effectively estimate the effects of mode shifting and congestion relief, however, they do make major assumptions when calculating the effects of the land-use multiplier. When local analyses are too costly or resource intensive, they simply suggest using the default national average land-use multiplier of 1.9, as calculated by the ICF. This produces results that suggest a far more uniform effect of public transit on fuel consumption and greenhouse gas emissions than studies have shown. In order to account for regional variation and more accurately determine the regional land-use multipliers, a typology based on local demographics and transit use could be developed. Similar to APTA's calculations for the mode shift factor, which increases in scale based on tiered population levels, a typology for the land-use multiplier could provide a more specific estimation based on easily attainable demographics such as population.

In the development of a land-use multiplier typology, a logical starting place is to account for local population, population density, and passenger revenue miles. These factors are the primary

ones in the other APTA calculations, so the data is readily available. Also, these are factors that have been shown to have a widespread effect on transit leverage. Population is a major factor as it frames the size of an urban region, and generally, the larger the city, the more opportunities become available with increased transportation. Population density has been found in several studies to be a major factor in transit leverage, as discussed in earlier sections. Density allows urban infrastructure to be accessed by many more people, conducive to commercial centers and job clusters. (Holtzclaw, 1991; Newman and Kenworthy, 1999). Finally, passenger revenue miles provides insight into the scale and effect of a transit system on local commuters. A populous region low passenger revenue miles, such as Los Angeles, will likely have a low land-use multiplier, as the public transit system is not a major means of transportation. However, high passenger revenue miles suggest that the system is of great importance to a regions commuters and the absence of such a system would have much greater effects on congestion and alternative transit.

During the transit analyses of three Kentucky cities, Jack Faucett Associates developed a such a typology to more accurately calculate the land-use multiplier. The typology uses data from the National Transit Database to classify a land-use multiplier based on population, population density, and passenger revenue miles. The typology was calibrated based on the past research in order to maintain consistency with empirical evidence that has placed the land-use multiplier, largely between 1 and 9.

Table 2. Sample transit land use multiplier typology developed by Jack Faucett Associates

		Very small	Small	Medium	Large	Very large
Measure	Range	A	B	C	D	E
Passenger revenue miles	From	1	50,000,001	150,000,001	500,000,001	5,000,000,001
	To	50,000,000	150,000,000	500,000,000	5,000,000,000	25,000,000,000
Population	From	1	50,001	500,001	1,000,001	10,000,001
	To	50,000	500,000	1,000,000	10,000,000	25,000,000
Density	From	1	1,251	2,501	3,751	5,001
	To	1,250	2,500	3,750	5,000	15,000
Land Use Multiplier	**From**	**0**	**1**	**2**	**5**	**7**
	To	**1**	**2**	**5**	**7**	**9**

While this basic typology does help to tailor land-use multipliers around specific demographic figures, there is still room for improvement. Incorporating additional factors into the typology would provide a more accurate analysis of the local conditions and the effect of public transit on the urban region. Additional factors that could be considered are the type of public transit, the proximity to other urban centers, and measures of economic development such as real estate prices and job cluster density. The type of public transit is a relevant factor, because it can influence the level of confidence that businesses and residents have in the stability of public transit. A rail station is a far more permanent investment than the routes of a bus line, so while buses may help remove cars from the road, they will not reduce congestion or encourage dense economic development to the same degree as a rail lines. Proximity to another urban center should be considered because of public transit's ability to link urban areas. Public transit connecting suburban peripheries to larger urban centers present opportunities for local residents to commute into the city for work and recreation. Therefore, public transit that connects to a much larger population and commercial center would likely have greater land-use multiplier than in a city of similar size that is isolated from other urban centers. Finally, a measure depicting the state of the local economy, through real estate prices or local sales volumes, would

represent the ability of the local community to support denser urban development, commercial regions and job clusters.

EXPERIENCE IN KENTUCKY

To perform a transit leverage analysis as part of the Kentucky Climate Action Plan, Jack Faucett Associates Inc. developed TARGGET (Transit Associated Reduced Greenhouse Gas Emission Tool). TARGGET is used to conduct energy and GHG reduction potential analysis for transit agencies consistent with the APTA-recommended practice.

TARGGET is an analytical, spreadsheet based tool designed to estimate a community's Greenhouse Gas (GHG) emission reductions as a result of an increase in transit services. A fully customizable tool, it can be utilized as part of a GHG inventory and forecast effort or as a tool to better understand the impacts of community level transit planning options.

The Kentucky Climate Action Plan proposed supporting an increase in transit use in order to reduce the continued growth of VMT. The goal for the proposed transit strategy was to increase transit ridership in the state by 100% from 2010 levels by 2020, and an additional 150% by 2030. The scenario was modeled by increasing transit passenger revenue miles by 100% between 2011 and 2020 and 150% between 2011 and 2030.

Using the strategy goal, the associated GHG emission reductions were estimated using the APTA method. As mentioned earlier, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit agency passenger revenue miles and service area population and density. This allows the analysis to develop Kentucky-specific estimates.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA). Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is also used to estimate gallons of fuel saved and the associated reduction in GHG emissions.

Mode shift was estimated by taking current and projected transit passenger revenue miles and multiplying them by APTA's mode shift factor based on transit service region population.

Congestion relief was estimated by taking current and projected transit passenger revenue miles and multiplying them by APTA's congestion relief factor, which is derived from the Texas Transportation Institute's 2009 Annual Urban Mobility Report. The Urban Mobility Report provides congestion profiles and factors for cities based on size. Land use leverage was estimated using the TARGGET tool, instead of APTA's national default land use leverage factor. TARGGET uses transit service area population, density, and passenger revenue miles to develop unique, Kentucky-specific land use leverage factors for each year and for each local transit agency to account for changes in population, density, and passenger revenue miles.

The table below provides transit-displaced VMT, GHG emissions, and fuel use in the Kentucky analysis. The table also compares the expected VMT reduction against Kentucky's statewide VMT estimates.

Table 3. Transit-Displaced VMT, GHG Emissions, and Fuel Use

Year	VMT Reduced	Emissions Saved (tCO2e)	Gallons of Fuel Saved	Kentucky Inventory VMT Baseline (Millions)	Scenario's VMT Reduction off KY Inventory Baseline (%)
2011	11,200,183	7,373	672,396	48,651	0.0
2020	138,061,123	74,252	6,785,369	51,998	0.3
2030	329,735,817	149,313	13,685,396	55,677	0.6
Total for 2011-2030	3,114,953,312	1,561,454	142,891,178	1,043,529	0.3

GHG = greenhouse gas; tCO_2e = metric tons of carbon dioxide equivalent; VMY = vehicle miles traveled.

The estimated GHG reductions, energy savings, net present value, and cost-effectiveness of Kentucky's proposed transit strategy are summarized in the table below. The strategy was found to reduce VMT, fuel use, and GHG emissions. While transit systems often have significant capital costs, the share of system expansion costs allocated to transit-displaced GHG emissions activities in Kentucky would be mostly offset by fuel cost savings and vehicle ownership and operation cost savings from mode shift, congestion relief, and land use leverage.

Table 4. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of Proposed Transit Investment

Quantification Factors	2020	2030	Units
GHG Emission Savings	–0.07	–0.15	$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)		1.56	$MMtCO_2e$
Energy Savings (2011-2030)		–143	Millions of gallons
Net Present Value (2011–2030)		$110	Millions of 2005$
Cost-Effectiveness		$71	$/tCO$_2$e

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

CONCLUSION

The APTA methodology to measure transit leverage can be used in tandem with the Department of Transportation's National Transit Database (NTD) to develop quick and cost-effective estimates of transit leverage for all transit agencies listed in the NTD. This advancement can be used by policy decision makers to estimate fuel use and greenhouse gas emissions reductions achievable through changes in transit supply policies.

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