“Carbon in Motion 2050” for North America and Latin America
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EXECUTIVE SUMMARY

Transportation contributed nearly 25 percent of global anthropogenic carbon dioxide (CO_2) emissions in 2007. The level of emissions depends on the distances people and goods travel, the modes with which they use, the fuel consumed per kilometer moved and the CO_2 associated with each fuel. Different developed countries have complied to different levels of emissions reductions targets, while developing countries are not subject to any national agreement to reduce their emissions levels. For the United States, President Obama has pledged to reduce CO_2 emissions between 14 percent and 17 percent by 2020 from 2005 levels and has set a goal to reduce 83 percent of emissions by 2050, implying a 30 percent reduction below 2005 levels in 2025 and a 42 percent reduction below 2005 in 2030 (The White House, 2009). Meeting these targets would help prevent further increases in global temperature and environmental degradation. As this paper will show, with modest changes to current transportation trends and efficient vehicles powered by alternative fuels that release approximately a third less CO_2 per unit of energy than today, CO_2 emissions in 2050 will be at 2005 levels for Latin America and 50 percent of 2005 levels for North America (ICCT, 2010; Schipper et al., 2009). While this North American level is well below 1990, it is very high globally on a per capita basis.

A more ambitious target analyzed in this study would give both regions half of the global per capita emissions average of 315 kg/capita, consistent with many public calls for very large great cuts in emissions. We find it possible to arrive at this low target for the Americas, but only with relatively large cuts in automobile and air travel in North America and an almost 90 percent decline in the CO_2 emissions per passenger- or tone-km of the main modes of light duty vehicles and trucking, a 75 percent decline for air travel, as well declines in transport activity in these modes. Without a liquid fuel source with extremely low CO_2 emissions used in very efficiency vehicles, these very stringent targets are unlikely to be met.

Recognizing that reducing emissions against a rising trend means taking a long-term view, this study has developed two scenarios, “Globalization” and “Glocalization,” for low carbon transportation development in North America (United States and Canada) and Latin America by 2050. The scenarios illustrate how different policy assumptions and energy intensities could reduce transportation CO_2 emissions in North and Latin America. In Globalization, strong international cooperation to decrease CO_2 emissions leads to innovations in vehicle technologies and stricter standards, while in Glocalization, local concerns for reducing transportation problems lowers distance traveled and shifts travel to less CO_2 intensive modes, through significant changes in land use and other planning policies.

Using data on energy intensities, transport activity by mode, and basic population and GDP projections from ICCT (2010) and IEA/SMP (Fulton and Eads, 2004) respectively, as inputs for our scenarios, we have found that in Glocalization, total transportation CO_2 emissions in 2050 could be approximately 78 percent less than in the "Business as Usual" (BAU) scenario for North America and only 34 percent of 2005 level. For Latin America, CO_2 emissions in 2050 could be approximately 76 percent less than BAU, but 71 percent of 2005 level. The 2050 Latin American emissions of CO_2 emission would be about half of what North America will emit in 2050. Compared to emissions in 2005, these regions' absolute levels fall by 70 percent and 50 percent respectively.

The somewhat greater reduction in emissions in the Globalization scenario is due to improvements in fuel efficiency and about a one-third reductions in the carbon content of a unit of fuel, measured over the life cycle of the fuel. However, shifts in transportation mode are limited, and there is only a small reduction in distance traveled for passenger and freight in North America, with some growth in Latin America. Compared to BAU in 2050, Globalization results in 72 percent less total emissions in North America and 54 percent less in Latin America. Compared with 2005, these declines are 75 percent and 51 percent respectively. The larger differences in the BAU and 2005 comparisons for Latin America arise because BAU foresees much stronger growth there than in North America as Latin American continues to motorize in either scenario, albeit much slower than in BAU.

By themselves, the technology improvements in the Globalization scenario reduce emissions by 50 percent in North America compared to 2005, and return emissions in Latin America at the 2005 level. Because the Glocalization scenario does not include a strong international effort to reduce CO_2 emissions, that scenario does not see the reduction in the CO_2 emissions of a unit of energy seen in Globalization.

The scenarios indicate that if transportation emissions are to be effectively decreased, it is not enough to simply reduce vehicle emissions per kilometer. It also is not enough to simply apply the auto restraints, mode shifts, and urban development strategies. In order to meet target reductions, aggressive technology improvements will have to be coupled with efforts to redirect growth in transportation activity away from its present domination by cars, air travel, and trucking. This would require the implementation of complementary policies that will encourage changes in land use planning and transportation investment to enable greater demand for low-carbon modes, such as mass transit, rail transport and non-motorized transport, and fiscal policies that will readjust transportation costs across different modes.

Three main policy groups are assumed to trigger modal shifts and trip reductions in our scenarios: Transportation Technologies and Strategies, Land Use Planning and Pricing Instruments Design. The levels of shifts we assume are consistent with findings from the literature, i.e., there is evidence that such shifts are feasible. Nevertheless, this confluence of strong policies from different spheres would call for an unprecedented level of local, regional and national planning, together with infrastructure development, combined with low energy vehicles and lower carbon fuels. Scaling up planning and investment to support this change is a major challenge to planners at every level if changes in land uses and transportation patterns are to contribute and bring the world to a low level of emissions around 2050.

The changes envisaged in these scenarios differ for the very highly motorized North America and the less motorized Latin America. North America must bring about reductions in total distance traveled in cars and by air, while Latin American has room to expand car use and air travel, albeit not enough room to expand at previous rates. Both regions must adopt very low-carbon technologies as well, but this may be easier in Latin America because there is far less capital sunk in a carbon intensive transport system for travel.

CONTENTS

INTRODUCTION

Transportation and Greenhouse Gas Emissions

The transportation sector contributes a significant amount of greenhouse gas (GHG) emissions globally, especially carbon dioxide (CO_2) emissions. This is a sector that has grown rapidly for the past two decades, the result of increases in urban population growth, economic development, demographic and income changes, and changes in land use and urban planning, which have all led to higher levels of urban transportation activities.

The transportation sector contributes approximately 23 percent of total global CO_2 emissions almost all from fossil fuel combustion (IEA, 2009b). The share of total greenhouse gas emissions (CO_2, methane, NO_2) is lower, about 13 percent in 2006 (CAIT, 2010).

The percentage of CO_2 emissions due to transportation is higher in Latin America (34.5 percent in 2007) than in the United States and Canada, which averaged approximately 31.2 percent in 2007 (IEA, 2009b). Latin American countries also had a higher percentage of transportation CO_2 emission level in 2007 on average than all other sectors (IEA, 2009b). Further, the absolute level of transportation emissions has been predicted to keep growing over the next few decades unless measures that encourage an alternative transportation development path are implemented (IEA, 2009a).

Study Objective

This study focuses on transport emissions of CO_2 in two regions, Latin America and North America (defined as the U.S. and Canada in this paper). The study documents transportation trends and CO_2 emissions likely to result existing and future policies. The goal of the study is to test scenarios of plausible changes in both transport activity and vehicle technology and-fuel combinations to explore what combination of technological changes, mode shifts, lifestyle and other changes that affect transportation would bring emissions in North and Latin America down to a lower level by 2050. The study illustrates plausible outcomes based on current development and future constraints with general references to policies and trends that could point to the outcomes.

The study is one of a larger set of regional studies on the topic. Two main scenarios, Globalization and Glocalization, have been developed for each study region, illustrating what and how different levels of CO_2 will be reached by 2050, given the various policy assumptions in place. The target emissions levels in the two back-cast scenarios are based on a world of equal per capita shares of emissions based on 50 percent of the 2000 value, which works out to 315 kg/capita of CO_2 from direct combustion. In the second set of projected scenarios, we projected levels of travel and freight activity by mode, which were combined with detailed technological projections of efficient vehicle technology and low-carbon fuels to give emissions in 2050. The same scenario logic was used, but there was no deliberate attempt to hit a particular target.

In a globally oriented world (Globalization), a high level cooperation on CO_2 concerns leads to rapid improvements in both vehicle technologies and the decarbonization of some propulsion sources, with modest reductions in current trends of motorized travel and freight. In a second world (Glocalization), there is much less international cooperation; so that technological progress will reduce carbon emissions from business as usual less than in the previous scenario, but local concerns for reducing transportation problems and internalizing many externalities result in considerably lower growth in air and car travel and to some extent freight shipping.

ITPS also suggests different approaches to governance. One is called "Independent autonomy" and appears to hold fewer regulations and other stimuli than the other, which is called "Restrictive Society". While it is not possible to generalize, we believe that the "Independent autonomy" is more likely associated with massive technological change, while the "Restrictive Society" could be associated with policies that provoke behavior changes, particularly changes in travel patterns, and, from an economy-wide perspective, the patterns of trade in goods and materials.

As noted above, two sets of calculations have been developed to examine whether and how the Glocalization and Globalization scenarios could affect CO_2 emissions from transportation in North and Latin America. First, we back-casted levels of travel and freight that, together with very low carbon intensities of freight and travel modes, combine to give total emissions of CO_2 that met or came close to the target specified. Meeting the stringent targets for North America would be very difficult, because 2005 per capita emissions levels are around 16 times greater than the target. Only a combination of large declines in automobile and air travel, modest declines in total freight hauled, automobile CO_2 emissions per passenger kilometer at the cutting edge of technology and large reductions in emission per passenger- or tonne-km in other modes could satisfy the target. Meeting the stringent targets for Latin America was more plausible, but still challenging, since present levels of travel and freight have emissions of 7 times the per-capita "targets." However, with limited growth in travel by automobile and air travel (compared to historical trends) and much lower emissions per passenger- or tonne-km in all modes, Latin America could meet this target.

A different approach was then developed by creating a second set of calculations "bottom-up." We projected travel and freight activity by mode, based on literature and plausible changes from business-as-usual projections, which are described in the following sections. The "emissions intensities" used in this study were calculated by the International Council for Clean Technologies (ICCT). These intensities consisted of ratios of fuel use and CO_2 emissions to vehicle-km, passenger-km, or tonne-km, depending on the transport mode and represent the ICCT's assessment of plausible values within the range of technologies expected. By combining these emissions intensities with our own estimates of transport activities, we produced CO_2 emissions that are still above the targets suggested by ITPS, but well below business-as-usual projections. In cases where projections were made based on vehicle utilization (i.e., per tonne-km or passenger-km), the utilization (in passenger or tonnes-vehicle) were estimations were made by the UC Berkeley team.

Scenarios are often employed to illustrate uncertainties about view of the future or provoke ideas that cannot emerge from projections alone (Schwartz, 1996). These have long been applied to project future transportation trends and their subsequent CO_2 emissions (OECD, 2008). The "quantification" that follows from discussing scenario logic is not transport or energy modeling. Rather scenario logic is used to justify the "what if" proposals that can be described with calculations. With the scenarios come assumptions about technologies, individual behavior, economic activity and even policies and why these differ from one scenario to the next.

In constructing scenarios, scenario logic could propose a world in which very advanced, small, low emission vehicles would be brought forth and accepted, or one in which major shifts to collective transport took place. By using scenarios, futures that are not the outcome of present trends or changes in trends supported by policy and technology changes are currently under discussion. For the purposes of achieving a low-carbon transport system, back-casting scenarios lead to calculations that force the reader to ask whether the policy or technology conditions required could occur. Scenarios, together with their respective sets of policies and measures assumptions, can be used to inform policy design or to evaluate policies to modify transportation demand, reduce carbon emissions level and achieve reduction goals in the long term. In the end, however, changes only come when policies are implemented and actually affect vehicles, transportation costs, financing of infrastructure etc., as well as the behavior of individuals and firms, particularly for freight movements.

A note on definitions in this study: the term "North America" includes only the United States (U.S.) and Canada, while "Latin America", as a region, includes Mexico, Central America, South America and the Caribbean (which is strictly speaking not Latin America). This departs from the standard continental definition that includes all countries south to Panama in the North America, but is consistent with economic divisions (i.e. "Global North" and "Global South"). This definition recognizes the significant effect that income has on transportation activity and technology opportunities.

In support of this definition, we note that while Mexico is a member of OECD, its GDP per capita is only about a quarter of the U.S. and Canada's, and is only slightly different from that of Chile and Argentina, and is modestly higher than that of Panama and Uruguay. For this and other reasons, we strongly believe that Mexican transportation patterns fit better with those of Latin America, and that the policy and technology opportunities for Mexico are closer to those of the rest of Latin America than to those of much more motorized North America. Although estimated 2005 transportation activity levels, fuel use, and emissions provided by ITPS included Mexico with North America, we combine Mexico and the rest of Central America plus the Caribbean nations under the category Latin America based on motorization levels and transportation development.

Both passenger travel and freight transportation are included in this study. Travel includes light duty vehicles (cars, household light trucks or pickups, and SUVs), all forms of bus and passenger rail travel, and domestic air travel. The modes of freight transportation included in this study are heavy and medium truck freight transport (projected separately but reported together), domestic water-borne shipping and rail. Air freight is not considered, first because of inadequate reliable data and also because it carries a significantly smaller share of tonne-km than other modes in both North and Latin America. The energy for air freight is implicitly contained in the estimates for air passenger transport. Shipments of oil, gas and coal by pipeline are excluded because of data problems, although the former represent nearly 20 percent of all tonne-km shipped in the U.S. (BTS, 2009).

The "base case" in this study includes two parts: data on travel and freight activity, energy use, and emissions by mode for 2005, and business-as-usual (BAU) projections of these emissions for 2050. Our data for North America (U.S. and Canada) are from the official sources of the U.S. Department of Transportation, U.S. Department of Energy, Natural Resources Canada and Transport Canada. Alternative information available from the Sustainable Mobility Project (SMP) (Fulton and Eads, 2004) was judged to be incomplete for rail, bus and air travel, and had no data on water-borne freight.[1] For Latin America, we originally planned to use data from the SMP, supplemented by published information from the International Energy Agency's "MoMo" model (Fulton et al., 2009). However, we found that these data severely underestimated trucking and bus activity for Mexico, and also overstated air travel for the region by including international departures. Therefore, we used data from Mexican and Brazilian Government sources combined with the SMP estimates of automobile and other light duty vehicle use for the Latin American region and Mexico instead[2]. Data for "other Latin America" countries were extrapolated on the basis of population and GDP.

Non-motorized travel (NMT) is not treated explicitly in this work. However, it may be assumed that NMT plays an important role in both of the scenarios developed in this work, particularly as a substitute for commuting or short automobile trips, which are very fuel intensive.

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[1] Mexican data (www.inegi.org.mx) show there are almost 10 times more bus travel than indicated in SMP (IMT, 2007).

[2] Note that there are no "data" from surveys, vehicle counts or odometer readings for automobile use or automobile travel at the national level of any major Latin American country. SMP developed reasonable estimates based on literature and discussions with experts. However, inspection of Mexican transportation data (www.inegi.org.mx) reveals that the fuel use assigned to aviation includes international air departures for Mexican's companies activity that is not included in this study, while the passenger-km registered are only for domestic travel. For Brazil, aviation data appear to give domestic travel and domestic-only fuel use. Because of these inconsistencies, we have made data adjustments. Multiplication of Mexico's domestic air travel times the modal energy intensity of North American air travel was used to approximate Mexico's energy use for air travel. In all, the 2005 data for Latin America must be taken as an approximation.

The reference projections for BAU generally follow the SMP growth rates. Where SMP over or underestimated activity in any mode for 2005, the 2005 data were adjusted and then projected at the same overall growth rate as in SMP. Overall the 2050 BAU case is given mainly as a reference point to show how much change the two scenarios would require from current trends, even though the future projections included considerable efforts to improve transportation energy use efficiency and reduce its dependence on fossil fuels (Fulton and Eads, 2004; Fulton et al., 2009).

By convention, the measurements of emissions are both tank-to-wheels, i.e. direct, from combustion only, and wells-to-wheels emissions, i.e. CO_2 from preparation of fossil fuels, biofuels, or electricity used by each vehicle mode included in a life-cycle analysis (Chester, 2008). The values given for direct or LCA emissions were calculated by the ICCT. Multiplying these values by the transport activity levels developed in this study gave the total LCA burden for each mode. Not included are the fixed infrastructure requirements associated with individual vehicles or modes, vehicle or infrastructure or other smaller activities related to transport, such as provision of insurance.

Chester (2008) finds that for individual vehicles, combustion and the fuel cycle to produce the fuels (or electricity) ultimately used in vehicles represents around 90 percent of the "total" emissions related to transport. However, for large, capital-intensive systems like highway construction, heavy rail or high-speed rail, the CO_2 associated with building the complete system may be much more important. For heavily utilized systems, such as rail systems in Japan, France, or Germany, these investment-related emissions are amortized over so much passenger–km that they wind up being small compared to the emissions for operating the system. These and other definitions are presented in Table 1 for reference.

Table 1: Terms and Definitions Used in the Calculations

Term	Definition	Examples	Notes
Travel Activity	Distance a passenger travels in passenger-km	Main modes: light duty vehicles (cars and light trucks, bus, rail, and air)	Values projected from 2005 "actual values", or developed in 2050 back cast.
Vehicle Occupancy	Number of passengers in a vehicle or passengers per vehicle-km	2 people/car; 140 passengers per aircraft	For air and rail travel, can be expressed as percentage of total passenger capacity actually utilized or sold
Freight Activity	Distance a given weight of freight is shipped, in tonne-km	Main modes heavy and medium trucks, rail, and domestic shipping (water-borne)	As with travel activity
Loading or Load Factor	Tonnes carried per vehicle-km		
Emissions	Emissions of CO_2 and other greenhouse gases in Metric tonnes of CO_2 equivalent	Direct (Tank to Wheels [TTW] or tailpipe) emissions from combustion	Emissions from combustion only
		Life cycle (Well to Wheels [WTW], LCA or upstream) emissions	Emissions that include those for preparing fuel or electricity
Energy and Fuel Content	Energy in megajoules (mJ) per unit volume of fuel, measured at lower heating value	Gasoline has 33.5 mj/liter; diesel 36.1 mj/liter; aviation kerosene 37.1 mj/liter (source IEA)	Source IEA. Values may vary from country to country. Values vary slightly by fuel grade. Lower heating value excludes energy that evaporates moisture in fuel

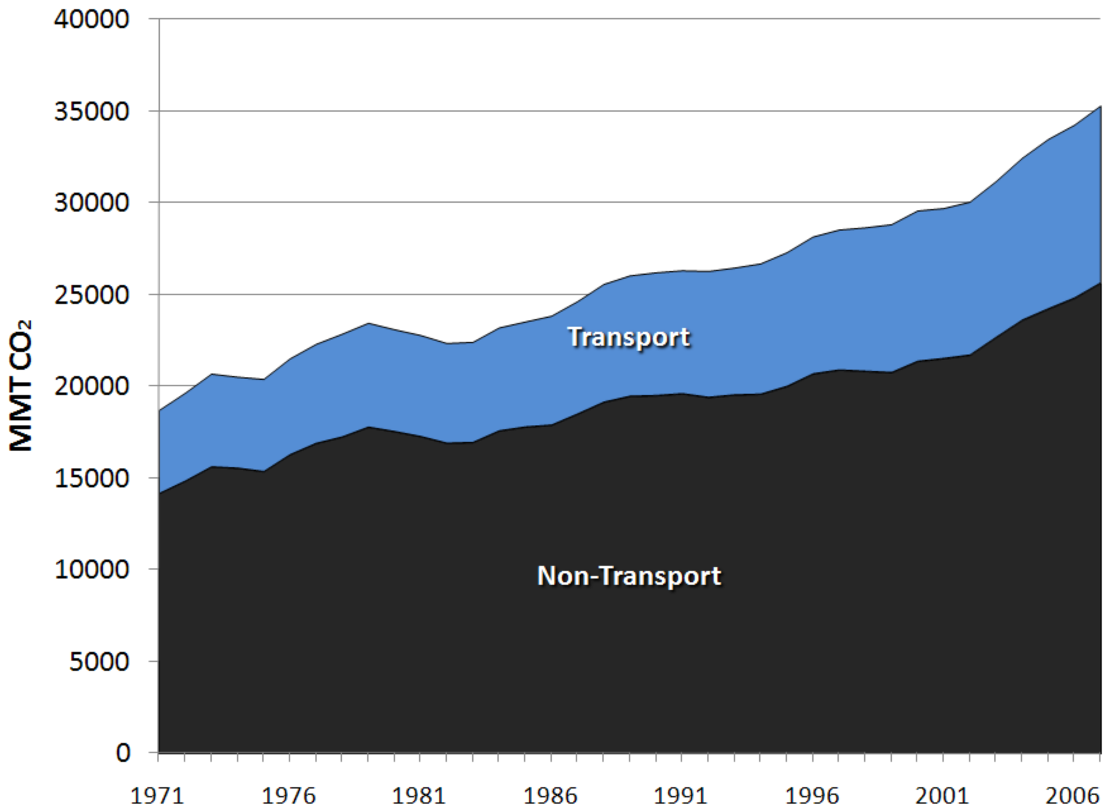
Table 1: Terms and Definitions Used in the Calculations

Term	Definition	Examples	Notes
CO_2 Content of fuels	Grams/megajoule (gm/mj) of fuel in combustion	Gasoline has 69.3 gm/mj; diesel 68.7 gm/mj; aviation kerosene 64.5gm/mj	Source IEA. Values vary slightly by fuel quality and country.
Vehicle Energy Intensities	Energy use per vehicle-km	Liters/100 km	Used for road vehicles only. Gasoline assumed to be the fuel unless otherwise noted
		Mj/vehicle-km	Can apply to all vehicles, but used in this study primarily for road vehicles
		Mj/seat-km	Used to represent the fuel intensity of buses, passenger rail trainsets and airliners.
Vehicle Carbon Intensities	CO_2 Emissions per vehicle km	Grams/vehicle-km	Given as vehicle fuel intensity x CO_2 content of fuel. Cites for direct (combustion), or TTW only
Modal Energy Intensities	Energy use per passenger or tonne-km	Mj/passenger-km or mj/veh-km	Uses net heating values of fuels
Modal Carbon Intensities	CO_2 emissions per passenger or tonne-km	Grams per passenger or tonne-km	Given in life cycle analysis (LCA) values unless noted otherwise

CURRENT TRENDS

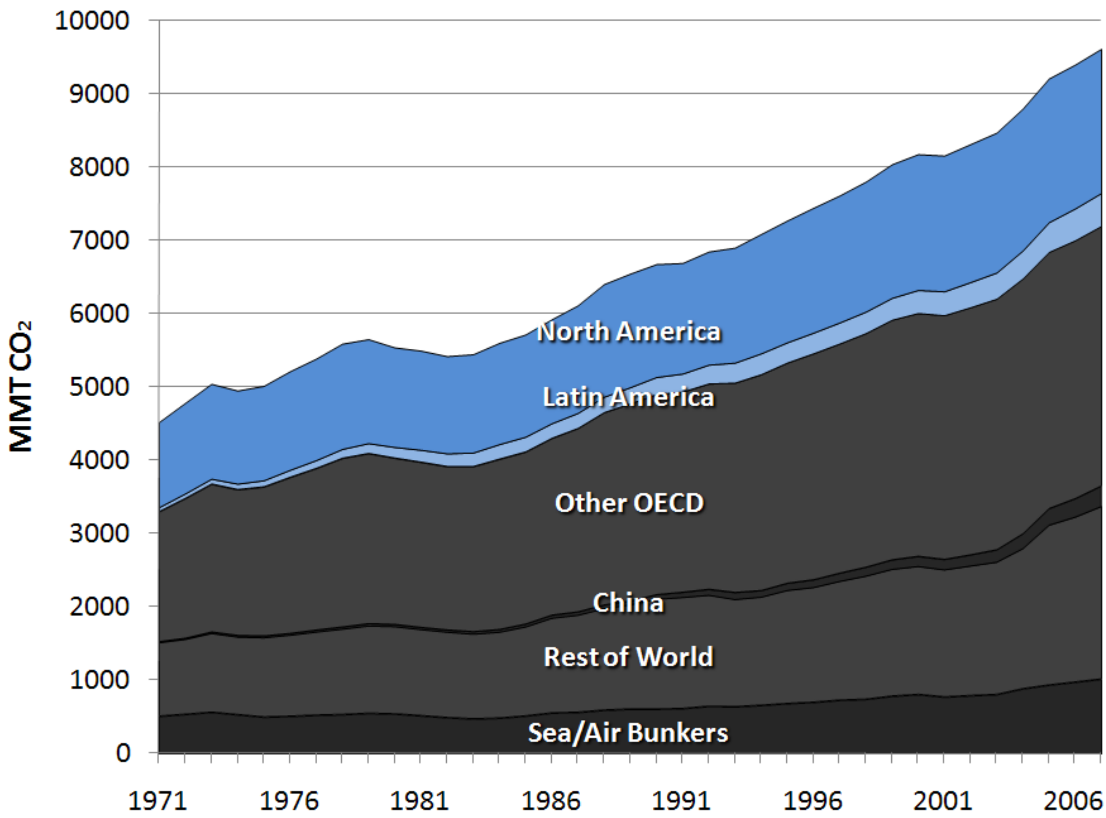
Since 1971, transportation's share of global CO_2 emissions has risen almost steadily and, as of 2007, has reached 23 percent of total global emissions, as shown in Figure 1.

Figure 1: Global CO_2 Emissions, Transport and Non-transport



At the same time, there exists significant regional variation between North America, Latin America, other OECD countries, China, and the rest of the world. Out of all these regions, North America (defined as the U.S. and Canada in this report) has, and has historically had, the largest share of transport emissions, while Latin America has a small share, as shown in Figure 2.

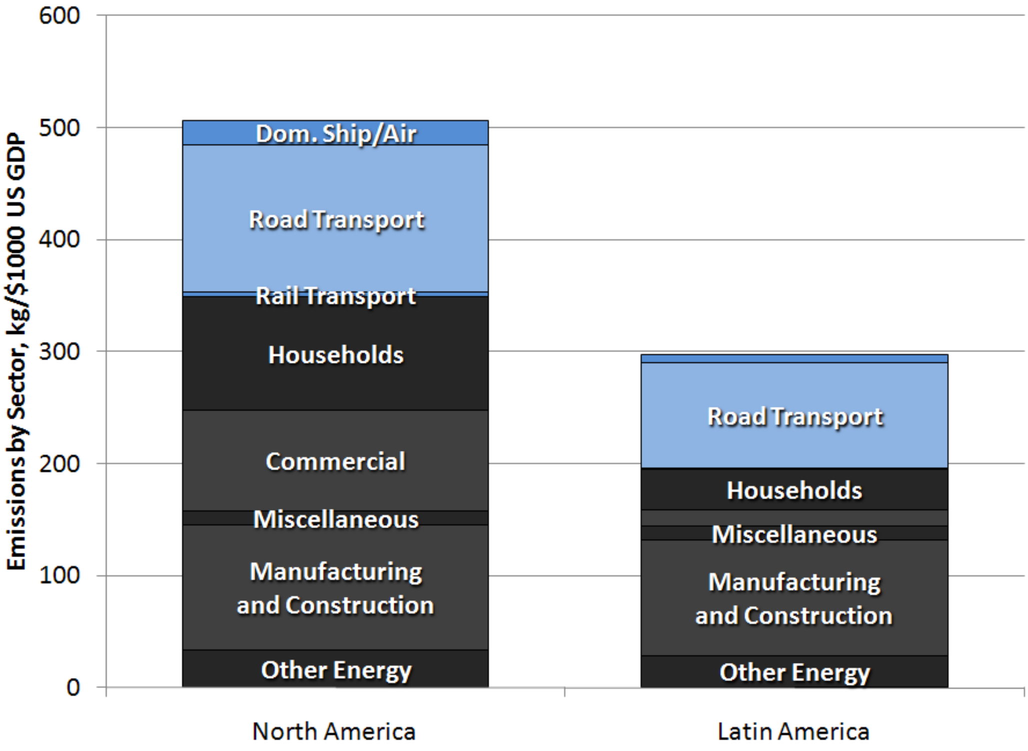
Figure 2: Global Transport CO_2 Emissions, by Region



This disparity between the two study regions is further highlighted when an accounting is made for Latin America having approximately 1.6 times the population of North America. Freight emissions in North America are 4 times higher per capita than in Latin America, with travel emissions per capita nearly 11 times higher.

Along with population, GDP is a useful normalizing tool to adjust for economic disparities between regions. Figure 3 shows CO_2 emissions for Latin America and North America in 2007 by sector, GDP-normalized, with electrical power emissions assigned to the relevant sector.

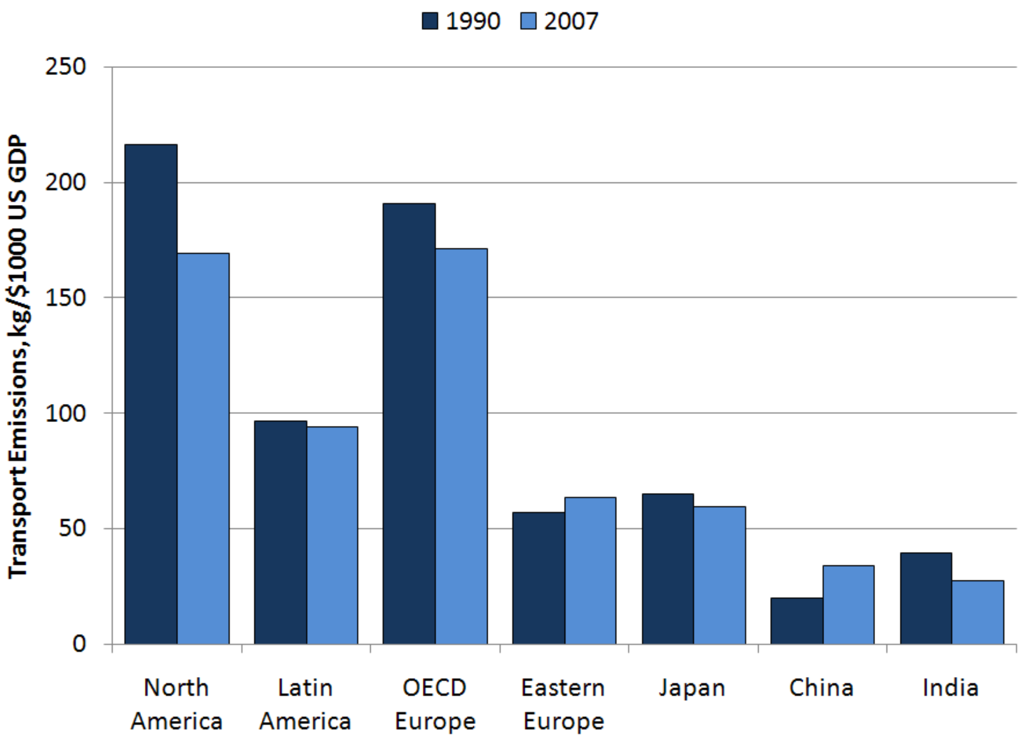
Figure 3: CO_2 Emissions for North and Latin America by Sector in 2007



The importance of transport in both regions is clear, as is the dominance of road transport. When account is taken of differences in per capita GDP, emissions from Latin America for all transport (and particularly road transport) is among the highest among developing countries, but still lower than Europe or North America. Road transport represents a full one-third of the total CO_2 emissions in Latin America, higher than the world average share and higher than the North American share. This is due not only to the relatively high motorization in Latin America, but also to the low usage of coal in other sectors and high usage of hydroelectric power (and biomass/ethanol in Brazil).

Figure 4 puts the two regions in a global and temporal context, showing the CO_2 emissions for road transport (light duty vehicles, buses, trucking, and two wheelers) per unit GDP. Most regions have seen a decrease in emissions per unit GDP since 1990, with the exception of Eastern Europe and China, North America has the highest ratio among developed countries, but that ratio fell between 1990 and 2007. This was largely because travel and freight activity did not keep pace with GDP while the fuel economy of cars, trucking, and air travel improved (Schipper and Sudarshan, 2010). Latin America's ratio, while lower, is the highest among non-oil-producing developing regions and held nearly constant during the 17 year period depicted.

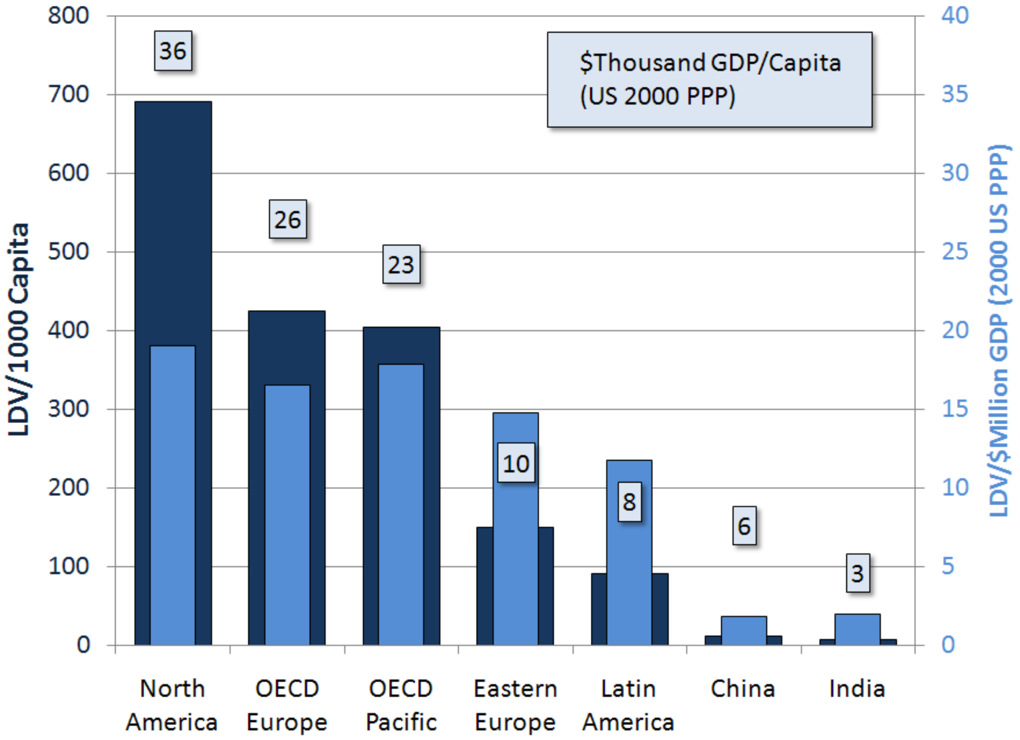
Figure 4: 1990 and 2007 CO_2 Emissions for Road Transport per Unit GDP by Region



Note: 1990 data for India are 1996; there are no 1990 data for road transport only.

Figure 5 shows light duty vehicle (LDV) ownership in different regions of the world in 2005 relative to both population and GDP. Latin America had a per capita ownership of light duty vehicles of 86 vehicles per 1,000 people (mostly private cars, SUVs, and light trucks), higher than other developing regions including the Middle East and Africa. It is this high LDV ownership that accounts for the high road transport CO_2/$GDP for Latin America and the same is true for the U.S. and Canada (Schipper et al., 2009). In both regions on road fuel intensity was greater than 11 l/100 km in 2005; for North America the reason is the large size of cars, while for Latin America the poor traffic conditions work against the fuel economy benefits of smaller cars.

Figure 5: Light Duty Vehicle Ownership Measures and GDP/Capita, 2005, Selected Regions



Notes: 10-20% of these light duty vehicles are commercial vans or pickups.

Source: IEA MoMo Database (IEA, personal communication, 2009).

Transport emissions are dominated by the road sector (about 75 percent for North America and 85 percent for Latin America), with air travel, rail shipping accounting for the rest. Table 2 and Table 3 give a breakdown for North America and Latin America, respectively, for 2005, based on official U.S. and Canadian data, as well as the Sustainable Mobility Project for Latin America including Mexico[3].

Table 2: Estimated Urban Emissions by Vehicle Type, North America 2005

Passenger Mode	Total Emissions ($Mt\ CO_2$)	Urban Emissions ($Mt\ CO_2$)	Freight Mode	Total Emissions ($Mt\ CO_2$)	Urban Emissions ($Mt\ CO_2$)
LDV	1336	962	Heavy Truck	358	36
Bus	34	20	Medium Truck	119	24
Rail	7	6	Rail	118	0
Air	292	0	Water	53	0
Total	**1668**	**988**	**Total**	**648**	**60**

Table 3: Estimated Urban Emissions by Vehicle Type, Latin America 2005

Passenger Mode	Total Emissions ($Mt\ CO_2$)	Urban Emissions ($Mt\ CO_2$)	Freight Mode	Total Emissions ($Mt\ CO_2$)	Urban Emissions ($Mt\ CO_2$)
LDV	189	151	Heavy Truck	147	15
Bus	54	35	Medium Truck	86	17
Rail	2	1	Rail	3.5	0
Air	14	0	Water	41	0
Total	**259**	**187**	**Total**	**279**	**32**

The Americas are among the regions with the highest rates of motorization (light duty vehicle ownership) in the world and have correspondingly high emissions from road transport. At the same time, North America has eight times more LDV/capita than Latin America. This suggests that while strategies to reduce CO_2 emissions from transport in North America must involve reductions in LDV use, similar goals can be achieved in Latin America even with a modest increase in LDV use. Still, that increase has to be slower than GDP. From 1990 to 2007 road transport emissions in Latin America almost tracked GDP while they fell in N. America. That Europe has half the light duty vehicle ownership and

[3] The SMP list over 500 passenger-km/capita of air travel for Latin America. This seems highly unlikely for domestic flying. Mexican and Brazilian sources give far lower figures (<200 p-km/capita) for the two largest countries of Latin America with the most well developed air travel networks.

car use per $ of North America at least suggests that there is no unique level of car ownership among wealthy countries.

Freight transportation plays a major role globally in contributing to total CO_2 emissions. Road freight alone currently consumes about 25 percent of total worldwide transportation energy use, 16 percent by heavy trucks and 9 percent by medium trucks (Fulton and Eads, 2004). Rail transportation, on the other hand, is only responsible for 1.5 percent of global transportation energy use, even including the primary energy associated with electricity production for rail (Fulton and Eads, 2004). A similar trend is reflected in North America and Latin America, where in 2005, heavy trucks and medium trucks contributed approximately 17 percent and 7 percent of total transportation CO_2 emissions respectively, while rail contributed merely 2 percent.

In North America, national freight transportation is dominated by rail, and heavy trucks, utilizing extensive and well-developed highway and railway networks. In Latin America, which includes Mexico, Central America, and Brazil South America, domestic rail networks are relatively small. Consequently, freight transportation is heavily dominated by heavy trucks (despite sparse and under-developed road networks.) Water transportation in North America is also significantly higher than in Latin America. In 2005, total freight shipped (tonne-km) in Latin America was about one sixth of the level in North America, but as Latin America develops, freight transportation is projected to continue to grow.

The data in Table 2 and 3 also illustrate both where transport activity takes place and how its emissions are split between travel and freight. In Latin America, intercity passenger travel is by air, rail and to some extent by light duty vehicle. In the US and Canada, it is mostly by auto and air, with a small share of rail and bus travel. Likewise automobiles are used for most urban trips in the US and Canada. In contrast, Latin American uses buses and rail for most of their motorized urban travel.

Urban based freight activity includes only a small amount of activity with heavy trucks, but a significant amount of medium and light truck use for distribution. For North America, emissions for passenger travel exceed those for freight by more than a factor of 2, and the estimated emissions for urban based-traffic dominate both travel and the total. For Latin America, the heavy reliance on truck-based freight and the modest use of cars means truck emissions slightly exceed emissions from cars. Since freight is almost all from non-urban traffic, Latin American emissions from non-urban areas exceed those estimated to arise in urban regions.

The division between urban-based transport, and that taking place between urban regions or entirely in non-urbanized areas, however rough, is important. One reason is that urban centered trips tend to be shorter and often on collective modes (rail, bus) in dense built up areas. This division is also important because urban-based car trips tend to be shorter than those in rural areas or between urban areas. The higher the share of local travel, the larger the impact of a shift to short-range electric vehicles, whether based on batteries or other forms of storage (NAS, 2009). Additionally, high population density in urban regions makes electric traction for rail and trolley bus economically attractive by spreading the costs of rails and/or electric trolley lines over large numbers of riders.

An equally important issue for analysts is dividing transportation activity and corresponding energy use between freight and travel. Factors driving travel activity and its fuel use, such as GDP, fuel prices differ in how much they affect travel vs. freight activity, mode choice, and fuel choice and fuel intensity. Factors like urban form probably have a much larger impact of fuel use for travel than for freight, which is by definition largely consumed between urban regions. On the other hand, freight mode choice is related to distances, and mix of goods shipped, which in turn is affected by national production patterns and international trade as well as the size of the country itself (Schipper et al., 1996). Simplifying the issue is that gasoline use is predominantly for light duty vehicles in the Americas; diesel is for trucking and buses. Use of other fuels besides gasoline for cars, including diesel, ethanol, and CNG distorts this simplification. Therefore it is important to use data (or make estimates) of fuel use by mode.

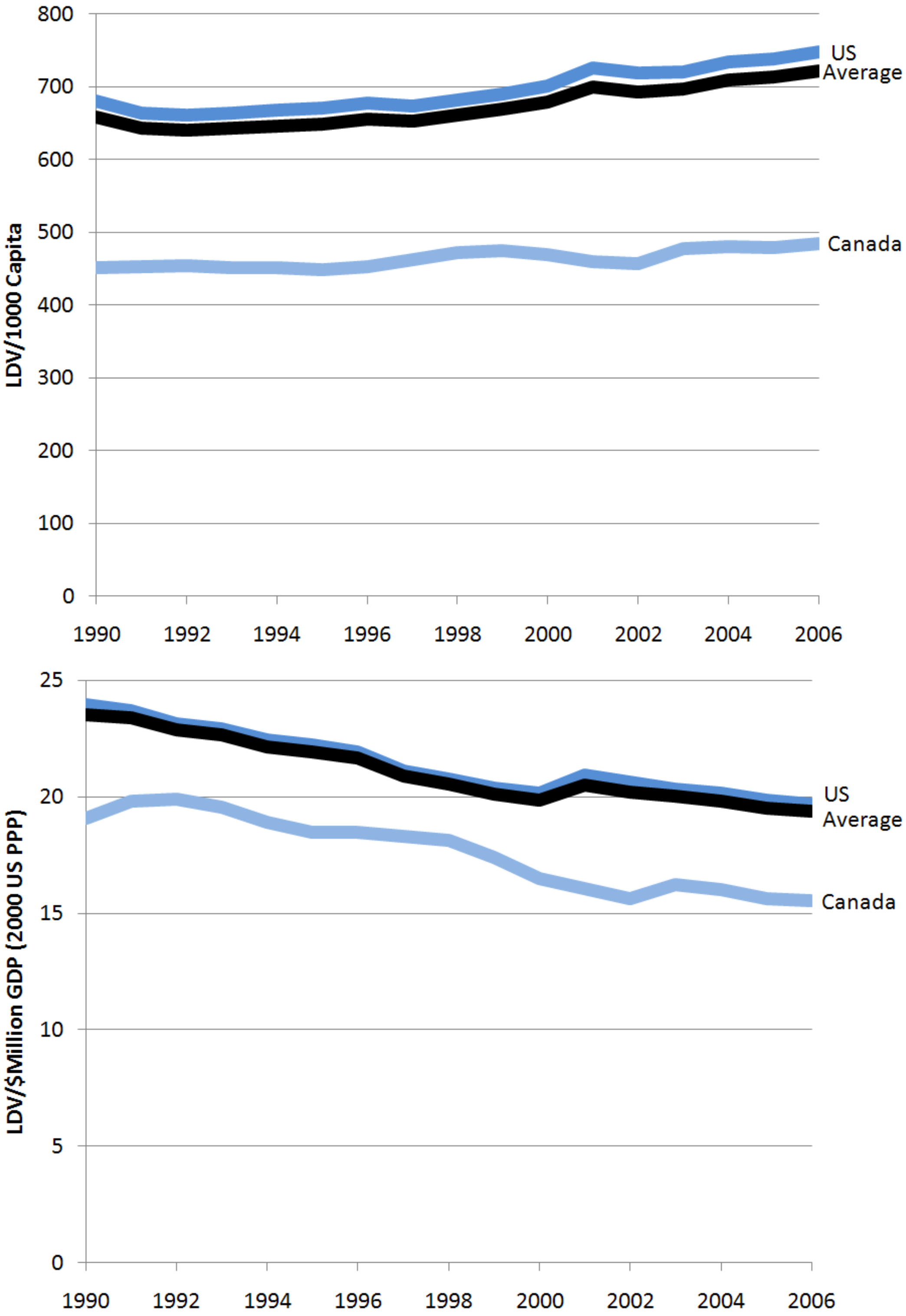
In general, energy consumption data published by individual countries or international agencies like the International Energy Agency, the United Nations, or regional intergovernmental agencies are collected by the categories of transportation shown in Figure 3. “Road transport” mixes travel and freight, as does rail and air and even water for a few countries with significant ferry, costal, lake or river travel. There are no global data that make the more detailed split, and only a number of industrialized countries actually keep track of vehicle activity (in km/year), travel (in passenger-km) and freight (in tonne-km) and split energy use by these important categories. The Sustainable Mobility Project cited here, and follow up work at the International Energy Agency that led to the MoMo

Model (Fulton et al., 2009) are the first serious global efforts to estimate these data over time.

North America in the Global CO_2 Context

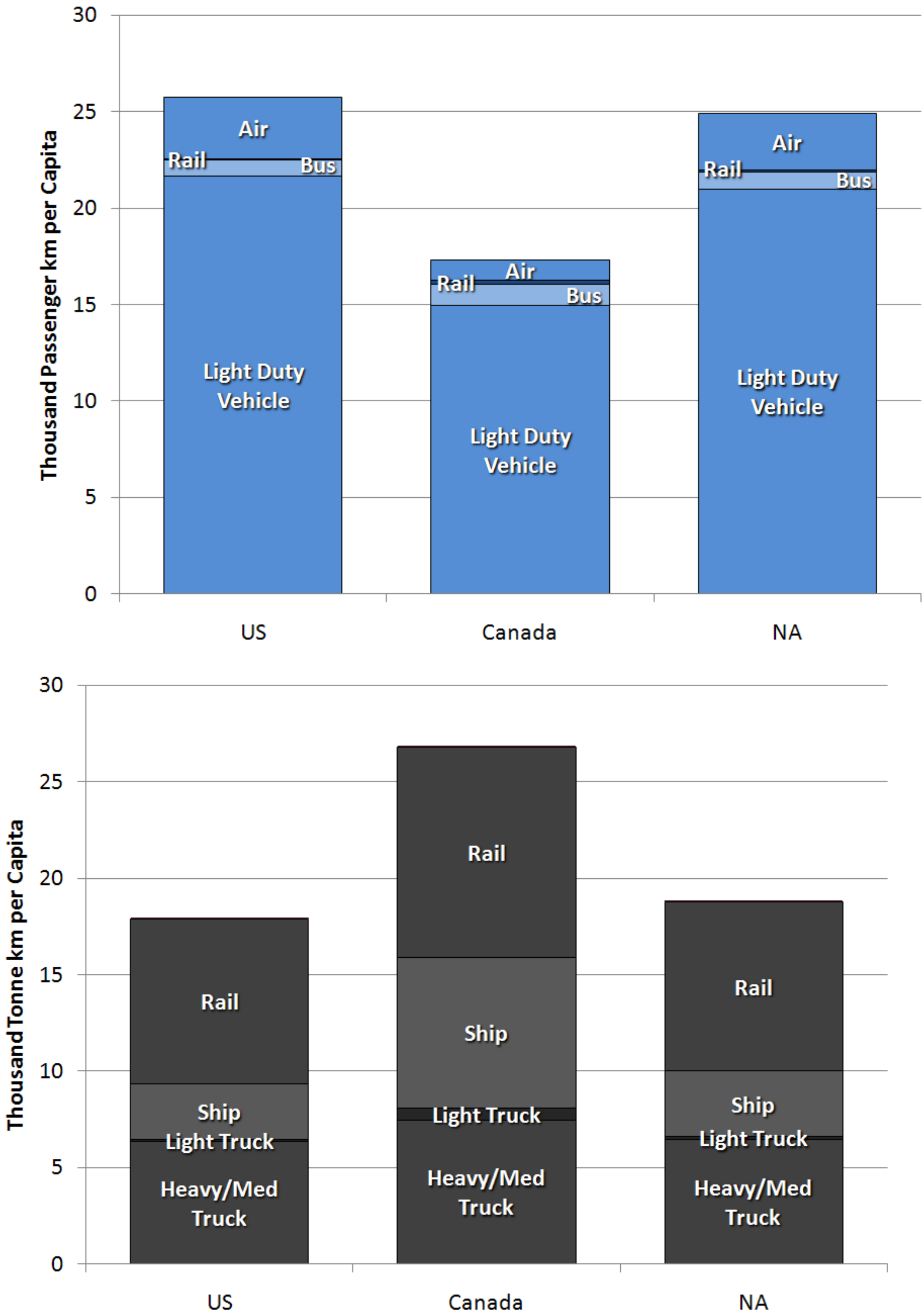
While both Latin America and North America are highly motorized, North America has eight times the LDV ownership per capita and more registered private motor vehicles than licensed drivers. However, with growth in automobile ownership slowing and growth in GDP outpacing it, North America seems to be approaching saturation, unlike Latin America. Within North America, Canada (34 million population) has historically had lower automobile ownership, whether by population or GDP, than the US (304 million population). This may in part be due to the lower real incomes of Canadians (about 79 percent of those of the U.S . These trends in automobile ownership, and the relative US/Canada difference, can be seen in Figure 6.

Figure 6: North American Automobile Ownership by Population and GDP



Reflecting this greater automobile dependence, passenger transportation is predominantly by private light duty vehicles in North America, especially in the United States. Rail and bus transportation take up a greater share of passenger kilometers traveled in Canada (7.5 percent versus 3.5 percent), but not enough to make up the difference of nearly a third between the two countries in total distance traveled. Freight activity levels, on the other hand, are similar, with Canada relying more on rail transportation and less on trucking and shipping. Air freight is insignificant in terms of weight (though not in terms of value) in each country, and rail passenger transportation (both intercity and urban) is similarly minor, although higher in Canada. These results can be seen in Figure 7.

Figure 7: North American Domestic Travel and Freight Activity by Mode, 2005



With such a high modal share, North America's approximately 235,000 light duty vehicles for passenger transportation are thus responsible for more than two thirds of road-based emissions. Trucking is responsible for the vast majority of the remainder, with a quarter of overall emissions coming from medium- and heavy-duty freight trucks. In terms of urban emissions, automobiles are even more dominant with an estimated 83 percent of all transportation emissions in urban areas. Intra-city freight trucking takes up most of the reminder, along with bus and rail (mainly from public transportation systems). Tables 4 and 5 illustrate the importance of light duty vehicles in North American transportation emissions.

Table 4: Road-based Transport Emissions by Vehicle Type, North America 2005

Vehicle Type	Vehicles (thousands)	Distance (km/year/veh)	Energy (EJ)	Emissions ($MMTCO_2$)	Share of Emissions
Pass. LDV	**235,000**	**18,500**	**16.00**	**1201.9**	**68.7%**
Motorcycle	7,150	2,500	0.03	2.1	0.1%
Bus	885	20,000	0.24	16.4	0.9%
Freight LDV	12,500	30,500	1.79	120.2	6.9%
Other Truck	9,250	26,000	5.87	409.6	23.4%
Total			**23.93**	**1750.2**	**100***

Note: 1 EJ (exajoule=10^18 joules) = 24 MTOE (million tonnes of oil).
Source: Original calculations and sources including Davis et al., 2009.

Table 5: Estimated Urban Share of Emissions by Type, North America 2005

Vehicle Type	Urban VKT Share	Urban VKT (billions)	Occupancy (p/veh)	Urban PKT (billions)	Emissions ($MMTCO_2$)	Share
Pass. LDV	**72%**	**3143**	**1.5**	**4691**	**865**	**83%**
Bus	60%	10	17	174	9	0.8%
Pass. Rail	80%	2	24	41	5	0.5%
Frt. Truck	30%	786			159	15%
Total		**3941**		**4906**	**1039**	**100***

Note: LDV includes motorcycles. Freight for Canada is from 1999. Canada assumed similar to the United States where Canadian data were unavailable.
Source: Original calculations and sources including Davis et al., 2009; FHWA, 2001.

With nearly ten times the population of Canada, trends in the United States dominate North American passenger transportation travel and emissions. Although there are notable differences between historical trends in the two countries, as will be discussed, both had the same general experience through the second half of the 20th century with an increase in travel by automobile negating many gains in terms of fuel economy. Despite a 15 percent improvement in overall fuel economy, the net result for the United States was a trebling of passenger transportation CO_2 emissions between 1960 and 2006, driven largely by increasing travel (Davis et al., 2009; BTS, 2008; Schipper and Marie-Lilliu, 1999, and FHWA, 1969-2001).

This increase was driven primarily by an increase in transportation activity to 3.4 times the 1960 level, strongly led by growth in absolute levels of car and air travel. With population increasing by 65 percent over the same period, per capita emissions from travel roughly doubled. While travel by car and light truck was 90 percent of travel in 1960 and continues to dominate, air travel grew faster and increased its share from under 3 percent to over 12 percent total travel by 2006. Rail and bus shares tumbled from just over 7 percent in 1960 to around 4 percent in 2006. Notably, this means that the modes of travel that consume the most energy per unit of service grew faster than those that use the least energy.

Mode shift toward automobiles and airplanes had a nearly insignificant role in raising emissions, partly due to the already small shares of transit and rail. Additionally, major reductions in carbon intensity occurred in air travel (66 percent fewer emissions per passenger kilometer) and cars (25 percent fewer emissions per vehicle kilometer and 15 percent fewer per passenger kilometer) have resulted in the modes being roughly equivalent in terms of emissions per passenger kilometer. These reductions in carbon intensity were the result of a complex set of factors including technological improvements to vehicles, improved transport industry management practices, response to competition, changing fuel prices, and influential national policy.

For most of the period since 1973, U.S. energy policy focused on oil use in the transport sector, including the introduction of its Corporate Average Fuel Economy (CAFE) standard program in 1975, which set standards for the sales-weighted average fuel economies of cars and light trucks for manufacturers to meet. The 1985 standard of 27.5 MPG (8.6 l/100km) for cars went without increase until the Energy Independence and Security Act of 2007, while the truck standard of 20.7 MPG (11.4 l/100km) held until 2004. Beginning in the 1980s, the separate light truck standard was used as something of a loophole to promote the adoption of minivans and sport-utility vehicles, which tended to weaken the program in addition to CAFE standards being less strict than their international counterparts (An and Sauer, 2004).

With no further tightening of CAFE standards until recently, new vehicle fuel economy averages have been rather flat from year to year. Further offsetting fuel economy was the falling average automobile occupancy from over 2 in 1969 (FHWA, 1969) to slightly over 1.5 by 2001 (FHWA, 2001). The drop in vehicle occupancy occurred as auto ownership increased and more households sent two commuters with their own cars to work.

Additionally, the average American household size fell from close to 3.4 in 1960 to about 2.6 after 2000. With fewer children and many more single person households, there were fewer people to share rides and vehicle kilometers traveled increased.

More recently the idea of a low carbon fuel standard has gained traction in the United States, although the only implementation at a federal level takes the form of mandates to produce increasing quantities of biofuels, beginning in 2008. California has developed an alternate low carbon fuel standard approach to start in 2010; rather than mandate specific fuels, the standard specifies greenhouse gas reduction targets to be met by producers in their fuel mix (Sperling and Yeh, 2009). The target is a 10 percent reduction in emissions per unit of energy by 2020. This approach is also beginning to be adopted by other states, but measurable reductions have, of course, yet to materialize.

While automobile fuel use was reshaped by efficiency standards, there were no similar policies aimed at air travel. Nonetheless, technological progress has allowed aircraft to carry more passengers on two engines today than they carried on four in 1973 (Davis et al., 2009). In terms of air travel, many direct flights between small cities were eliminated in favor of hub-and-spoke patterns (Greene, 1990), contributing to load factors of about 80 percent in 2006 compared with around 50 percent in the early 1970s (Davis et al., 2009). While this meant aircraft became more crowded, the resulting decline in the energy or carbon intensity of air travel of 60 percent between 1973 and 2006 was the largest among any major transportation mode. But this increase in occupancy – percentage of seats filled - obviously cannot be repeated, so only larger (filled) planes and fewer short haul routes plus improved technologies all have to combine to reduce intensities further.

Rail passenger traffic, including commuter rail, intercity rail, and metros in large cities, was affected by various restructuring activities. Some intercity passenger rail lines had very low energy intensities, such as those well utilized lines in the northeast corridor or major commuter lines. Amtrak's energy intensity (including primary energy for electricity) was well below that of auto or air travel. The energy intensity of commuter rail, light rail, and metros were also well under that of the automobile, even counting the primary equivalent of electricity used to power many passenger lines.

Bus travel, including intercity buses, school buses, and urban buses, had a mixed record. For parts of the 1990s, the average city bus released more GHG emissions per passenger mile than the average car/light truck because buses had so few passengers. However, by

2000 a new generation of buses used progressively less fuel per mile; above an average of nine passengers per bus, the energy intensity is below that of automobiles again. Intercity buses and school buses had lower energy intensities so that the overall energy or carbon intensity of bus travel was lower than that of car travel throughout the entire period. The utilization of urban buses (persons per bus) fell slowly throughout the 1970s, but this trend began to reverse from the late 1990s forward (APTA, 2009). Occupancies of these buses, currently on the order of one quarter of seats, are crucial for reducing emissions, as extra passengers require only marginal increases in fuel.

Finally, changes in fuel prices must be given some credit for changes in passenger transportation. Gasoline prices were nearly 50 percent lower in terms of gasoline cost per mile and share of household expenditures from 1985-2000 than 1960-80, and while fuel costs in 2008 did reach a historical peak in real price, the gasoline cost per mile and share of household expenditures did not surpass their 1980-82 peak due to increases in fuel economy over time. Yet in the more recent period, transit ridership was back at its 1957 absolute level (APTA, 2009). According to preliminary information from the Federal Highway Administration, VMT fell by 2.6 percent from 2007 to 2008 (FHWA, 2009). Full data on transportation modes are not yet available, but the emerging picture shows less car use and a continued slight shift to transit.

While many of the key trends presented for the U.S. also hold for Canada, there are several differences leading to an overall lower dependence on the private automobile (and lower transportation carbon dioxide emissions). Many are subtle social differences difficult to enumerate, although some likely have something to do with a historically lower GDP/capita in Canada (Schimek, 1996). The impacts of policy, on the other hand, are more easily distilled.

For example, historical gasoline tax revenue allocation was one way in which policy differentially influenced transportation activity. The National Defense Highway Act of 1953 introduced heavy subsidization of highways by the U.S. Federal government, with 90 percent of costs covered by revenues from the gasoline tax (justified as a "user fee"). In contrast, the Canadian federal contribution to highways was on the order of 10 percent, with the gasoline tax flowing into general revenue. Highway building in the US thus commenced on a grand scale not matched in Canada (Condon, 2004). The American urban experience of today, with multiple continuous freeways and/or a tight freeway loop within the downtown area, is quite rare in Canadian cities. The result for the U.S. was both increasing automobile dependence and suburbanization: through much of the latter half of the 20th century, single family homes were 69 percent of total housing versus 53 percent of Canadian (Schimek, 1996).

Canadian cities are generally denser and less sprawling with stronger cores and mixed-use development than their counterparts in the United States. Comparing the five largest Canadian metropolitan areas with the ten largest in the U.S., population densities are on the order of 50-75 percent higher in terms of jobs and population, with downtowns twice as dominant in share of jobs (16 percent vs. 9 percent). Distances traveled to work in the U.S. are nearly twice as long as in Canada across comparatively sized metropolitan areas (Pucher and Buehler, 2006). Thus, it appears that a large share of Canadians live in relatively compact cities with greater access to transit than Americans. Overall, Canadians traveled 31 percent fewer kilometers by automobile (15,000 passenger kilometers/capita versus 22,000) and 46 percent more by bus in 2005 (1300 versus 900). Modal shares also show s differences in the census journey to work data, the most comparable data sources between the two countries, presented in Table 6. These differences in urban structure may be one explanation why Canadians travel less per capita than residents of the United States.

Table 6: Modal share for the work trip in Canada and USA, 2000/2001

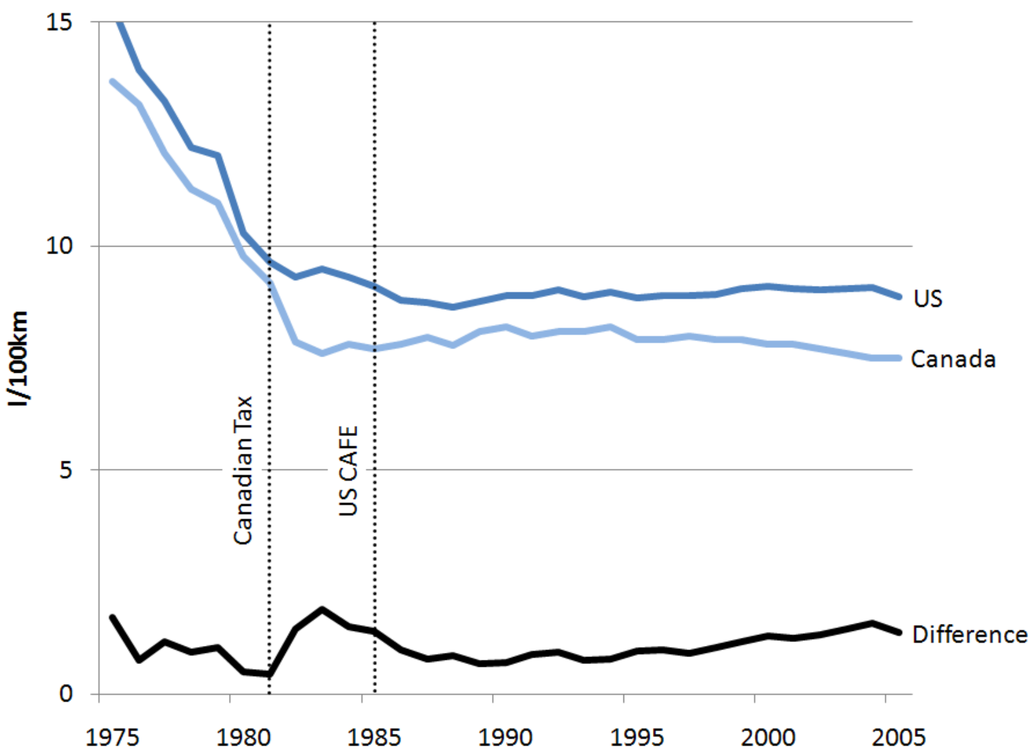
Transport Mode	United States (%)	Canada (%)
Auto	87.9	80.7
Transit	4.7	10.5
Bicycle	0.4	1.2
Walk	2.9	6.6
Other	4.1	1.0
Total	**100***	**100***

Source: Original calculations and sources including Pucher and Buehler, 2006.

Transit and walking mode shares are twice as high in Canada, while bicycle mode shares are three times as high. The latter is partially explained by and partially explains Canada having less than half the bicyclist fatality rate as the U.S. Although Canadian transit use was higher even before 1970, service kilometers per capita diverged through the 1970s with an increase of more than 50 percent in Canada versus 9 percent in the U.S. Notably, this increase only managed a 16 percent increase in ridership, but this was during the long decline of transit in both countries. Importantly, Canadian transit service is not, on the whole, more subsidized than U.S. transit, and has managed higher ridership with higher fares (Schimek, 1996).

In terms of fuel economy, fuel taxation policy is again a key difference between the two countries. While the Canadian gasoline tax is not high by international standards, it is nonetheless on the order of 2.5 times the U.S. rate (IEA, 2006 as cited in Sterner, 2007). Gasoline prices in Canada and the U.S. began to diverge through the 1980s when Canadian gasoline purchasing power suddenly dropped by one quarter in the early half of the decade (Frigon, 2007). This drop coincides with a large Canadian fuel tax increase (and the release of price controls), a move that the U.S. did not mirror (Schimek, 1996). Although obscured by other trends, the effect of this tax increase can be seen in new light duty vehicle fuel economy, particularly in the years between the increased Canadian gasoline tax in 1981 and tightening of U.S. CAFE standards in 1985, as shown in Figure 8.

Figure 8: New Light Duty Vehicle Average Fuel Economy



Interestingly, Canadian fuel economy standards were no tighter than U.S. standards from their adoption in 1985, and unlike the U.S. they take the form of voluntary agreements rather than mandates. In 1985, a Company Average Fuel Consumption standard of 8.6 l/100km for cars was set (equal to the U.S. CAFE standard set that year), followed by a 1995 target of 11.4 l/100km for trucks (also the U.S. standard). Industry performance has bettered these standards in almost every year, but it is likely that other market effects and the closely tied economies would have resulted in compliance to at least this U.S. CAFE level regardless. Notably, increased light truck ownership mirrored the U.S. experience only to the mid-1990s, after which the Canadian level stopped increasing and U.S. light truck shares increased a further 10 percent.

A further 2005 memorandum of understanding, signed by the Canadian government and 19 manufacturers, agreed to collectively reduce GHG vehicle emissions by 5.3 Mt in 2010 from the base case (approximately 85 Mt in 2005 increasing to 90 Mt in 2010). This base case is set based on factors deemed to be outside the industry's control, including vehicle sales, scrappage rates, kilometers driven by age, and car/light truck mix (Reilly-Roe, 2005). Ultimately, however, it is more likely that the differences between the two countries are more due to fuel tax and spending priorities (as well as innate social differences) rather than these voluntary agreements.

Latin America in the Global CO_2 Context

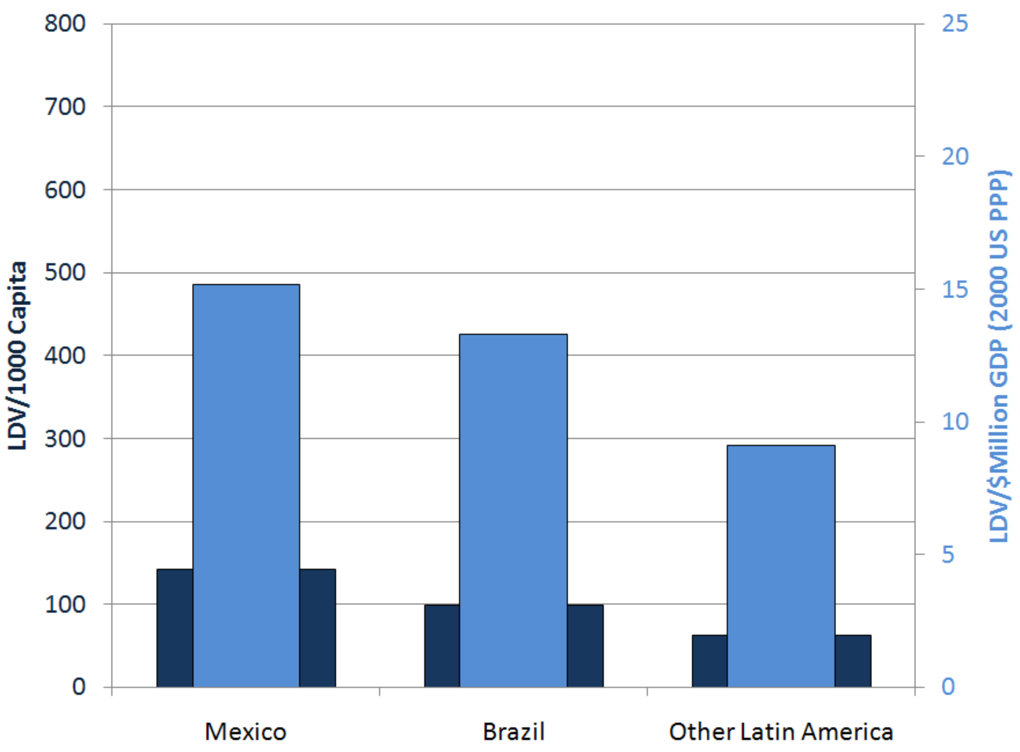
Today Latin America is a small contributor to the world's emissions of GHG. However, the region's car ownership, use, and emissions are higher than might be predicted on the basis of population or GDP, and car traffic clogs the streets and pollutes the air of many Latin American cities. Furthermore, Latin American carbon emissions from transport - mostly cars - are predicted to grow three-fold by 2030 as both auto ownership and vehicle-kilometers traveled expand (Fulton and Eads, 2004; Schipper et al., 2009). The total emissions will still be small compared to those of OECD countries, but they will not be trivial. An understanding of CO_2 emissions from road transport in the region requires a clear picture of the vehicle fleet and vehicle use (in vehicle-km). Table 3, reprinted below for reference, gave estimated data for CO_2 emissions by mode from transport in Latin America (Fulton and Eads, 2004).

Table 3: Estimated Urban Emissions by Vehicle Type, Latin America 2005

Passenger Mode	Total Emissions (Mt CO_2)	Urban Emissions (Mt CO_2)	Freight Mode	Total Emissions (Mt CO_2)	Urban Emissions (Mt CO_2)
LDV	189	151	Heavy Truck	147	15
Bus	54	35	Medium Truck	86	17
Rail	2	1	Rail	3.5	0
Air	14	0	Water	41	0
Total	**269**	**187**	**Total**	**279**	**32**

Behind these aggregate data lies high vehicle ownership from a developing world perspective. However, there exists significant variation within Latin America for two main reasons. First, there are relatively wide disparities in income per capita between Mexico, Argentina, Chile and Costa Rica at one end and El Salvador, Bolivia, and Nicaragua countries at the other. Among large countries, Mexico has the highest car ownership (in cars/1000 people) or per unit of GDP, with Brazil close behind, and both ahead of the average for the rest of Latin America. Figure 9 shows the levels of per capita automobile and SUV ownership from 1990 to 2005 in Latin American countries both on a per capita and per $ of GDP basis. One factor affecting Mexico and Central America is the relatively large number of used cars from North America that find their way to these countries.

Figure 9: Light Duty Vehicle Ownership Measures, 2005, Selected Regions



WBSD data permit a rough estimate of vehicle use and freight activity and fuel use in 2000. We have made two important changes to these data. First, from Brazilian and Mexican sources we know that bus travel is almost an order of magnitude higher than that given by the SMP. By contrast, the SMP estimates of passenger air traffic, almost 500 passenger-km/capita, appear to be far too high unless international traffic is included. Since Brazil and Mexico are the largest Latin American countries with the most developed domestic air networks, and among the wealthiest, it is hard to believe that domestic air travel within each other Latin American country could have such a high level of air travel. Data estimated by the WBCSD's Sustainable Mobility Project (WBCSD, 2004) and more recently refined by the International Energy Agency (IEA, 2009b) provide information on vehicle types, their energy intensities, and the average km driven each year for Latin American countries.[4] CO_2 emissions by vehicle type can be calculated from these data. Tables 7 and 8 present the results[5] for road-based transportation in Latin America.

Table 7: Road-based Transport Emissions by Vehicle Type, Latin America 2000

Vehicle Type	Vehicles (thousands)	Distance (km/year/veh)	Energy (EJ)	Emissions ($MMTCO_2$)	Share of Emissions
Pass. LDV	**40,127**	**13,000**	**2.11**	**155.4**	**41.7%**
Motorcycle	6,948	7,500	0.05	3.0	0.8%
Minibus	930	40,000	0.21	14.1	3.8%
Bus	511	40,000	0.20	14.5	3.9%
Freight LDV	4,459	13,000	0.23	16.2	4.4%
Med.Truck	5,385	22,000	1.15	77.6	20.8%
Heavy Truck	2,314	50,000	1.38	92.2	24.7%
Total			**5.33**	**372.9**	**100***

Note: 1 EJ (exajoule=10^18 joules) = 24 MTOE (million tonnes of oil). Emissions for rail, ship, and air were included in the original SMP spreadsheets but are omitted here.
Source: WBCSD Sustainable Mobility Project and IEA, Data include Mexico.

Table 8: Estimated Urban Share of Emissions by Vehicle Type, Latin America 2005

Vehicle Type	Urban VKT Share	Urban VKT (billions)	Occupancy (p/veh)	Urban PKT (billions)	Emissions ($MMTCO_2$)	Share
LDV	**80%**	**453**	**2**	**907**	**127**	**62%**
Minibus	80%	30	20	595	11	5.5%
Bus	50%	10	50	511	7	3.5%
L. Truck	80%	46			13	6.3%
M. Truck	50%	59			39	18.8%
H. Truck	10%	12			9	4.5%
Total		**510**		**2013**	**208**	**100***

Note: LDV includes motorcycles.
Source: Original Calculations.

[4] The IEA used their "MoMo" model (Fulton et al., 2009) for the Sustainable Mobility Project work and is currently developing it further. This includes a major effort to develop a set of data on vehicles in use by fuel type, fuel use per vehicle per kilometer, and total fuel use totals that match figures reported to the IEA.

5 The total fuel use for each particular fuel and vehicle type is calculated using the estimated number of vehicles, distance/vehicle, and fuel/distance, with national road fuel use (IEA) used as the control total.

For the region as a whole, about half of road transport emissions are for passenger traffic, the other half for freight travel. The dominant vehicle type is light duty vehicles, most of which are passenger cars[6]. For this study, we further estimated the urban share of traffic (VKT) and emissions, as well as passenger kilometers traveled (Table 8).[7] It is assumed that the remaining road traffic is either rural based, or intercity.

Table 8 shows that about 60 percent of all road transport emissions in Latin America appear to be associated with urban areas, with light duty vehicles responsible for well over half of the urban emissions[8]. Further assuming that LDVs in urban regions have average occupancy of two people, motorcycles one person, minibuses 20 people, and large buses 50 people, we estimate that in 2000, two trillion passenger km were produced in these motorized modes in Latin America urban areas.

Data from major metropolitan regions of Latin America are consistent with the estimates of urban traffic and emissions generated from national and regional data for specific cases (Schipper et al., 2009). Table 9 shows the results for Mexico City in 2006. The data come

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6 LDV, or light duty vehicles, include all cars, vans, pickups and SUVs, of which an estimated 10% are for strictly commercial purposes and counted under LDV freight.

7 Data are based on recent International Energy Agency refinements of country-level data from the Sustainable Mobility Project (WBCSD, 2004), provided to us for this work by the (Private communication with IEA, 2009). To develop urban area estimates from the country-level data, we assume that 80% of car, motorcycle and minibus fuel is consumed in or around urban areas, largely because the incomes to support car ownership as well as mini-bus use are 80% in urban areas. We estimate that 50% of large bus traffic is in cities, but that 90% of the truck activity, the other half of the bus activity, and 10% of car traffic is intercity. The term "urban area" is thus used loosely here to exclude emissions arising from long-distance intercity road traffic as well as traffic confined to rural areas. Since congestion tends to be much worse in urban areas than elsewhere, and congestion tends to boost fuel use per km, our assumptions for apportioning fuel use probably underestimate the urban share. To estimate passenger kilometers, we assume the vehicle occupancies shown in the table. Finally, to estimate emissions, we assume that the urban fleet characteristics and fuel types are the same as those for the national reports. Since urban vehicles may be somewhat cleaner and better maintained than those in rural areas, this may overestimate the urban portion of emissions.

8 Rail is excluded from the table, but urban rail, mostly electric-powered, contributes very little emissions from electricity generated to run it in even countries and cities with the most urban rail, e.g., European countries (or cities like Paris and London). See Schipper and Marie (1999).

from the region's emissions inventory, which is updated every other year. Surveys from large cities also show that large buses and mini-buses carry roughly 50-60 percent of trips, cars 10-30 percent, metro and rail (where available) about 10 percent, and non-motorized transport. Buses provide the dominant intercity mode of transport, followed by cars and, at a much lower level, rail and air. In urban regions, however, traffic and emissions from light duty vehicles dominate, which is why particular emphasis is placed on them in this study.

Table 9: CO_2 Emissions, Vehicles, and Traffic, Mexico City, 2006

Vehicle Type	MMT CO_2	Vehicles (thousands)	VKT (billions)
Cars	10.49	3,395.8	46.31
Taxis	2.60	155.1	10.38
VW Bus Colectivos	0.70	39.7	2.64
Other Colectivos	0.74	36.1	2.54
Pick Up	0.83	133.4	3.48
Other Veh <3t	0.63	81.6	1.80
Truck Tractors	1.63	60.9	1.38
Autobuses	1.87	43.1	1.79
Other Veh <3t	0.54	100.8	2.20
Motorcycles	0.37	180.7	4.47
Total	**20.40**	**4,227.3**	**76.98**

Source: Mexico City Emissions Inventory (SMA, 2006)

In a previous study, the UC Berkeley team had reviewed CO_2 and transport trends in Latin America in the context of urban transport policy (Schipper et al., 2009). Emissions from all transport are dominated by road transport, as Table 9 suggests. Noting the constant congestion in most large cities, it was suggested that the most important contribution to lower future CO_2 emissions from transport would come from transport reform to slow the growth in car ownership and use. This must come on top of actions to affect directly emissions through greater efficiency.

As one example of the outcome of transport reform, Schipper et al. (2009) analyzed the provision of the first part of Metrobus, a BRT corridor in Mexico City, one of many dozens now in use or under development in Latin America. They found that of the roughly 500,000 tonnes of CO_2 emitted by traffic on the Insurgentes Corridor where Metrobus was placed, almost 50,000 tonnes/year of CO_2 were saved in roughly equal parts: substitution of large BRT buses for smaller buses and minibuses, smoother traffic along Insurgentes despite the loss of a lane in each direction to the BRT, and the nearly 10 percent of Metrobus passengers who previously drove their cars to their destinations. These CO_2 savings illustrated co-benefits, the restraint or reduction in CO_2 emissions that arise as an indirect result of other measures, i.e. “free” from the point of view of CO_2 reduction. It was also noted that had the Metrobus vehicles been hybrid buses, that step would have saved less than 10 percent as much CO_2 as the others at a considerable direct cost. Ultimately hybrid buses are likely to gain a large share of all buses because of lower local emissions and longer-living power trains (Schipper et al., 2007), but the largest savings still arise because of transport measures.

One reason that Latin America has a ratio of total CO_2 emissions to GDP is the prominence of hydroelectric power and lack of coal in the power sector. Another, less significant reason is sugar-cane based ethanol and small amounts of biodiesels, which accounted for about 25 percent of all road fuel in Brazil in 2007 (IEA, 2004) but only 3.8 percent of Brazil’s total primary energy use and less than 1.3 percent of total primary energy use in Latin American including Mexico. Brazil accounts for well over 90 percent of the biofuels used in Latin America. While the biofuels share of road transport fuel in Brazil fell through 2005, it has risen since then. The outlook for expanded biofuels production in Brazil is good, but whether biodiesel will succeed in large scale is unclear (Goldemberg, 2008; Goldemberg and Guadabassi, 2009).

Brazil has started labeling new vehicles for fuel economy and is at least studying standards (CONPET, 2009). Mexico is farther along on the latter (Lacy, 2008; Islas Cortes, 2009). These two countries, which dominate Latin America’s energy use and CO_2 emissions, have been subject to important long-term studies of CO_2 emissions reduction from the transport sector. The Brazilian low carbon study (World Bank, 2009) foresees a roughly 20 percent reduction in emissions over a rapidly rising baseline through 2030, while the Mexican Study (Sanchez-Catano et al., 2008) foresees a larger cut approaching 40 percent. One reason for the different results is the high penetration of biofuels in Brazil compared to almost none in Mexico limits the impact on CO_2 emissions of measures in Brazil that would have a greater impact in Mexico because of the higher CO_2 content of fuels in Mexico. These studies represent a good start, but do not yet reflect official opinion or more important policies. Additionally, their results are far smaller than what is sought in the present work.

Scenarios

The methodology employed in this study involves both back-casting and projection. The starting values describing the base year were taken from the Sustainable Mobility Project (SMP) and in some cases modified by national data for 2005 for the U.S., Canada, Mexico and Brazil. The business-as usual case for each region was taken from SMP, with the important shift of Mexico from North America to Latin America. Key values for 2005, taken from the discussion in the "Current Trends" section are summarized in Table 10.

Table 10: North America and Latin America Key Statistics for 2005

North America Travel	LDV	Bus	Rail	Air	Total
Travel Volume (billion PKT)	6560	341	47.9	1420	8370
2050 BAU Projection	*9230*	*341*	*93*	*4440*	*14100*
Travel/Cap. (thousand PKT)	19.9	1.04	0.15	4.32	25.4
2050 BAU Projection	*20.8*	*0.768*	*0.21*	*10.0*	*31.8*
Total CO_2 Intensity, g/PKT	204	99.9	147	205	199
2050 BAU Projection	*157*	*94*	*76.5*	*192*	*166*
Total LCA, kg/capita	4060	104	21.5	887	5070
2050 BAU Projection	*3280*	*72.2*	*22.9*	*1920*	*5290*
Total LCA, Mt CO_2	1340	34.1	7.06	292	1670
2050 BAU Projection	*1450*	*32*	*10.2*	*853*	*2350*

North America Freight	H. Truck	M. Truck	Water	Rail	Total
Freight Volume (billion tkm)	2710	268	1120	2530	6620
2050 BAU Projection	*5930*	*587*	*1490*	*4870*	*12900*
Freight/Cap. (thousand tkm)	8.24	0.815	3.40	7.68	20.1
2050 BAU Projection	*13.4*	*1.32*	*3.36*	*11.0*	*29.0*
Total CO_2 Intensity, g/tkm	132	443	106	21.1	97.9
2050 BAU Projection	*113*	*386*	*103*	*21.1*	*89.5*
Total LCA, kg/capita	1090	361	359	162	1970
2050 BAU Projection	*1510*	*510*	*345*	*231*	*2600*
Total LCA, Mt CO_2	358	119	118	53.3	648
2050 BAU Projection	*670*	*226*	*153*	*103*	*1150*

Latin America Travel	LDV	Bus	Rail	Air	Total
Travel Volume (billion PKT)	671	948	16.8	65.9	1700
2050 BAU Projection	*4160*	*1670*	*25*	*456*	*6300*
Travel/Cap. (thousand PKT)	1.21	1.71	0.03	0.119	3.07
2050 BAU Projection	*5.18*	*2.07*	*0.0306*	*0.6*	*7.9*
Total CO_2 Intensity, g/PKT	281	57.1	147	205	152
2050 BAU Projection	*124*	*71*	*147*	*192*	*115*
Total LCA, kg/capita	340	98	4.46	24.4	467
2050 BAU Projection	*640*	*147*	*4.52*	*109*	*901*
Total LCA, Mt CO_2	189	54.1	2.47	13.5	259
2050 BAU Projection	*514*	*118*	*3.63*	*87.7*	*724*

Latin America Freight	H. Truck	M. Truck	Water	Rail	Total
Freight Volume (billion tkm)	853	192	139	261	1440
2050 BAU Projection	*2920*	*682*	*215*	*500*	*4310*
Freight/Cap. (thousand tkm)	1.54	0.346	0.25	0.47	2.61
2050 BAU Projection	*3.63*	*0.848*	*0.268*	*0.6*	*5.4*
Total CO_2 Intensity, g/tkm	172	452	293	19.9	193
2050 BAU Projection	*172*	*430*	*294*	*294*	*233*
Total LCA, kg/capita	265	156	73.7	9.38	504
2050 BAU Projection	*626*	*365*	*78.8*	*12.8*	*1080*
Total LCA, Mt CO_2	147	86.5	40.9	5.2	279
2050 BAU Projection	*503*	*293*	*63.3*	*10.3*	*870*

Back-casting Approach

Back-casting is an approach used to learn about the future by starting with a quantitative (or qualitative) change in the future as an outcome. From the present state, analysis shows what must change to get to the back-cast future. Essentially the outcome is assumed, rather than derived, and paths are traced backwards in time to the present or base year. Here the only target for 2050 specified is total per capita CO_2 emissions, which is multiplied by the projected 2050 population to give total CO_2 emissions.

CO_2 emissions in transport depend on both transport activities (e.g. travel and freight by mode) and the emissions intensity of each activity. Therefore, the emissions levels of the future that represent the outcome – here the "target" – could be composed of any combination of transport activities multiplied by the corresponding intensities to give the target emissions levels. In the back-casting cases, we estimated plausible (but not necessarily feasible) levels of both activity and CO_2 intensities that yield the targets presented below. Since both transport activity and transport emissions are overwhelmingly dominated by light duty vehicles (cars and light trucks), trucking and air travel, the outcome depends on choosing the parameters for these three modes. Most low CO_2 transport futures depend on buses and rail travel and freight assuming a significant share of what is borne by, or projected to be borne by, the more CO_2 intensive modes of cars, trucks, and air. In addition, low CO_2 futures also depend on a combination of efficient vehicles and much lower carbon fuels, significant reduction in transport activity and substantial land use changes. For our transport calculations, we took some care to balance the reductions in activity on the energy and CO_2 intensive modes with some increases in use of the other modes, shifting modal shares. At the same time, the CO_2 intensities estimated were roughly a third below those estimated by the ICCT (2010) for this project, for which details and documentation are provided in a separate report.

The levels of travel and freight activity suggested for the simple back-casting for the year 2050 are illustrative only. They are the results of estimating what levels would combine with very low fuel and CO_2 vehicle intensities to yield target CO_2 emissions per capita given by ITPS. Similarly, the intensities selected are those that yield the targets. By comparing the back-cast values with present values, it is shown how rapidly both transport activities and intensities change to map the present (2005) into the future (2050).

The two targets used for the back-casting exercise were suggested by ITPS in consultation with study members and other experts. These levels yield global direct CO_2 emissions from transport at either the level of year 2000 absolute emissions amount or half that amount. In either case, the "shares" for each region of the study will be equal on a global per capita basis, using population forecasts supplied by the International Energy Agency. Whether this level of emissions or the allocations on a per capita basis is fair or even realistic is not crucial at this point. Rather, picking such a level, however low, is key to understanding what opportunities and options might yield such levels of both transport activity and emissions intensities by 2050.

ITPS has challenged us to produce a world where, by 2050, every country's per capita emissions will be the same and total transport sector emission will be half of what they were in 2000 on an absolute basis. With a projected world population of over 9.2 billion people and a goal of reducing emissions from 5.8 billion tonnes of CO_2 in 2000 to half by 2050, CO_2 emissions would need to be 315 kg/capita in 2050. Apportioning this reduction to passenger travel and freight, using their relative shares of current emissions (66 percent and 33 percent respectively), will result in 210 kg/capita for passenger travel and 105 kg/capita for freight.

The target amounts to a per capita emissions decline of around 94 percent for North America, where 2005 emissions for travel alone was close to 5 tonnes/capita for passenger travel and 1.8 tonnes/capita for freight[9]. For North America, it means both declines in automobile, aircraft and truck use, as well as a very large reduction in the carbon intensity of these modes. We make no comment whether this target is meaningful for North America or any region, taking it rather as a challenge.

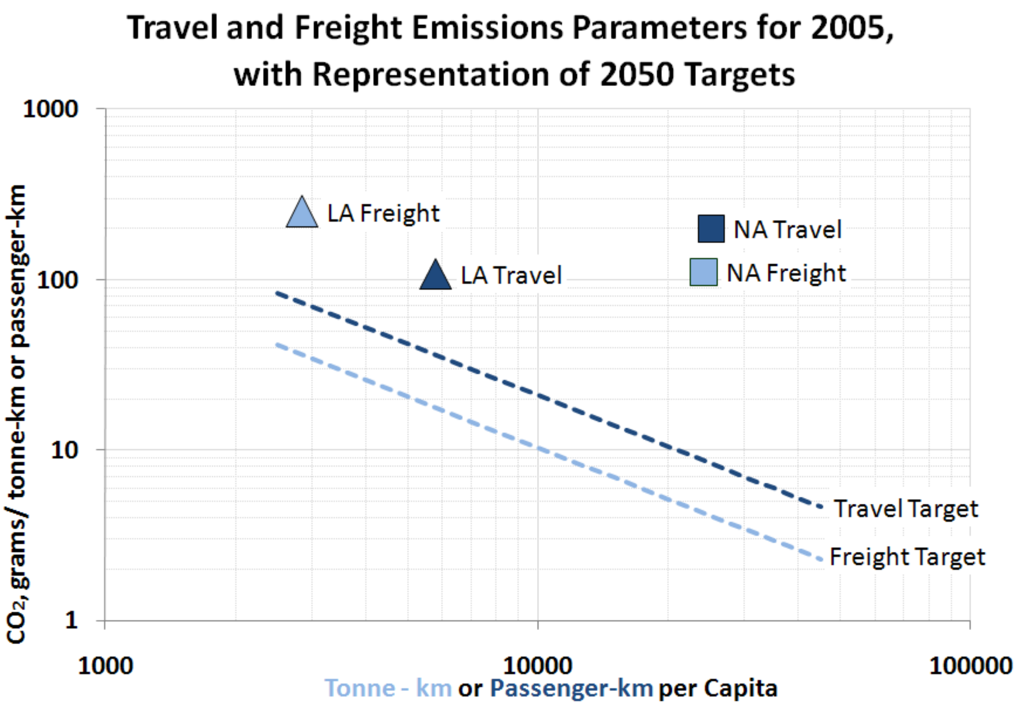
Latin America's per capita emissions for 2005, also shown in Figure 1, lay much closer to the target line, particularly for travel. But Latin Americans have only one fifth the per capita GDP that North Americans have, and about 1/7th the number of cars per capita. We expect some increase in car ownership and overall mobility with economic growth. It is conceivable that in Latin America technological improvements and factors that slow switching to cars could reduce emissions/passenger-km more rapidly than passenger-km

[9] This breakdown into travel and freight is only illustrative. In the US in 2005, the breakdown was closer to 75/25, but since 1960, emissions from freight have grown faster than those from travel, a trend that is likely to continue, thus motivating our 66/33 split for 2050.

grew, or even faster, and the large share of travel by bus could remain high. For Latin America to remain at its low level of emissions while growing in the future, Latin America would have to avoid the car and truck-intensive development patterns of developed countries, while reducing the present CO_2 intensities of all modes. This would require a change of direction for Latin America, but not absolute decline as in North America. For most of the rest of developing world, including India, China, and Africa, this target affords some increase in the absolute level of emissions from 2000 levels, with increasing levels of these CO_2 intensive modes offset by big declines in the CO_2 intensity of each mode.

To achieve these levels in any region, some combination of fuel use/passenger-km, passenger-km, and carbon/fuel has to occur for travel and similarly for freight. Figure 10 simplifies this, expressing emissions as the product of average life cycle analysis (LCA) emissions per passenger km and total passenger km/capita for one line, and similarly for freight on the second. For any point in the graph, the product of the X and Y coordinates gives per capita emissions for that combination of per capita passenger-km and emissions per passenger-km and similarly for per capita tonne-km and emissions per tonne-km of freight. The solid line in Figure 10 represents the passenger travel target, while the dotted line represents the freight target. Any point on either line represents a combination of aggregate transportation activity and CO_2 emissions intensities that “meets” the proposed targets. Actual 2005 emissions for travel and freight, for both North and Latin America are also shown in Figure 10. The log-log scale is used in this figure to represent a wide range of per capita travel and per capita emissions.

Figure 10: Illustration of the Travel Activity-Emissions Intensity Tradeoff



With little zero carbon or near-zero carbon liquid fuel on the horizon today, it is hard to imagine a combination of fuel efficiency and low-carbon liquid fuels that alone would provide the low-carbon propulsion on the present scale for North America (about 17 million barrels per day of transport fuels), let alone for the entire globe today (over 60 million barrels of oil per day in various products). It is, however, possible to imagine a combination of shifts to low or no carbon electric drive, great increases in fossil fuel efficiency of propulsion, large shifts away from individual four-wheeled vehicles as we know them today, and reduction in passenger and tonne-km that might yield greatly lower emissions. Figure 10 does not guarantee any of these changes in 2050, but only illustrates what combination would lead to the target emissions. Travel modal energy and carbon intensities can vary by a factor of 5 (between air or automobile travel vs. bus or rail travel).

A strong disclaimer is in order here. Figure 10 depicts straight lines for the travel and freight targets that imply a one to one tradeoff between travel mobility and the carbon intensity of that travel such that all points along the target line are equivalent. However, policy should carefully consider the part of the line to aim for because the "costs" (in terms of investment or loss of welfare or consumer surplus) of changing travel by 1 percent or changing emissions intensity by 1 percent are not equal. Moreover, many key transport policy strategies that would appear to lower mobility, such as those that impose variable prices on transport services that are not charged this way, like use of roads or insurance, might actually increase welfare. Mode shift away from light duty vehicles or air travel towards collective modes or non-motorized transport may also be a result of sound transport strategies. In either case, the "cost" could be negative, i.e., there could be a net benefit to society from the change.

By contrast, technologies that reduce emissions in a given kind of vehicle by either increasing the efficiency of that vehicle or permitting it to run on lower carbon sources (including possibly electricity) have well-defined costs, as well as benefits. These costs may rise or fall over time with new technology or changes in resource availability. Since most technological solutions rarely affect the level or quality of transportation (with the important exception of the down-sizing of light duty vehicles' weight and power, which was an explicit part of the "technology" part in our "Glocalization" projections), they can be considered somewhat separately from policy affecting transport activity (levels of use, modes used). Although technology advancement has been recognized as a critical factor in increasing energy efficiency and lowering CO_2 emissions consequently, emissions reduction technology per se does not solve transport problems like congestion or barriers to accessibility. Thus "solving" the CO2 problem from transport should not lead to abandonment of important transport policy development.

Projections

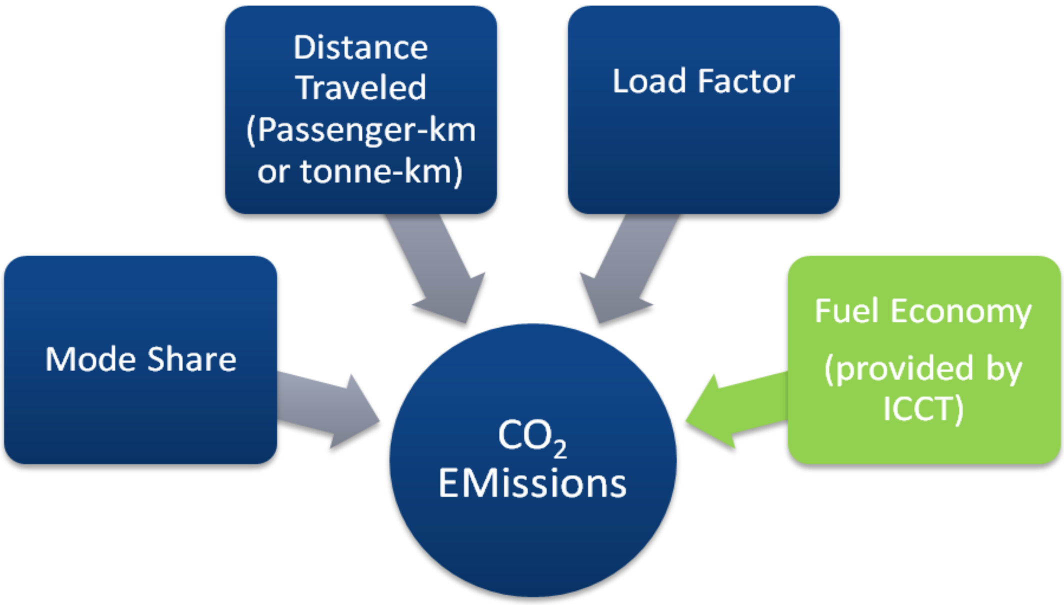
For our transportation projections model, we have incorporated fuel intensities values developed by the ICCT and added our own assumptions on travel behavior, distance traveled and policy implementation. The ICCT has improved the Sustainable Mobility Project model to be able to quantify scenarios of total fuel use and CO_2 emissions for this project. The ICCT has documented the important changes in fuel intensities and the CO_2 content of fuels (or electricity) in their forthcoming report (ICCT, 2010). The ICCT took the UC-modified vehicle occupancy/load factors so that the new SMP model would report vehicle intensities (largely a technological estimate), modal intensities that reflected occupancy/load, and similar parameters for carbon.

The ICCT model reports only one scenario at a time. Therefore, in order to accommodate multiple scenarios (Business-as-Usual, Globalization, and Glocalization) within the single scenario SMP model, an additional spreadsheet was created and dubbed "Driver." Driver uses Excel VBA macros to force the SMP model to run each scenario and its set of assumptions in turn. Before moving on to the next scenario, Driver saves relevant output for future use and compiles it in three sets of worksheets. While many of the output variables are contained in summary sheets in SMP, other necessary output for analysis is collected from various worksheets scattered around the SMP model spreadsheet. These outputs can then be passed to graphs and tables to portray the modeling results for all three scenarios.

A primary advantage of this method is that only one model spreadsheet must be maintained, rather than three separate spreadsheets, with one per scenario. Any minor changes to the model and/or linking to additional output variables do not, therefore, require major effort to implement. An additional implication and advantage of this method is that Driver isolates the SMP model as a "black box" and simplifies user interaction with the model.

The structure of the transportation projection exercise is shown in Figure 11, which is a snapshot of our scenarios building process, showing the basic inputs used for the projections estimations.

Figure 11: Snapshot of Scenario Building Process



Our approach assumes a set of policy options that will be implemented in Latin and North American countries over the next four decades. There are three main groups of policy assumptions, namely Transportation Technologies and Strategies, Land Use Planning and Pricing Instruments Design. Each group of policy assumptions has four specific policies, standards or regulations that have been shown to effectively reduce the CO_2 emissions of transportation (Table 11).

Transportation and climate change policies introduced in different regions could have varying impacts and result in different outcomes when combined with other policies. The degree of influence on a specific region could also change over time. Table 11 shows a summary of the policy assumptions that serve as the fundamental drivers in our model. These policies are simply estimates and are neither quantified nor used as direct inputs for the model, apart from fuel economy standards. The policy path of each policy will vary according to the region where it is being implemented, but the first set of policies assumed to be introduced is Transportation Technologies and Strategies. This set of policies is most direct and already in place in many countries in North American and Latin America. Therefore, it is assumed that policies related to transportation technologies or fuel economy standards will be implemented first before different countries start altering land use planning or designing pricing instruments. A more detailed description of each policy can be found in a later section of this report.

Table 11: Policy Options and Assumptions for Latin America and North America

Policy Option	Assumption
Transportation Technologies and Strategies	
Fuel Economy Standards	Stricter mandatory standards for vehicles to have higher fuel efficiency
Advanced Vehicle Technology	Introduce a mix of vehicle technologies in the market, such hybrid-electric vehicles
Alternative Transportation Fuels	Develop renewable transportation fuels and fuels derived from natural gas
Intelligent Transportation Systems	Integrate users, vehicles and infrastructures through wireless, electronic and automated technologies
Land Use Planning	
Public Transportation Investment	Encourage investment in bus and rail networks
Transit-Oriented Development	Promote higher density and mixed land uses along transit corridors
Jobs-Housing Balance	Allow development of job opportunities closer to homes of qualified employees
Influential Urban Design	Improving built environment to reduce the need for unnecessary motorized travel
Pricing Instruments Design	
Fuel and Vehicle Taxation	Increase the cost of owning and maintaining private vehicles
Carbon Emission Taxation	Charge users according to how much their vehicles pollute
Congestion Pricing Scheme	Higher fees will lower traffic congestion and air pollution by decreasing peak travel
Parking Pricing Strategies	Design parking pricing schemes that will reflect the true cost of parking and reduce cruising time

IMAGES OF THE FUTURE

ITPS has introduced two worlds that help to define scenarios. They differ by where most policy initiative comes from. One is "globalization" that represents a "top down" approach to climate protection in which world leaders agree to take actions. This scenario draws on global initiatives and cooperation. The other scenario, "Glocalization", assumes a more "bottom up" problem solving world, emphasizing more local initiative and control. In reality, some combination of both top-down and bottom up initiatives – taxes, regulations and efficiency standards, agreements with vehicle manufacturers, interests that affect land uses and urban planning, etc will be necessary.

ITPS also suggests different approaches to governance. One is called "Independent autonomy" and appears to hold fewer regulations and other stimuli than the other, which is called "Restrictive Society". While it is not possible to generalize, we believe that the "Independent autonomy" is more likely associated with massive technological change, while the "Restrictive Society" could be associated with policies that provoke behavior changes, particularly changes in travel patterns, and, from an economy-wide perspective, the patterns of trade in goods and materials. Table 12 summarizes the differences between the two scenarios.

Table 12: Differences between Globalization and Glocalization Assumptions

	Top-down Society: Globalization	**Bottom-up Society: Glocalization**
GDP per capita, Thousand $US (2000 PPP)	North America: $36.4 (2005; $56.3 (2050)	Same
	Latin America: $7.5 (2005); $17.1 (2050)	Same
GDP, Trillion $US (2000 PPP)	North America: $12 (2005); $28.2 (2050)	Same
	Latin America: $4.2 (2005); $13.8 (2050)	Same
Population (OECD, IEA)	North America: 339 mn (2005); 444 mn (2050)	Same
	Latin America: 554 mn (2005); 804 mn (2050)	Same
Crude Oil Price	$60/bbl	$120
Political Framework	Environmental policies are among top political priorities and a high degree of accord develops in the international arena.	Policies are mainly driven by local and regional initiatives based on community's needs.
Governmental Responsibility	Global warming is the top priority in every level of the society.	Local / regional issues such as land use, congestion, pollution are prioritized.
International Cooperation	Active for environmental problems and dissemination of technology.	Level of cooperation is local / regional.
Lifestyle	International lifestyle spreads and travel distance increases although information technology also develops. International transaction increases.	Regional diversity and regional identity become the norm. "Local lifestyle" spreads with a preference for local production as well as for exploring their native district.
Energy	The reduction of oil usage is not motivated from the viewpoint of energy supply.	Self supply of energy within the region and the use of natural energy will improve. There is a strong motive to reduce oil usage.
Transport System	Dissemination of vehicle technology is fast Long distance travel increases Some urban sprawl	Dissemination of vehicle technology is relatively slow Long distance travel decreases Relatively high share of public transport due to higher urban density

Source: Data on GDP and population from ITPS, based on the IEA MoMo Model.

“Globalization” or the “Top Down” Society Scenario

The ITPS description of this world suggests there is a global focus on efforts to reduce CO_2 emissions from vehicles by all means, with only modest reductions from a baseline of vehicle, travel, and freight activity as proposed by the WBCSD work. An all-out technology effort requires strong international cooperation among vehicle and propulsion developers and fuel/electricity suppliers, consistent with the “Globalization” world suggested by ITPS.

In the Globalization scenario, where international technological cooperation seems to be emphasized, we expect only modest modifications to transportation activity per se. Indeed, the ITPS description suggests long-distance travel will continue to increase, although they suggest local mass transit will be supported. The latter is consistent with the need to address growing traffic congestion in major urban areas of North America, as well as in Latin America even in a scenario where the strongest focus is on CO_2, not transportation as such. That congestion in cities is arguably higher in Latin America than North America today at much lower motorization (Schipper et al., 2009), whatever the reason, suggests that authorities in Latin America should be paying attention to this problem in any future.

International cooperation means that vehicle technologies can be shared or licensed easily and rapidly so that there are few bottlenecks on fast to rapid improvements world-wide. An important driver of this development is local fuel economy (or emissions) standards for vehicles, coordinated internationally. Cooperation also implies agreements to promulgate carbon taxes high enough stimulate technology development. However, much of the world already pays road-fuel related taxes that are the equivalent of several hundred $US per tonne of CO_2, hence even at the highest CO_2 tax now implemented, in Sweden (about $140/tonne), CO_2 taxes have only a modest impact on overall fuel demand compared with the much greater remaining taxes. On the other hand, even a low carbon tax drives high carbon fuels out of power production and discourages making liquid fuels from coal, shale, or other hydrocarbons through carbon-intensive processes. The international agreements on CO_2 in the Globalization scenario will lead to CO_2 taxes that help suppress the demand for oil and make up for the lack of growth in oil prices. A carbon tax of $125/tonne CO_2, close to the level in place in Sweden (Makerowicz et al., 2010) is about $1.10US/gallon or the equivalent of $46/bbl on gasoline.

A successful off-carbon effort means much lower demands for oil, hence, oil prices alone cannot be counted on to drive this development. Indeed, a successful low carbon effort would leave oil prices low, since by definition the demand for oil products in absolute terms would be well below what is today. The level suggested for 2050, $60/bbl in year 2000, is indeed lower than the price at this writing. That price is not inconceivable if global demand in 2000 is considerably lower than it is today because of concern for CO_2 emissions. But a substantial tax on fuels as a carbon tax has to drive up the price paid by consumers to support the low-carbon efforts. Alternatively other policies (such as shifts in taxation from fuels to vehicle use, congestion pricing, or policies without direct taxation) are important to keep vehicle use from rising. This price pressure must be felt over all fossil fuels, lest their low prices encourage waste and therefore higher CO_2 emissions.

Low oil prices have an interesting impact on this work. Unless low carbon biofuels and fuel cells are inexpensive, the unit cost of energy will rise well above that of oil. This is another reason why a large carbon tax is important. At the same time, travelers in the "Global" society likely will face only modestly higher variable (i.e. fuel) costs of using vehicles compared with today. This is because efficiency must increase so much that even potentially expensive biofuels would still have costs/vehicle-km within reach of present costs, which for much of the world (but not the U.S. or Canada) are totally dominated by fuel taxation. If electric traction from fuel cells is chosen, the variable costs still do not rise by much because the on-board efficiency is so high. Because the cost of a vehicle-km does rise somewhat for fuel cells, we have modified the SMP activity levels downward. By contrast, if battery electric drive (not used in the present scenarios) becomes the dominant technology, there is the possibility of consumers having very low energy costs per km (with however high capital costs for batteries). In either case, authorities must watch carefully to see what replaces the revenues from use of road fuels.

Since the "Globalization" scenario suggests little concern for oil prices, we constructed this world as one led by international technological progress, not oil prices. Oil is still the main fuel for air travel, and still plays some role in much road transport, but at a much smaller scale because of both great improvements in efficiency and the presence of electric propulsion as fuel cells and some biofuels.

In the quantification of the fuel and CO_2 intensities of each mode, the ICCT sees a great push towards low-carbon fuel cells for light duty vehicles, and wide penetration of hybrid vehicles. Buses and trucks draw partly on low carbon biodiesel, while passenger and rail freight is heavily electrified from low-carbon sources.

We foresee no serious changes in land uses, transport activities, or mode shares from those projected by the SMP model. This is consistent with the description of the "Global" society described by ITPS. However, modest measures will be undertaken nationally and locally to reduce congestion on highways, airports, and in urban transport systems that will boost utilization of these modes (in persons per vehicle), reducing automobile use and travel somewhat as well. Such improvements employing ITS traffic controls also reduce fuel use and emissions per passenger-km delivered because of less idling and smoother traffic (Skabardonis, 2004). The higher cost of CO_2 emissions contributes to this reduction and offsets the efficiency improvements in air travel, slowing its growth from the 2005 value. This world will depend heavily on international cooperation with fuel economy standards, technology development in general, and new metrics for evaluating the full fuel cycle of greenhouse gas emissions from alternatives to oil products. To some extent this relies on the "restrictive society" described by ITPS. Taxes in general are necessary to reduce emissions, by letting emitters pay the direct and to some extent, social costs of transportation. Fuel economy standards are the other important component of the low-carbon thrust. This push brings forth improved technology.

Overall, the key policies of this scenario start with a global carbon tax. Such a tax is unlikely to be a major determinant of transportation activity, because its cost per km is likely to be small, but it is still important for driving high-carbon fuels out of energy markets. Fuel economy standards will have a major impact on vehicles and will be aligned internationally. But major transport reforms are not foreseen in this scenario, at least in North America. In Latin America, by contrast, the national provocations to improve urban transport will be effective in maintaining a high share of collective transport and improving conditions in cities. If strong measures are undertaken to reduce traffic congestion, these will lead to fuel and emissions savings for all motorized travel because of improved traffic conditions.

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North America in the Globalization Scenario

Since light duty vehicles, trucking, and air travel currently dominate North American transport CO_2 emissions, the focus will be on improving key transportation technologies, encouraging advanced vehicle technology research and development. This could include technologies supporting increases in energy efficiency or vehicles using alternative fuels. For vehicle technology improvements alone in the Globalization scenario, the ICCT foresees a 66 percent decline in fuel use/km for light duty vehicles, a 50 percent decline in fuel use per seat km for aircraft, and a 55 percent decline in fuel use/vehicle kilometer for heavy trucks. Since these three modes emit more than 85 percent of the CO_2 today and since these steep declines in fuel intensities offset the total increase in vehicle-km driven or seat-km flown, the net result is a decline in total CO_2 emissions. With reductions in the CO_2 content of fuels on a life-cycle basis, the decline is larger.

For travel, a key element of CO_2 saving in this world is that US and Canadian vehicles must become smaller, lighter and less powerful, but not less safe (Cheah et al., 2009). At present, the U.S. average on road fuel economy is approximately 11*l*/100km, comparing with close to 8*l*/100km on the road in Europe. The difference is almost totally explained by vehicle size and power (Schipper, 2009). Since most of the auto makers selling in Europe also sell in the U.S., making this first improvement requires little new technology. We assume size and power will not increase, so that all technological improvements will be focused on reducing fuel use per kilometer of light duty vehicles.

Another key trend in North America in this Globalization scenario will be to raise vehicle occupancy slightly, especially for cars and aircraft. The improvement in vehicle occupancy means that fewer vehicle-km are required to deliver a passenger kilometer. Different policies and regulations would have to be designed and implemented to trigger changes in vehicle utilization. Programs, policies and pricing that could entice drivers out of single occupant cars for commuting include improved transit service, as well as higher parking costs and congestion pricing or road tolling.

In this world, there is a significant increase in the share of travel on buses and rail to close to 10 percent, as suggested by ITPS. This increase draws mainly from solo commuters and shoppers in single-occupant vehicles, which in turn raises the utilization of the remaining trips in light duty vehicles (in passengers/vehicle). We foresee modest improvements in regional and medium distance bus and rail services to relieve some of the growing congestion of roads and airports. Air travel continues to grow, but at a slower rate.

Aircraft load factors are around 75 percent of seats as airlines struggle to remain competitive and energy efficient in the face of CO_2 taxes imposed on fuel.

For freight in Globalization, North American freight trends continue, with the tonne-km/GDP ratio falling slightly faster than previously. Increase in interregional trade and movement of goods to ports stimulates domestic activity, but that is in part offset by continued dematerialization of the US and Canadian economies. Trucking benefits from increased fuel economy and better vehicle utilization, including less empty running, as logistics companies make full use of information technology to utilize trucking space to the fullest extent possible and enable utilization of significantly larger trucks. Rail freight increases market share slowly as services improve, particularly to handle the increase in global trade moving through North America domestically from or to ports. Increasing small shipments are sent by rail or trailer-on-flat car or container as shippers avoid congestion on roads. Railroads are strengthened to handle increased imports and exports at major ports and avoid both highway congestion and increased pollution from trucking around ports. The result for rail is a small increase in its market share of total tonne-km shipped. Water borne freight in the U.S. holds steady after a big decline in the 1990-2006 period reflecting a loss of domestic oil shipping. Between now and 2050, however, both oil and coal will lose significant market shares in total energy supply, which will reduce the growth in rail and especially water-borne shipping within North America, the modes that carry much of these energy forms[10].

The average miles per shipment of manufactured goods in the U.S. was about 721, while the total ton-miles was 1.38 million in 2007 (U.S. Census Bureau, 2007). Out of total shipment, trucks were used to transport 55 percent of total ton-miles, while rail and water transportation modes were used for approximately 23 percent and 4 percent respectively. Retail trade, such as electronic shopping and mail order houses has a higher average miles per shipment, which was 1,169 in 2007, with a total ton-miles of approximately 6.40 billion (U.S. Census Bureau, 2007). Oregon, Idaho, California, and Arizona are states with

[10] This analysis does not encompass natural gas sent by pipelines, which in tonne-km volume carry 17 percent as much freight as the three modes covered (BTS, 2009). Additionally the pipelines represent an important source of CO_2 themselves, because almost all the power is provided by natural gas-run compressors. Leaked methane from both pipelines and compressors also represents an important source of GHG emissions in North America. Pipelines carrying oil in North America are not insignificant but represent a much smaller volume of freight than natural gas pipelines.

the highest average miles per shipment in the U.S. for this sector and over 20 percent of total shipments were made by trucks (U.S. Census Bureau, 2007). Since different commodities are shipped over different distances using different modes of transportation, it is assumed that in Glocalization, fewer purchases would be made online and more local business transactions would be encouraged. Compared to the Globalization scenario, there would be less freight transportation with long shipping distances in Glocalization. However, there is a significant drop in energy trade (coal and oil) in both scenarios, which as noted made up 50 percent and 33 percent of all tonne-km shipped in 2002.

In the Globalization scenario, the modal share of heavy trucks will be smaller than in the Glocalization scenario, while the modal share of rail will be larger. There would be more international consensus and compliances to follow in the Globalization scenario and therefore, a stronger incentive to introduce more freight rail networks and loads. The same assumptions will hold for Latin America.

Latin America in the Globalization Scenario

Cars are important in Latin America even if they only provide roughly 25 percent of all passenger travel (WBCSD, 2004). Mexico and Brazil are already major vehicle producers (cars, trucks, buses), while there is knockdown assembly and some primary vehicle productions elsewhere. Since most of these productions are managed by major American, Japanese and European auto firms, there are no intrinsic barriers to advanced vehicle technology in Latin America. More importantly, most new vehicles made and sold in Latin America are smaller than those sold in the US or Canada, which reduces fuel used. It is possible to foresee continuing car ownership and use increase, but with that increase dominated by small, low fuel using vehicles. However, current poor traffic conditions will worsen, together with an increase in on-road fuel economy to above 10*l*/100km as foreseen by the SMP (WBCSD, 2004; Fulton et al., 2009). We believe that traffic conditions will have to improve through strong policies, even in this “less restrictive” policy climate. For Latin America, car ownership in Globalization grows to 290 cars/1000 people. As a result of the concentration of relatively higher income households in cities, cars and their use will also be concentrated in cities, thus, leading to increased congestion from today’s already high levels. For this reason, it is assumed that car ownership and use will not grow as strongly, as it did in Europe, so that the ratio of car ownership to GDP will remain lower than Europe’s. Nor do we expect car use to have the same 70-80 percent of travel it had in European countries when they had this level of car ownership, primarily because of congestion.[11]

In this scenario, we expect local authorities will take some steps to improve traffic flow and manage transport demand, lest major cities become even more congested than they are today. This implies local transport planning and policy measures that will reduce vehicle-km/vehicle to some extent, even in a scenario that is driven mostly by international and national, not local initiatives. These initiatives, however, slow the rate of growth in car ownership relative to GDP.

Instead of continued car dominated growth, we see stronger bus and rail traffic in cities. Latin America manages to maintain most of its 50 percent share of urban transport in collective modes, both small colectivos and larger buses and metros. We note the success of recent top-down national programs to boost clean, low CO_2 urban transport in Colombia, Mexico and Brazil as evidence that even in a Globalization world, national authorities succeed in improving collective transport service. Efforts to build or improve intercity rail for both travel (and freight) corridors are launched in Mexico and elsewhere in Latin America. Latin America's high-class intercity buses gradually out-compete informal transit between cities. Domestic air travel grows, but its growth is limited to the largest or most elongated countries.

The other countries of Latin America, whose GDP/capita in 2050 will be close to that of Brazil today but only 2/3 of that of Mexico, will increase their car ownership, albeit at a slower rate in the past. The same traffic problems already plague Central American and remaining Latin American cities, hence we also foresee slower growth in car ownership relative to GDP as a reaction to the growing inconvenience of car use.

Latin American freight is presently largely truck-based, according to SMP. This dominance will continue, but we expect increasing road congestion will stimulate construction of important rail freight lines to connect ports and major cities, lines that can also provide fast passenger service. Mexico, Brazil, Peru, and Argentina could see increased coastal or river shipping between domestic ports.

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[11] Taken together, Germany, Italy, the UK and France reached this income level in 1978 with close to 300 cars/1000 people and an 80 percent car share of all travel (Schipper and Marie, 1999).

The Bottom Up Society: "Glocalization"

In the absence of a sure low- or zero- carbon propulsion system, radical changes in transport activity could be required to reduce CO_2 emissions well below present per capita levels. To the extent that significant externalities in transport exist not related to CO_2 itself, such changes are justified and bring with them important co-benefits of reduced CO_2 emissions (Schipper et al., 2009; Parry et al., 2007; Maddison et al., 1996). In "Bottom Up" society, large changes in transport policies and measures supported primarily (but not exclusively) by desires to improve local access and community health bring about a radical change in overall transport and both urban and rural development. For the U.S. and Canada, this means significant changes in land uses from present patterns; for the Latin American countries it means the end to following what appears to be North American style of sprawling cities, and embracing of land use and development patterns that favor non-motorized transport and collective transport that offer great access and choice than today's congested cities and busy main interurban roads. CO_2 reductions flow mainly as significant co-benefits from these transport strategies, which have their roots and political support in local concerns about transportation problems and local environmental issues like noise and air pollution. In Glocalization, it is local transport policies that raise the cost of using individual vehicles significantly. For example, shifting a part of insurance costs to driving could raise the price of using a car by U.S.$0.08/km.

In "Glocalization", we foresee no major shift in freight flows of the bulkiest commodities (ores, grains, energy etc), most of which are carried by rail and domestic shipping. Local transport and traffic policies reshaping trucking use to force greater efficiencies in distribution and light truck deliveries (i.e. DHL and other express services). Because information technology carries an ever larger share of documents, many of the lightest deliveries disappear entirely. Urban regions construct major logistics centers to handle both large truck-distribution transfers and to improve transfers among modes. Medium and longer-haul trucking sees major increases in vehicle utilization, as further development of information technology permits shippers and carriers to coordinate better movements of vehicles. Overall, trucking increases activity in absolute terms, but tonne-km/vkt increases so that truck vkt does not increase as rapidly. The trucking share of tonne-km in Glocalization is higher than in Globalization because of the decline in long-distance rail and water-borne freight in Glocalization, which according to ITPS, sees less long distance trade, particularly in North America. Whether a focus on local production is meaningful in such large countries as the U.S. or Canada is not clear, but we tried to keep to the philosophy of the scenario by reducing overall freight relative to GDP more rapidly than at its historical rate.

Higher energy costs slow the expansion of international trade, and bring more close-by production into focus. Since most raw materials flow within country by rail or domestic shipping, this shift is important for slowing the evolution of truck freight, which slows its rise in North America and loses some of its overwhelming domination in Latin America as rail freight networks are built with good inter-modal facilities to ease transfer to local trucking.

ITPS foresees a focus on local energy-related issues and energy sources. This could imply a push to make liquid transport fuels for coal or gas in North America and parts of Latin America, which could raise the GHG emitted per unit of fuel. Or it could prompt a greater push for biofuels, either those that grow "naturally" with high yields relative to the life cycle carbon emitted, such as ethanol from hydrocarbons, cellulosic ethanol, or synthetic biofuels from algae, residues and other materials. In its calculations, the ICCT foresaw little effort to develop low carbon fuel cells or electric traction for rail systems, so the carbon intensities of most vehicles are higher in Glocalization than in Globalization. This is offset somewhat by higher vehicle utilization in Glocalization (in persons or tonnes per vehicle) than in Globalization, the result of strong local transport policies.

To summarize, policies driving this scenario focus on access and healthy cities, in contrast to the history of automobile centered development. Transport and urban policies reshape North American transport and reorient what was auto-oriented development in both North and Latin America. CO_2 savings through mode shift and lower overall travel and freight come as co-benefits of other strategies. Technology also contributes to CO_2 savings, but private cars in Glocalization are smaller and less powerful than in Globalization, adding an almost 20 percent additional savings of fuel.

North America in the Glocalization Scenario

Glocalization leads to a concerted effort to reduce individual automobile use through transport policies. In the United States such a development has been well illustrated by a pair of recent studies, Growing Cooler (Ewing et al., 2008) and Moving Cooler (Cambridge Systematics, Inc., 2009). While not without controversy, these reports present useful summaries of various studies suggesting how land use changes, improved collective transport, higher charges on vehicle use and other policies could lead to significantly less travel in cars, some of which is replaced by collective transport or non-motorized transport. These reports serve as guides to what might result, but much more work is required to quantify firmly the impacts of policies on vehicle use and overall mobility and mode share.

In this scenario, we illustrate what happens when such measures as suggested in these and other studies are pursued exhaustively. While much of the North American region's infrastructure is mature and built, the time frame of 2050 is long enough for significant changes to occur to land uses that will significantly increase both urban and suburban densities. We postulate a significant decline in automobile kilometers traveled, some of which is compensated by a significant increase in per-capita use of urban transit and interregional bus and rail, by approximately four or six times. High speed rail defines corridors previously given over to car and air traffic. With higher population densities, traffic congestion is managed with congestion pricing and parking fees based in part on vehicle footprint. This development stimulates a gradual but steady and large reduction in the size and power of automobiles in all regions to well below the size of those in Europe today. With increased access provided by transit and non-motorized transportation, the number of cars per capita is 10 percent lower than in its global value, particularly as boomers and the post-boomer generations retired in a world less built around large cars and suburban malls.

A key policy driver in this world is the much higher variable cost of transportation. CO_2 and fuel taxes make up some of this higher cost, but the internalization of externalities, higher road-use (VKT) charges to pay for roads themselves, switching of fixed-cost insurance to that based in part on km driven all reduce the use of private cars. Clear dedication of road space to fast buses and BRT also gives travelers an alternative to private cars that is both faster and less costly.

The other key element of this scenario is strong land-use planning. For North America, this means purposeful place-making around transit nodes (transit oriented residential and commercial development) and conversely, strong emphasis on collective modes for bringing people to major centers of homes, offices, services, and leisure, and significant increases in travel by non-motorized modes – walking and biking. One impetus for land use planning is the deterioration of urban space through domination of the automobile. Another will be the rising cost of moving a kilometer, which could stimulate denser development to enable individuals to reach jobs, services, friends and leisure traveling fewer kilometers. The same could be said for freight, particularly distribution.

One of the themes of this “Glocalization” world is that more activity is local or regional. Long-distance air travel slightly in per capita terms, in contrast to its historical growth that outpaced GDP for most of the post World War II era. Air still serves the major long distance routes, but much business travel is replaced by IT and teleconferencing.

In general, Glocalization in North America would still encourage the use of heavy trucks for freight, as without international pressure or agreements to combat climate change, local incentives and regulations will encourage a higher use of freight trucks than rail. The ratio of freight hauled (all modes, in tonne-km) to GDP falls 25 percent faster than its historical rate (i.e., about 1.25 percent/year) because of the slackening of international and long-distance trade as consumers turn to more materials and products made nearby. Still trucking carries the highest share of the value of goods shipped (BTS, 2008). Its role in carrying high-value commodities remains, while the absolute tonne-km shipped by truck increases. Strong pressures on local and interstate road use costs push up truck load factors by 50 percent from their assumed values in Globalization. Congestion and pollution from trucks around ports will prompt governments and the private sector on both continents to improve rail connections with every major port to inland areas, which will in turn stimulate more frequent rail freight between major manufacturing and shipping centers. The drop in coal use will reduce growth in shipping and rail freight.

Latin America in the Glocalization Scenario

For Latin America, urban and inter urban transport infrastructures are not yet as developed as they are in North America. Hence, change involves taking a new direction now for urban development and inter-urban transport. By 2050, such changes could have a large impact on the region. Indeed, such developments in Latin America are already supported by national policies with a strong local component. As Colombia (Bogota) and, more recently Mexico (Mexico City) demonstrate, strong national urban transport policy support starts with a clear success story in an urban region (Munoz-Raskin et al., 2009; Mier y Tieran, 2009).

Despite Latin America’s present high level of car ownership relative to GDP (Schipper et al., 2009), continued rapid increases in ownership face increasingly poor traffic. It is possible that leaders at the State and National level will take actions to reduce the pressures from rising car use, as the new programs in Colombia and Mexico suggest. Thus, we reduce car ownership/1000 in Latin America in Glocalization by 10 percent over its Globalization value.

In the bottom-up world, Latin American intercity transport develops around existing bus networks, which today are strong and modern in some cities of Mexico and Brazil. Rapid service (with internet and entertainment on board) provides the backbone of travel where rail corridors are not feasible because of low demand. However, high and medium speed rail is developed in key corridors (Mexico City-Queretaro-Leon, Rio-Sao Paulo-Campinas-Curitiba etc.), reducing growth of airline travel in the largest countries. Urban regions improve inter-modal facilities so passengers move quickly from local BRT or rail systems into intercity bus or rail service.

In Glocalization, policies directed at vehicle technology are not ignored. The lower level of international cooperation means that progress in technology is not as rapid as in "top down". However, national fuel economy standards, coupled with much smaller car size and power, means that real on-road fuel economy can reach almost 4 *l*/100 km on the road, in part because transport measures improve traffic flow.

Freight in Latin America will evolve differently in Glocalization. In Latin America today, trucking dominates freight, with only Brazil having significant river and coastal shipping. In Glocalization, utilization of trucking improves in response to congestion on intercity roads, as well as at the edges of urban regions - more tonne-km per vehicle km. Cooperation of the truck and fuel providers also hastens improvement in vehicle fuel economy, particularly given the presence of major U.S. and European manufacturers throughout the Latin America region.

In Latin America, Glocalization sees logistics and distribution centers built rapidly in outlying areas of major cities to avoid further highway and urban congestion. Flexibility of work hours to receive goods at night or very early in the morning, and increased personal security (for drivers and at points of unloading) will allow more distribution of freight at hours when roads are clear. These improvements enable the distribution of freight in urban areas with fewer vehicle km. The rail corridors established for passenger travel are utilized at night for medium distance freight distribution. Faced by pressure from congested urban areas near the sea, ports are improved and connected to major cities by rail, allowing more efficient use of coastal shipping in both South and Central America.

Table 13 shows a summary of the different policy packages that should be implemented in order to achieve the ultimate reduction in CO_2 emissions in each region. Both sets of scenarios require a combination of different polices. In general, policies for North America should focus on strengthening existing transportation emissions standards and reducing transportation energy intensities in the short term, while promoting behavioral changes that will lead to a well-distributed modal split among different transportation modes in the long term. Transportation policy options for Latin America should provide climate co-benefits, which imply policies that will improve current transportation conditions and reduce climate change impact at the same time should be supported and given higher priority.

Table 13: Policies Implementation and Emphasis in Each Scenario and Region

Policy	Globalization	Glocalization
Transportation Technologies and Strategies		
Fuel Economy Standards	✔	✓
Advanced Vehicle Technology	✔	✔
Alternative Transportation Fuels	✔	
Intelligent Transportation Systems	✔	✔
Land Use Planning		
Public Transportation Investment		✔
Transit-Oriented Development		✔
Jobs-Housing Balance		✔
Influential Urban Design		✔
Pricing Instruments Design		
Fuel and Vehicle Taxation	✔	
Carbon Emission Taxation	✔	
Congestion Pricing Scheme		✔
Parking Pricing Strategies		✔

Note: Each tick "✔" denotes a strong emphasis on a dominating policy. The smaller ticks indicate the policy or measure is not absent, but less significant.

Although certain policies are more strongly emphasized in Globalization than Glocalization and vice versa, it does not imply that the policies not emphasized will not be implemented in the long term. For example, Transportation Technologies and Strategies will have a larger role in Globalization because of the strict global cooperation standards that each region has to comply with and by comparison, Land Use Planning will serve a smaller role in influencing travel behavior and demand patterns in this scenario. Similarly, in Glocalization, where local policies dominate transportation regulations, measures related to changes in land use planning will inflict a higher degree of influence on reducing

CO_2 emissions than in Globalization. Different policy assumptions made in the Globalization and Glocalization scenarios will affect modal shares and distance traveled (tonne-km) of the various transportation modes studied, for passenger travel and freight transportation.

RESEARCH RESULTS

In this section, we show results from the two approaches to project CO_2 emissions from transport in the Americas in 2050. First, we show back-casts results based on the emissions target set forth by ITPS. Finding these results unrealistic for North America (but plausible for Latin America), we then produce projections together with key values of vehicle and modal energy and carbon intensities provided by the ICCT. The projections for North America wind up 65-68 percent below 2005 absolute emission levels, compared to an increase of 63 percent in the business as usual case.

Back-casting a Low Carbon Future

The first approach, back-casting, started with the lower of two targets suggested by ITPS and back-cast a range of mode shares and very low CO_2 intensities to see if a combination yields the two per capita emission goals suggested by ITPS. Recall that the target was derived by ITPS by taking the 2000 global per capita average emissions for transport and cutting it in two, to 315 kg/capita. The result appeared unrealistically ambitious at the current time. Achieving the target required a 94 percent reduction from 2005 levels of per capita emissions for North America from nearly 6000 kg/capita down to the target of 315 kg/capita for both travel and freight. Arriving at this target means s a very steep decline in both personal mobility and CO_2 emissions per unit of travel or freight. For Latin America, the required decline in per capita emissions for travel is much smaller, since 2005 emissions for travel lay around 600 kg/capita, compared to a “target” of approximately 180 kg/capita for passenger travel alone.

Back-casting for North America

Our back-cast of North America transportation emissions brings the per capita emissions from travel and freight down to close to 350 kg/capita, or from just under 5000 Mt of CO_2

(tailpipe) or 5700 Mt (LCA) in 2005 down to only 152 Mt by 2050, which is consistent with the target suggested by ITPS of 315 Kg/capita139 measured at the vehicle tailpipes. As shown in Table 14a, the modal carbon intensities (CO_2/passenger-km) that were assumed in each back-cast scenario are very low for North America. Tables 14a and 14b also show the scenario results of CO_2 emissions by transportation mode for passenger travel and freight transportation in North America respectively.

Table 14a: Travel Back Casting Results for North America, 2050

2005 Actual	**LDV**	**Bus**	**Rail**	**Air**	**Total**
Travel Volume (billion PKT)	6560	341	47.9	1420	8370
Modal Share	78%	4%	1%	17%	100%
Tailpipe Intensity, g CO_2/PKT	173	87.6	44.3	179	170
Total Tailpipe, Mt CO_2	1140	29.9	2.12	255	1420
Total LCA, kg/capita	4060	104	21.5	887	5070
Total LCA, Mt CO_2	1340	34.1	7.06	292	1670

2050 Glocalization	**LDV**	**Bus**	**Rail**	**Air**	**Total**
Modal Share	65%	13%	17%	4%	100%
PKT/capita	7500	1500	2000	500	11500
Fuel Economy, l/100km	2.5	22.5			
Vehicle Occupancy, p/veh	2.12	25			
Carbon Intensity, g CO_2/PKT	15.6	16	39	126	
Total LCA, kg/capita	117	24	77.9	63.1	282
% Change from 2005	-97%	-77%	+263%	-93%	-94%
Total LCA, Mt CO_2	51.9	10.7	34.6	28	125
% Change from 2005	-96%	-69%	+389%	-90%	-93%

2050 Globalization	**LDV**	**Bus**	**Rail**	**Air**	**Total**
Modal Share	78%	6%	9%	7%	100%
PKT/capita	13500	1000	1500	1250	17300
Fuel Economy, l/100km	2	20			
Vehicle Occupancy, p/veh	1.75	20			
Carbon Intensity, g CO_2/PKT	7.57	10.6	3.98	55.6	
Total LCA, kg/capita	102	10.6	5.98	69.5	188
% Change from 2005	-98%	-90%	-72%	-92%	-96%
Total LCA, Mt CO_2	45.3	4.71	2.65	30.8	83.5
% Change from 2005	-97%	-86%	-63%	-89%	-95%

Table 14b: Freight Back Casting Results for North America, 2050

2005 Actual	H. Truck	M. Truck	Water	Rail	Total
Freight Volume (billion tkm)	2710	268	1120	2530	6620
Modal Share	41%	4%	17%	38%	100%
Tailpipe Intensity, g CO_2/tkm	116	386	93.3	18.5	86
Total Tailpipe, Mt CO_2	315	104	104	46.8	569
Total LCA, kg/capita	1090	361	359	162	1970
Total LCA, Mt CO_2	358	119	118	53.3	648

2050 Glocalization	H. Truck	M. Truck	Water	Rail	Total
Modal Share	47%	3%	15%	35%	100%
Freight Volume (billion tkm)	1850	120	602	1400	3970
Fuel Economy, l/100km	22.5	4			
Load Factor, t/veh	15	2			
Carbon Intensity, g CO_2/tkm	32.1	42.8	19.4	17.2	
Total LCA, kg/capita	134	11.6	26.4	54.6	226
% Change from 2005	-88%	-97%	-93%	-66%	-89%
Total LCA, Mt CO_2	59.2	5.15	11.7	24.2	100
% Change from 2005	-84%	-96%	-90%	-55%	-85%

2050 Globalization	H. Truck	M. Truck	Water	Rail	Total
Modal Share	36%	3%	15%	46%	100%
Freight Volume (billion tkm)	2230	186	928	1400	4750
Fuel Economy, l/100km	20	3.5			
Load Factor, t/veh	12	1.5			
Carbon Intensity, g CO_2/tkm	11.9	16.6	14.8	2.97	
Total LCA, kg/capita	59.7	6.97	31	18.6	116
% Change from 2005	-95%	-98%	-91%	-89%	-94%
Total LCA, Mt CO_2	26.5	3.09	13.8	8.26	51.6
% Change from 2005	-93%	-97%	-88%	-85%	-92%

The aggregate carbon intensity (LCA) of travel in 2005, in practice that of car and air travel together, was just over 200 gm/pass-km, while that of freight was 111 gm/tonne-km. In Globalization, the intensity of travel falls by a factor of 15, while that of freight falls by a factor of 10. Recall that Glocalization tends to have less technological progress, so vehicle energy intensities are higher than in Globalization. But because of the pressure of transport policies, vehicles utilization or load factors are higher in Glocalization, which in some cases means fewer emissions/passenger-km than in Globalization. In either scenario, however, the required vehicle or modal carbon intensities are very low compared to present levels. In globalization, car fuel on average has only 25 percent of current CO_2 content, and even in Glocalization, that figure is 50 percent of current level.

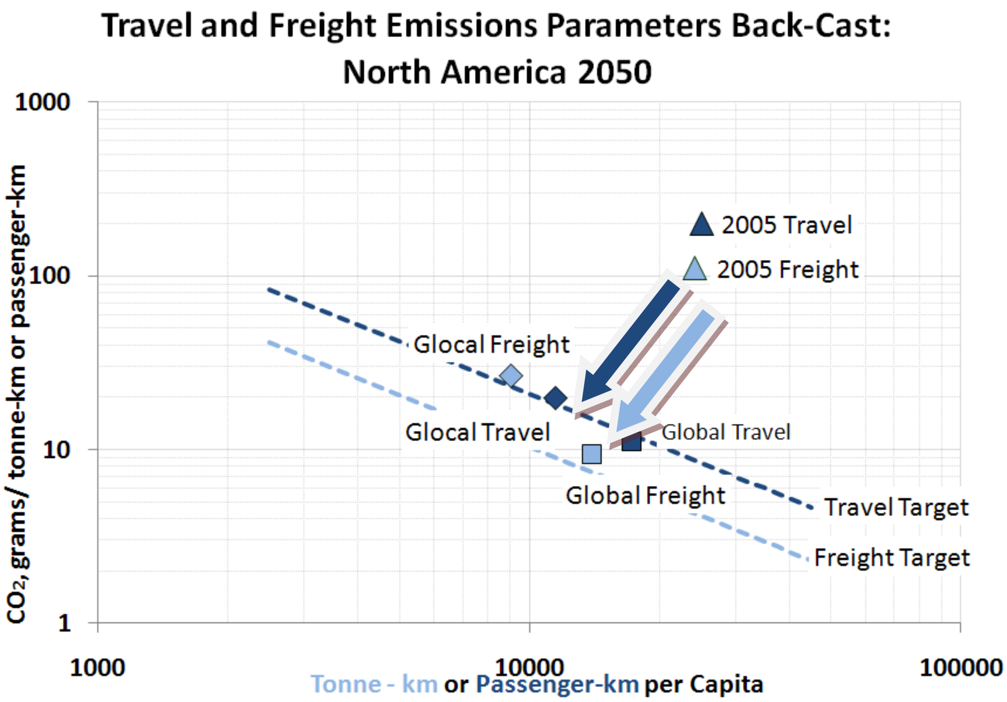
In our view, only a significantly large share of truly low or zero carbon fuel, combined with very low energy intensities of cars (2.5 l/100 km in Glocalization, 2 l/100 km in Globalization, all in gasoline equivalents, compared with over 11 l/100 km in the Americas in 2005) could give such low emissions from travel. Many automakers claim to have prototypes that approach these low values, but putting them on the road (with room for up to four people) is another matter. Were such vehicles a certainty, the constraints put on overall travel - a large drop - from this back-casting could be relaxed.

Levels of per capita travel fall notably in this back-cast. In Globalization, per capita travel in North America is about 1/3 lower than in 2005, a decline greater than the changes estimated in Moving Cooler, a recent study of the U.S. alone (Cambridge Systematics, Inc., 2009). Car travel falls by 1/3 from 2005, air travel by 75 percent, changes that do not seem likely without great changes in lifestyles and behavior. At the same time, rail travel grows from an insignificant 50 pass-km/capita in 2005 to over 1250 pass-km/capita by 2050. This implies that a great deal of travel in short and medium distances are by conventional rail and high speed rail. Without a low carbon source of jet fuel, air travel at even the present level in North America (almost 2200 pass-km/capita) is unsustainable.

In Glocalization, travel in North America falls even more than it does in Globalization. The carbon intensities of travel fall considerably less than in Globalization, but total travel must fall to 1/3 below its Globalization level (and only 40 percent of its 2005 level) to compensate if the targets are to be met. Car travel drops by a factor of 3, respectively, and air travel by 90 percent in Glocalization. These changes imply large lifestyle and land use changes that are associated with both lower trip rates and shorter distances traveled, particularly in cars. They represent the per capita travel levels (in passenger-km) from before World War II. For North America, whose cities and regions sprawl in two dimensions, it is hard to imagine how even a huge increase in rail travel, which is generally in corridors such as Japan or Stockholm-Copenhagen in Sweden, could assume 5000 passenger-km or more per capita of conventional and high speed rail travel in North America. Still the results show that without an extremely low carbon source of propulsion in very efficient vehicles, travel must fall significantly to meet the low target specified.

The overall change for North America results in lower activity per capita and much lower CO_2 per unit of activity (Figure 12). These decreases in travel imply a very high cost of each kilometer or an even higher cost of carbon. They further illustrate that without a very low carbon source of fuel for all modes, North American travel has to fall drastically for the per capita CO_2 targets to be met.

Figure 12: Emissions Back-cast Results for North America



Back-Casting Results for Latin America

For Latin America, the back-casting to the targets requires less radical change, because per capita emissions are so much lower than in North America. Absolute levels of both travel and freight activity are shown to have risen. Tables 15a and 15b give key results by transportation mode. Per capita car ownership in Globalization is about double its 2005 level, while it is 50 percent higher in Glocalization. With a projected population 1/3 higher than in 2005, this raises the numbers of light duty vehicles in already congested cities significantly. On the other hand, both Globalization and Glocalization postulate large increases in rail travel and freight, but only Globalization projects a significant increase (by a multiple of five) in air travel.

Table 15a: Travel Back Casting Results for Latin America, 2050

2005 Actual	LDV	Bus	Rail	Air	Total
Travel Volume (billion PKT)	671	948	16.8	65.9	1700
Modal Share	39%	56%	1%	4%	100%
Tailpipe Intensity, g CO_2/PKT	261	51.1	44.3	179	139
Total Tailpipe, Mt CO_2	175	48.5	0.742	11.8	236
Total LCA, kg/capita	340	97.6	4.46	24.4	467
Total LCA, Mt CO_2	189	54.1	2.47	13.5	259

2050 Glocalization	LDV	Bus	Rail	Air	Total
Modal Share	47%	44%	6%	3%	100%
PKT/capita	3690	3500	500	200	7890
Fuel Economy, l/100km	2.75				
Vehicle Occupancy, p/veh	2.1	35			
Carbon Intensity, g CO_2/PKT	24.3	14.3	22.2	189	
Total LCA, kg/capita	89.5	50.2	11.1	37.8	189
% Change from 2005	-74%	-49%	+150%	+55%	-60%
Total LCA, Mt CO_2	71.9	40.3	8.94	30.4	152
% Change from 2005	-62%	-26%	+262%	+125%	-41%

2050 Globalization	LDV	Bus	Rail	Air	Total
Modal Share	54%	37%	3%	6%	100%
PKT/capita	4390	3000	250	500	8140
Fuel Economy, l/100km	33.5				
Vehicle Occupancy, p/veh	2	20			
Carbon Intensity, g CO_2/PKT	15.9	14.7	4.98	139	
Total LCA, kg/capita	69.7	44.2	1.25	69.5	185
% Change from 2005	-80%	-55%	-72%	+185%	-60%
Total LCA, Mt CO_2	56	35.5	1	55.9	148
% Change from 2005	-70%	-34%	-60%	+314%	-43%

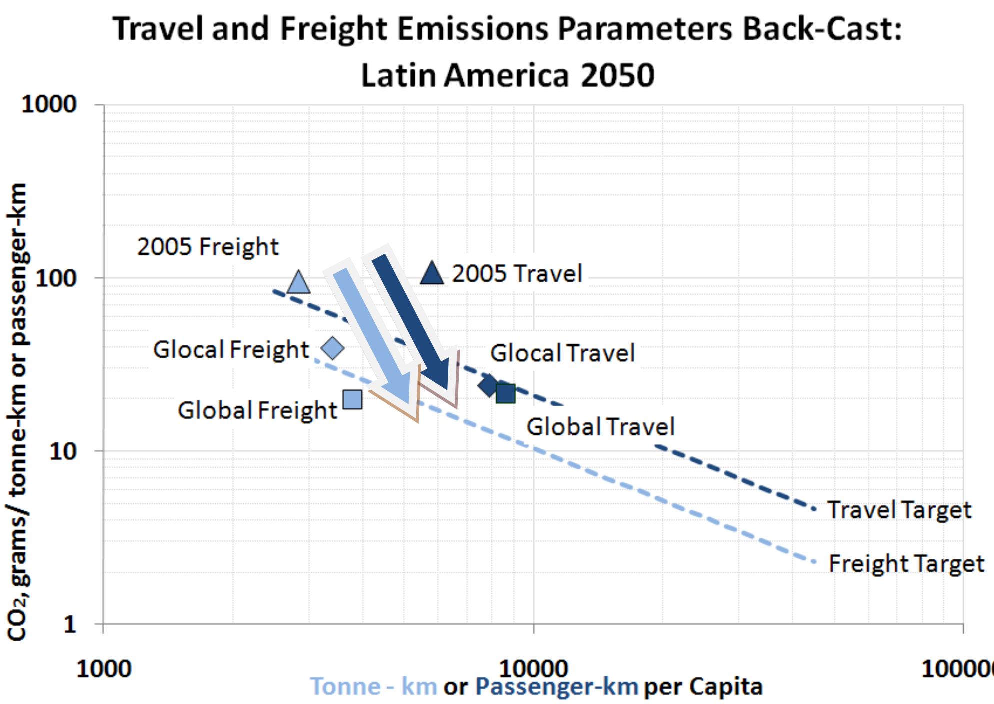
Table 15b: Freight Back Casting Results for Latin America, 2050

2005 Actual	**H. Truck**	**M. Truck**	**Water**	**Rail**	**Total**
Freight Volume (billion tkm)	853	192	139	261	1440
Modal Share	59%	13%	10%	18%	100%
Tailpipe Intensity, g CO_2/tkm	151	404	259	18.5	171
Total Tailpipe, Mt CO_2	129	77.3	36	4.83	247
Total LCA, kg/capita	265	156	73.7	9.91	504
Total LCA, Mt CO_2	147	86.2	40.9	5.49	279
2050 Glocalization	**H. Truck**	**M. Truck**	**Water**	**Rail**	**Total**
Modal Share	57%	3%	15%	25%	100%
Freight Volume (billion tkm)	1540	82.2	411	685	2710
Fuel Economy, l/100km	26	5			
Load Factor, t/veh	10	2.5			
Carbon Intensity, g CO_2/tkm	48.6	37.4	23.7	23.7	
Total LCA, kg/capita	92.8	3.82	12.1	20.2	129
% Change from 2005	-65%	-98%	-84%	+104%	-74%
Total LCA, Mt CO_2	74.6	3.07	9.75	16.3	104
% Change from 2005	-49%	-96%	-76%	+196%	-63%
2050 Globalization	**H. Truck**	**M. Truck**	**Water**	**Rail**	**Total**
Modal Share	52%	3%	15%	30%	100%
Freight Volume (billion tkm)	1560	91.5	458	915	3020
Fuel Economy, l/100km	24	5			
Load Factor, t/veh	12.5	2			
Carbon Intensity, g CO_2/tkm	23.9	13.8	15.8	9.88	
Total LCA, kg/capita	46.3	1.58	9.01	11.3	68.2
% Change from 2005	-83%	-99%	-88%	+14%	-87%
Total LCA, Mt CO_2	37.2	1.27	7.24	9.05	54.8
% Change from 2005	-75%	-99%	-82%	+65%	-80%

The vehicle fuel intensities for light duty vehicles are not as low as in North America because of the important role of traffic congestion in raising such intensities. The intensities of bus travel are low because buses are large and full.

Figure 13 illustrates back-casting results for Latin America. Shown in the figure are the two “target lines” and the results for travel and freight back-cast under the Globalization and Glocalization scenarios. While the carbon intensities of freight and travel must fall significantly, the levels increase in both scenarios (see also Tables 15a and 15b).

Figure 13: Back-Cast Results for Latin America



Conclusions from Back-Casting

The conclusions from back-casting are simple. Bringing CO_2 emissions from transport down to the proposed level of roughly 6 percent of per capita 2000 emissions (for North America), is an impossible job without fuels with very low CO_2 emissions combined with large improvements in vehicle efficiency (together the carbon intensity of vehicles) and increases in vehicle utilization (people or tons/vehicle). If the carbon intensity of vehicles falls by 90 percent, vehicle utilization increases by 30 percent and travel and freight activity in the most intensive modes (light duty vehicles, air travel and trucking) falls by 20-40 percent from its 2005 levels, these targets would then be realized. For Latin America, achieving these targets is less daunting only because motorization and emission levels are lower than in North America.

Bottom-Up Projections

A second set of scenarios was developed "bottom up". The ICCT developed the fuel and emissions intensities of vehicle travel for light duty vehicles and buses, and the modal energy intensity for rail and air travel (expressed as emissions/seat-km). For freight modes, vehicle intensities for trucking were developed by the ICCT in considerable detail, while the intensities of rail and water-borne freight were projected from present observed patterns. We projected the base-line passenger and tonne-km from 2005 values, in some cases using the SMP projections and varying them, in other cases (air and bus travel, truck freight) using the SMP rates of change but different starting data. We have also varied the vehicle utilization factors (people or tonnes/vehicle or railcar) in some cases to alter the vehicle-km traveled for a given number of passenger or tonne-km. By this modification of vehicle intensities provided by the ICCT, we differentiated between Globalization and Glocalization to reflect the policy pressures reducing vehicle use (but not necessarily travel or freight levels) in Glocalization.

Projections for Passenger Travel

Travel (cars and SUVs, together called "light duty vehicles", buses, urban and intercity rail and domestic air) make up the largest portion of the transport sector covered here. In North America, cars dominate both travel and emissions, while in Latin America motorized travel is led by buses. Tables 16a and 17a show the projections results for passenger travel in North America and Latin America respectively.

Table 16a: North America Travel Projections

2005 Actual	LDV	Bus	Rail	Air	Total
LDV Ownership, veh/1000cap	753				
Travel Volume (billion PKT)	6560	341	47.9	1420	8370
Modal Share	78%	4%	1%	17%	100%
Tailpipe Intensity, g CO_2/PKT	173	87.6	44.3	179	170
Total Tailpipe, Mt CO_2	1140	29.9	2.12	255	1420
Total LCA, kg/capita	4060	104	21.5	887	5070
Total LCA, Mt CO_2	1340	34.1	7.06	292	1670

2050 Glocalization	LDV	Bus	Rail	Air	Total
LDV Ownership, veh/1000cap	695				
Modal Share	71%	9%	5%	15%	100%
PKT/capita	15600	1910	1050	3300	21900
Fuel Economy, l/100km	2.83	14.7			
Vehicle Occupancy, p/v or %	2	22.8	66%	75%	
Carbon Intensity, g CO_2/PKT	12.7	6.36	23.9	108	
Total LCA, kg/capita	646	40	83.3	408	1180
% Change from 2005	-84%	-62%	+287%	-54%	-77%
Total LCA, Mt CO_2	286	17.8	36.9	181	522
% Change from 2005	-79%	-48%	+423%	-38%	-69%

2050 Globalization	LDV	Bus	Rail	Air	Total
LDV Ownership, veh/1000cap	869				
Modal Share	72%	5%	2%	21%	100%
PKT/capita	17700	1190	524	5000	24400
Fuel Economy, l/100km	4.84	16.3			
Vehicle Occupancy, p/v or %	1.65	15	50%	75%	
Carbon Intensity, g CO_2/PKT	25.1	10.7	3.39	95	
Total LCA, kg/capita	595	15.9	6.5	544	1160
% Change from 2005	-85%	-85%	-70%	-39%	-77%
Total LCA, Mt CO_2	264	7.04	2.89	241	515
% Change from 2005	-80%	-79%	-59%	-17%	-69%

Table 17a: Latin America Travel Projections

2005 Actual	LDV	Bus	Rail	Air	Total
LDV Ownership, veh/1000cap	89.4				
Travel Volume (billion PKT)	671	948	16.8	65.9	1700
Modal Share	39%	56%	1%	4%	100%
Tailpipe Intensity, g CO_2/PKT	261	51.1	44.3	179	139
Total Tailpipe, Mt CO_2	175	48.5	0.742	11.8	236
Total LCA, kg/capita	340	97.6	4.46	24.4	467
Total LCA, Mt CO_2	189	54.1	2.47	13.5	259

2050 Glocalization	LDV	Bus	Rail	Air	Total
LDV Ownership, veh/1000cap	178				
Modal Share	48%	46%	2%	4%	100%
PKT/capita	3620	3470	137	295	7530
Fuel Economy, l/100km	3	15			
Vehicle Occupancy, p/veh	2.25	31.8	66%	85%	
Carbon Intensity, g CO_2/PKT	20.7	7.08	32.2	108	
Total LCA, kg/capita	128	54.7	14.7	36.4	234
% Change from 2005	-62%	-44%	+230%	+49%	-50%
Total LCA, Mt CO_2	103	44	11.8	29.3	188
% Change from 2005	-46%	-19%	+378%	+117%	-27%

2050 Globalization	LDV	Bus	Rail	Air	Total
LDV Ownership, veh/1000cap	197				
Modal Share	59%	35%	1%	5%	100%
PKT/capita	4400	2620	68.5	398	7490
Fuel Economy, l/100km	5.05	15.3			
Vehicle Occupancy, p/veh	2	21.5	50%	75%	
Carbon Intensity, g CO_2/PKT	38.4	10.5	4.56	95	
Total LCA, kg/capita	181	34.6	1.15	43.3	260
% Change from 2005	-47%	-65%	-74%	+77%	-44%
Total LCA, Mt CO_2	146	27.8	0.922	34.8	209
% Change from 2005	-23%	-49%	-63%	+158%	-19%

Total Travel and Mode Shares

The total travel volume follows the SMP projections as a base line. We note that the ratio of total travel to GDP falls in either scenario in both regions, just as how it has fallen historically in North America. In our scenarios, however, total travel relative to GDP falls faster than it has historically because of higher travel costs, congestion, and to some extent concerns about CO_2. In the Glocalization scenario, the real cost of using a car increases significantly because of policies shifting costs and charges to kilometers driven, such as congestion pricing or pay-as-you-drive insurance. While it is too early to say whether the recent drop in per capita car travel (before the recession) is only a function of higher fuel prices (Millard-Ball and Schipper, 2010), our scenarios posit a decline to give a contrast with the BAU. We note that in BAU, however, per capita travel in cars is barely 3 percent higher in 2050 than it was in 2005. Hence, falling car travel is not impossible and consistent with two recent transportation emissions studies for the U.S. (Cambridge Systematics, Inc., 2009 and Ewing et al., 2008).

Indeed, the resulting level of travel for 2050 in Glocalization is approximately of the same level as what Canada experienced in 2005, so the change for the U.S. could not be called draconian. In all, the per capita level of car travel falls by 25 percent in Globalization and 50 percent in Glocalization, leaving North America with mode shares that resemble those of Sweden today. In each case about half of that decline in car use is made up by increased rail and bus travel. The rest comes from trips not made, or taken on foot or cycle. It is assumed that a large share of these trips was previously made in single-occupant cars. That shift helps raise light-duty vehicle occupancy in either scenario to 1.65 in Glocalization and 2.0 in Glocalization (Table 9).

Per capita air travel grows by 60 percent in Globalization but only by 10 percent in Glocalization. The Glocalization assumptions imply little growth in long-distance travel. Furthermore, we assume that a significant part of the 777 pas-km/capita of rail achieved in Globalization (and an even higher level in Glocalization), is contributed by high speed rail along appropriate U.S. and Canadian corridors that would otherwise have been medium-distance air and automobile travel.

For Latin America, the key variable for travel is car ownership. This was projected as noted, using Spain's car ownership and use in 1990 as a guide. Vehicle occupancy was assumed to be 1.75 people/car in Glocalization and 2 people/car in Glocalization, figures the U.S. experienced in the 1970s and 1969 respectively, with much higher levels of car ownership. In OECD countries, higher car ownership is associated with lower occupancy, so these occupancy factors may actually be low.

For Latin America, uncertain travel figures for other modes were projected based on maintaining steady growth in bus travel, increasing the very small amount of rail travel, and increasing air travel (from a 2005 value of 104 pass-km/capita) by a factor of 3.5 in Glocalization and 2.6 in Glocalization (Table 16b). Per capita bus travel in Latin America in 2005 was almost a factor of 10 higher than in North America, both because of much higher utilization of both mini-buses and large buses in urban transport and because intercity travel is still dominated by buses. We assume that the share of total traffic taken by mini-buses falls, which is the trend today as many Latin American regions reform urban transport practices to reorganize urban transport around larger vehicles and reduce the oversupply of operators – with relatively empty vehicles (Ardila, 2008).

Concerning air travel, people in the U.S. flew only 447 passenger-km/capita in 1965, a year when their per capita GDP was close to the 2050 level foreseen for Latin America. While flying has become much cheaper over time, the figures adopted for Latin America seem reasonable since they represent only domestic flying, which is only likely to take place on a large scale in Argentina, Brazil, Chile, and Mexico. GDP is not the only driving force behind domestic air travel, as geography (the size of the country) and access to competing modes (and their costs), such as high speed rail or good motorways is important for distances up to 1000 km. A key uncertainty is whether even medium speed rail networks will be built or enhanced in Latin American countries, where currently even in the largest countries, intercity rail travel is low in comparison with that in buses.

Fuel Economy, Vehicle and Modal Energy Intensities and Carbon Intensities

The ICCT made projections of vehicle fuel economy for light duty vehicles, buses, rail train sets and aircraft. In Glocalization, we “downsized” car power and weight according to figures developed by the ICCT, resulting in intensities lower than those in the more technologically driven Globalization scenario, as noted in Tables 14 and 15. Buses are both more efficient (less energy/veh-km), have some penetration of bio-diesel fuel or diesel hybrid engines, and have more passengers, all of which reduces emissions per passenger-km significantly.

For the other modes, the ICCT provided a set of figures that gave energy use per unit of travel based on a given vehicle occupancy factor. By varying the occupancy factor (percentage of aircraft or rail seats occupied, tonnes/vehicle) we could vary the effective modal energy intensity in the Glocalization scenario, under the assumption that fuel used to move vehicles is roughly independent of the load in the vehicle.

Overall, total travel in North America is lower in Globalization and almost a third lower in Glocalization than in 2005, contributing to lower emissions. But far more change is contributed by significantly lower emissions per unit of travel. It is instructive to separate the impacts of technology changes – lower CO_2 intensities – from the deliberate changes in distances traveled and mode choice in each scenario. Applying the Globalization intensities (from the ICCT) to the BAU activity levels results in 38 percent of the BAU emissions in North America and 13 percent of BAU emissions in Latin America, roughly 66 percent higher than the values obtained from both travel changes and intensity changes in each region's Globalization results. Making the same shift in the Glocalization leads to 50 percent of BAU emissions for North America and 14 percent of BAU in Latin America, approximately 115 percent higher than in the full Glocalization scenarios respectively. This shows that the combination of significant reductions in travel (in North America) or in projected growth in travel (in Latin America) have an important impact on the results from lower technologies alone.

Projections for Freight

Our 2050 calculations were made using baseline (2050) data from two main sources, IEA and WBCSD's SMP, a global transportation spreadsheet model, and ICCT. We have used SMP's baseline data, including population and GDP, together with energy intensities calculations and estimations, as well as fuel economy assumptions from ICCT. Tonne-km for North America was taken from official U.S. and Canadian sources, while trucking, shipping and rail tonne-km data for Latin America were taken from SMP and official Mexican source (IMT, 2007). Total rail freight for Latin America was compiled from national sources by Thompson (2009). Fuel data for Latin America were taken from the SMP. Over the long time period studies (45 years) the uncertainties in overall levels of freight (in tonne-km by mode) and allocation of fuel (e.g., allocation of road diesel between buses and trucking) are probably small compared to the overall projected growth. Still these uncertainties must be borne in mind. Tables 16b and 17b give the projections of freight transportation in North and Latin America respectively.

Table 16b: North America Freight Projections

2005 Actual	H. Truck	M. Truck	Water	Rail	Total
Freight Volume (billion tkm)	2710	268	1120	2530	6620
Modal Share	41%	4%	17%	38%	100%
Tailpipe Intensity, g CO_2/tkm	116	386	93.3	18.5	86
Total Tailpipe, Mt CO_2	315	104	104	46.8	569
Total LCA, kg/capita	1090	361	359	162	1970
Total LCA, Mt CO_2	358	119	118	53.3	648

2050 Glocalization	H. Truck	M. Truck	Water	Rail	Total
Modal Share	40%	3%	12%	45%	100%
Freight Volume (billion tkm)	3420	256	1030	3840	8540
Fuel Economy, l/100km	14.2	11.2			
Load Factor, t/veh	15	3			
Carbon Intensity, g CO_2/tkm	10.3	41.5	55.7	16.8	
Total LCA, kg/capita	210	62	147	166	585
% Change from 2005	-81%	-83%	-59%	+2%	-70%
Total LCA, Mt CO_2	93.3	27.5	65	73.6	259
% Change from 2005	-74%	-77%	-45%	+38%	-60%

2050 Globalization	H. Truck	M. Truck	Water	Rail	Total
Modal Share	35%	3%	14%	48%	100%
Freight Volume (billion tkm)	3330	285	1330	4560	9510
Fuel Economy, l/100km	14.2	11.2			
Load Factor, t/veh	10	2.5			
Carbon Intensity, g CO_2/tkm	15.4	49.8	33.5	7.99	
Total LCA, kg/capita	135	37.8	114	109	396
% Change from 2005	-88%	-90%	-68%	-33%	-80%
Total LCA, Mt CO_2	59.9	16.8	50.8	48.3	176
% Change from 2005	-83%	-86%	-57%	-9%	-73%

Table 17b: Latin America Freight Projections

2005 Actual	H. Truck	M. Truck	Water	Rail	Total
Freight Volume (billion tkm)	853	192	139	261	1440
Modal Share	59%	13%	10%	18%	100%
Tailpipe Intensity, g CO_2/tkm	151	404	259	18.5	171
Total Tailpipe, Mt CO_2	129	77.3	36	4.83	247
Total LCA, kg/capita	265	156	73.7	9.38	504
Total LCA, Mt CO_2	147	86.5	40.9	5.2	279

2050 Glocalization	H. Truck	M. Truck	Water	Rail	Total
Modal Share	56%	10%	11%	23%	100%
Freight Volume (billion tkm)	2380	432	478	996	4290
Fuel Economy, l/100km	13.8	10.8			
Load Factor, t/veh	9.41	3			
Carbon Intensity, g CO_2/tkm	24.4	60.3	155	16.8	
Total LCA, kg/capita	130	55.6	105	23.2	313
% Change from 2005	-51%	-64%	+42%	+147%	-38%
Total LCA, Mt CO_2	104	44.6	84.2	18.6	252
% Change from 2005	-29%	-48%	+106%	+258%	-10%

2050 Globalization	H. Truck	M. Truck	Water	Rail	Total
Modal Share	50%	10%	9%	31%	100%
Freight Volume (billion tkm)	2250	470	420	1390	4520
Fuel Economy, l/100km	13.8	10.8			
Load Factor, t/veh	6.27	2.5			
Carbon Intensity, gCO_2/tkm	36.5	72.4	93.1	7.99	
Total LCA, kg/capita	123	48.9	55.4	17.4	245
% Change from 2005	-54%	-69%	-25%	+86%	-51%
Total LCA, Mt CO_2	98.9	39.3	44.5	14	197
% Change from 2005	-33%	-55%	+9%	+169%	-29%

In general the energy required to move freight in a given mode depends on the mass (in tonnes) and distance shipped. These two estimates are usually combined into a single variable, tonne-km, which is recorded by most national authorities for each mode. More detailed breakdowns given by the U.S. Commodity Flow Survey (BTS, 2010) show the kind of goods (such as fuels, grains, ores and raw metals or other materials etc., finished products or just "mixed goods") that are shipped and over what average distances. Generally bulk and low-value goods or products moving long distances go by rail or ship where available, while higher value goods, as well as bulk materials and goods traveling short distances go by truck and even air (Schipper et al., 1996). The historical rise of trucking's share (in tonne-km) is a consequence of the change of what kinds of goods are shipped in an economy (i.e. fewer bulk materials relative to GDP, but it is also a result of the spread of the population away from major rail centers. Finally, while this study does not count international freight, the shipment of materials or goods to/from export/import gateways is an important component of domestic freight that is counted. To the extent that the total amount of goods shipped internationally from/to a country rises faster than GDP, that trend will raise the level of tonne-km relative to GDP, which otherwise has been falling in North America.

Total Volume of Freight Activity and Modal Shares

Total freight shipped, in tonne-km is estimated by projecting the 2005 ratio of tonne-km to GDP and the GDP for 2050. From the modal shares and total freight volume, we derive volume for each transportation mode in billion tonne-km. The shares by mode vary between scenarios in ways discussed qualitatively below. Values for 2005 as well as projections for 2050 are shown in Tables 15b and 16b.

For the U.S., the ratio of tonne-km to GDP dropped by approximately 0.9 percent/year from 1960 to 2006. In Globalization, this ratio falls (for North America) at the same rate, reflecting continued growth in longer-distance freight, while in Glocalization the ratio drops 25 percent more rapidly, at 1.13 percent/year, as more shipping and trade is local. A consequence of decarbonization in North America may be less long-range hauling of coal and petroleum (30 percent of waterborne and 50 percent of rail tonne-km), which reduces the share of both rail and domestic marine shipping in both scenarios and contributes to the decline in the tonne-km/GDP ratio. The overall result portrayed has total freight volume in tonne-km falling by about a quarter in Globalization and a third in Glocalization. But the lower level of long distance freight means rail, which hauls more long distance freight, loses share to trucking in Globalization.

In Latin America, trucking dominates freight at present, a result of both the lack of widespread rail infrastructure in larger Latin American countries, as well as the number of relatively small countries where trucks can cover most of the country, particularly mountainous regions. With no reliable historical data we can only project overall freight in Latin America based on the approximate (present day) ratio of tonne-km/GDP, using SMP as a rough guide. With no major coal or grain producers like the U.S. and Canada and waning oil production in Mexico, we also do not expect large growth in domestic shipping of these bulk commodities. Without infrastructure and investments in rail networks, rail-based freight rail cannot grow to rival and surpass heavy trucks as a dominant freight transportation mode in Latin America, but significant investments in that region could permit rail to boost its absolute level of freight shipped significantly. Overall, the ratio of tonne-km to GDP in Latin America is anticipated to fall significantly.

Vehicle Load Factors and Modal Energy and Carbon Intensity

In trucking, load factor measures share of truck capacity (in tonnes) that is utilized. Load is the absolute loading in tonnes. Values of load are in general higher in North America than in Latin America because trucks in North America are larger in size and weight. Overall load factor, the share of the vehicle capacity that is used, depends on logistics and overall operating efficiency. Long haul trucks will increase in size and weight limits, which will then reduce the fuel use (and emissions) per tonne-km hauled. For rail freight, present modal intensities were projected with a small improvement in diesel engine efficiency, as well as a rising share of electric traction. There being no reliable detailed data on train-set efficiency, projections made by ICCT were made per tonne-km hauled. For shipping, fuel use was projected directly by the ICCT assuming a drop in fuel intensity per tonne km.

The intensities (in mj/tonne-km) are developed by us by combining the vehicle fuel and CO_2 intensities derived by the ICCT with utilization (in tonnes per vehicle or trail). In Glocalization, modes have higher load factors (tonnes/vehicle or train) and therefore lower energy use/tonne-km (or alternatively, fewer vehicle km run per tonne-km delivered). The carbon intensity of fuel declines in Globalization because of the use of bio-diesels and the assumption that electrification will occur for most rail freight, with electricity from low-carbon sources. In Glocalization, where there is little direct effort to decarbonizes fuels, rail is powered by diesel or electricity from the projected North American or Latin American power sector mix. Thus, carbon intensities in Glocalization are higher than in Globalization.

Table 18 summarizes total emissions from freight for both regions. If we calculate how much technology alone changes emissions from BAU, we find that when BAU activity levels are combined with Globalization technologies, emissions are 21 percent of BAU for North America and 20 percent of BAU in Latin America. Compared to the actual Glocalization scenario, technology changes alone leave emissions roughly 40 percent higher than both changes in technology and freight volume alone in Globalization. In

Glocalization, the declines are less, leading to 41 percent of BAU in Globalization and 28 percent in Glocalization. Technology changes alone leave emissions 80 percent higher in North America and 50 percent higher in Latin America in the Glocalization scenario. Once again this shows how both changes in transport activity and technology – carbon intensities – combine to give a great projected decline in emissions relative to BAU and compared to 2005.

Table 18: Summary of Results

	North America			**Latin America**		
Emissions, Mt CO_2	**Travel**	**Freight**	**Total**	**Travel**	**Freight**	**Total**
2005 Actual	1668	648	2317	259	279	538
2050 BAU	2348	1153	3501	724	870	1594
Back Casting Target			140			253
Back Cast 2050 Global	125	100	225	152	104	255
Back Cast 2050 Glocal	84	52	135	148	55	203
Projected 2050 Global	522	259	781	188	252	439
Projected 2050 Glocal	515	176	691	209	197	406

The results of our projections are shown in Figures 14 and 15 for North America and Latin America respectively. Note that light duty vehicles (cars), trucks, and air travel still dominate CO_2 emissions. For both regions, the results for either scenario in 2050 are below the 2005 levels, but the relative decline compared to either BAU or 2005 is greater for North America. The decline for Latin America is relatively less, both because the various carbon intensities do not fall as much and because we expect more absolute growth in both travel and freight activity to 2050.

Figure 14: North America Transportation Emissions by Mode, Scenario, and Year

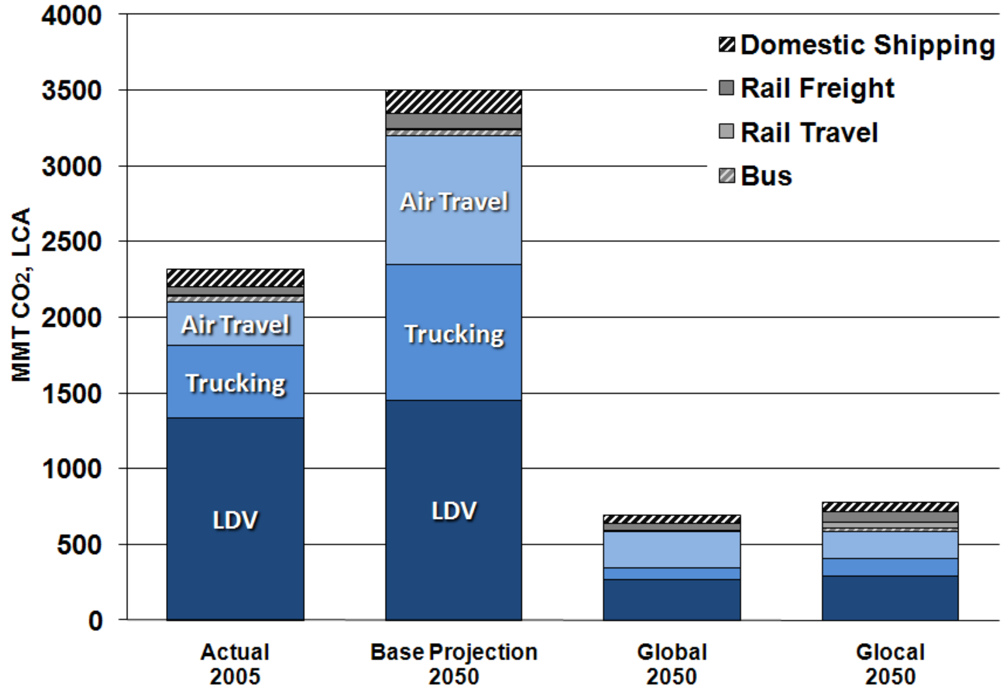
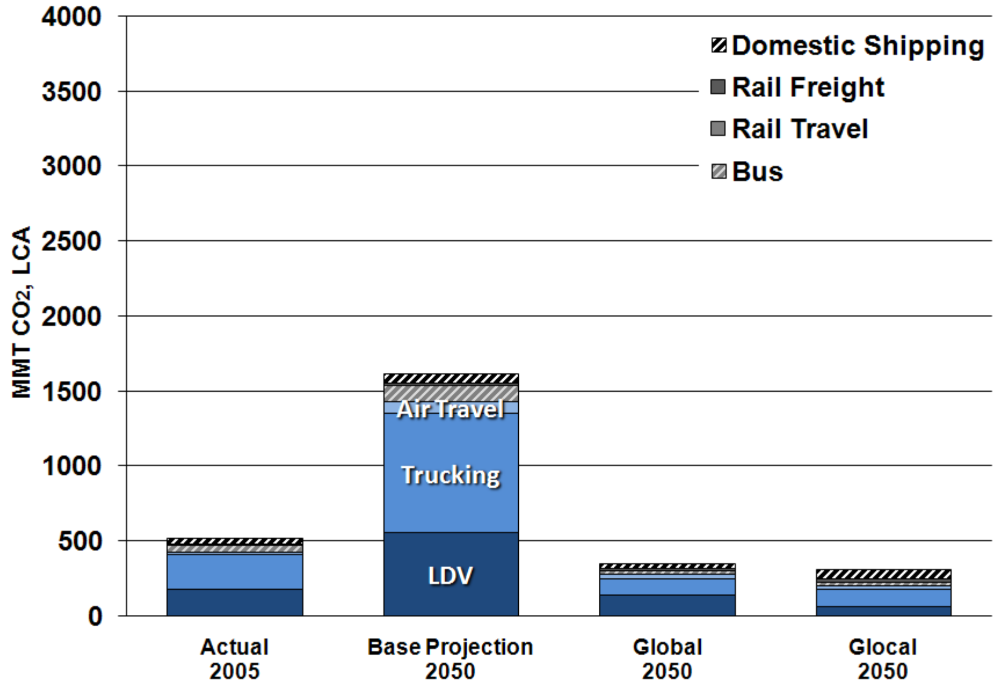


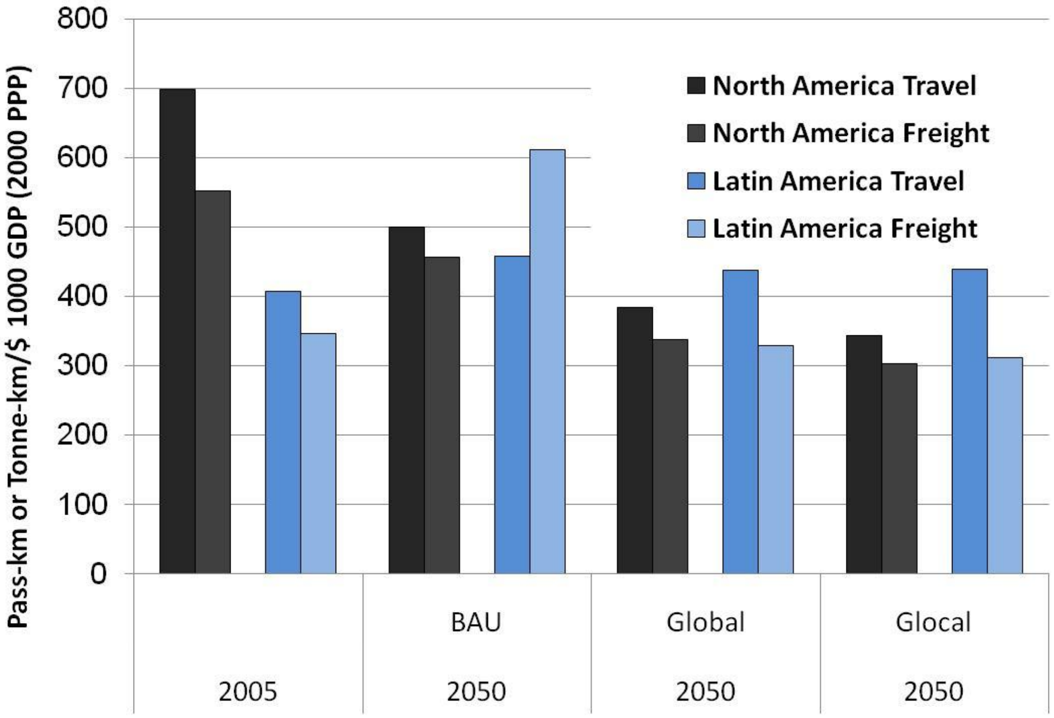
Figure 15: Latin America Transportation Emissions by Mode, Scenario, and Year



The drop in emissions in both region and scenario is a result of three aggregate changes that were calculated bottom up in our approach. Relative to GDP, Emissions/GDP can be broken down into transport activity/GDP x emissions/transport activity for travel and freight, respectively. This is a simplification of the ASIF identity (Schipper et al., 2000). The projections were made using four modes each of travel and freight.

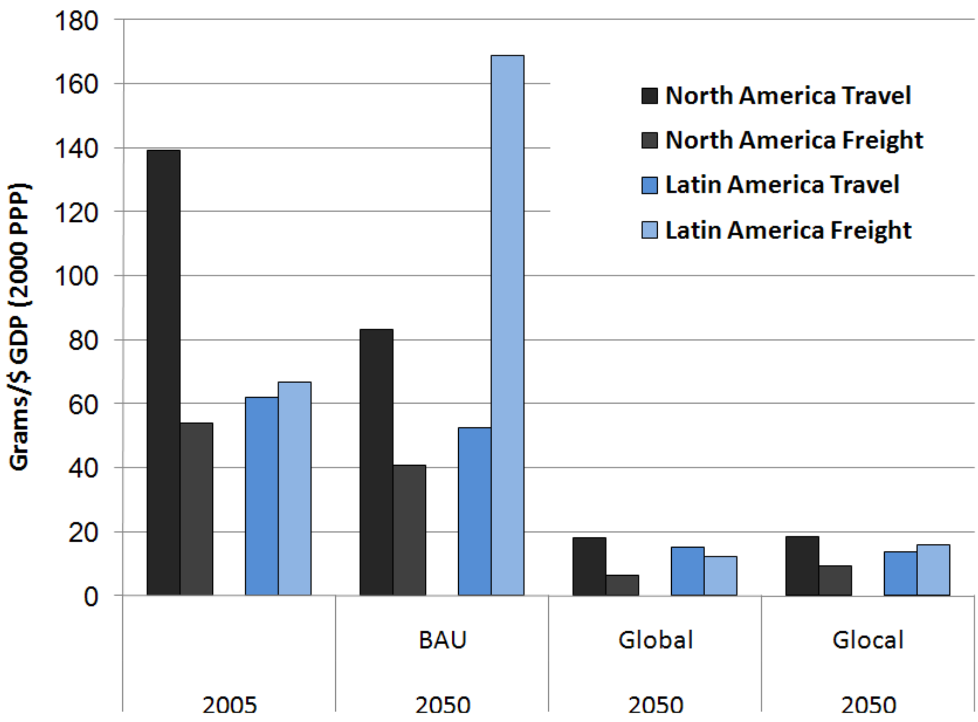
First, we projected that the ratio of passenger-km to GDP would fall, as would the ratio of tonne-km to GDP. These trends accelerate changes observations for North America, and we postulated such changes could occur in Latin America without real historical data, based on our expectation that Latin America could avoid the car-centric development model of North America (even in the Globalization) and also grow on less manufacturing and trade of material goods as was the case for North America. Figure 16 shows the changes in the ratio of both p-km and t-km to GDP in both regions and scenarios, compared to GDP.

Figure 16: Distance Traveled per Unit GDP in North America and Latin America



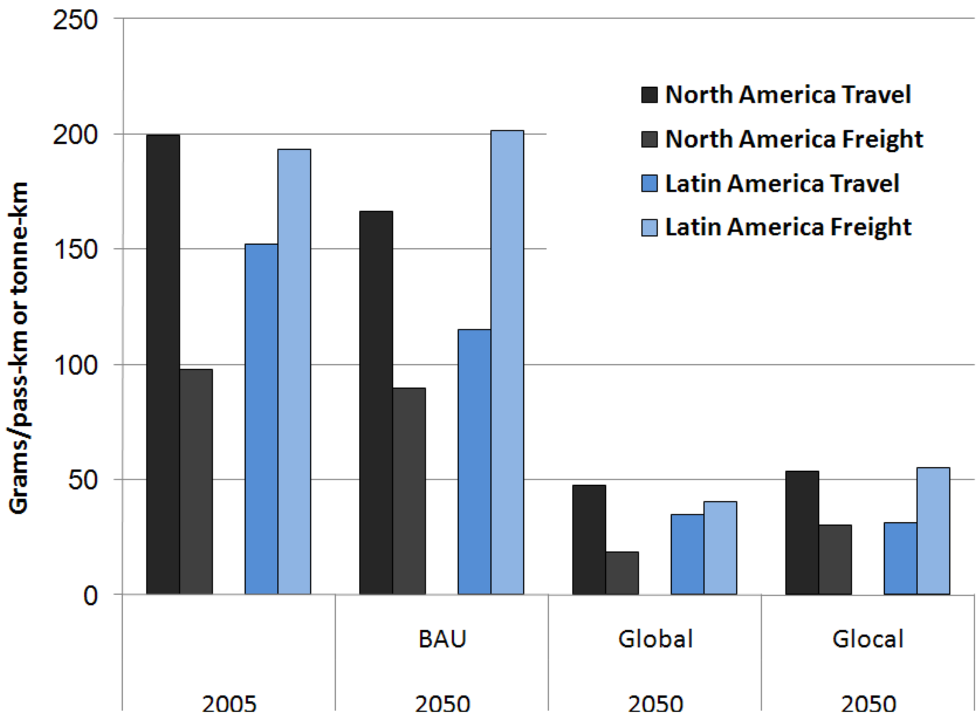
Next we projected ratios of CO_2 emissions to travel or freight by mode. The aggregate ratio of CO_2 (LCA) to travel or freight activity dropped in all scenarios. Most of the decline occurred because the carbon intensity of each mode fell significantly. For North America, however, the relative decline in car and air travel also reduced aggregate CO_2 emissions/GDP (Figure 17). For Latin America, the absolute share of travel in cars rises in all scenarios, but is lower than in BAU. The share of trucking falls slightly in all regions and scenarios relative to BAU, but is higher in Glocalization than in Globalization because there are fewer commodities being shipped longer distances.

Figure 17: CO_2 Emissions per Unit GDP for Travel and Freight



When these two changes are combined mode by mode, the results yield dramatic declines in emissions/GDP that are larger than the growth in GDP (Figure 18). This means that the absolute level of emissions for either mode or region is less in 2050 than in 2005.

Figure 18: CO_2 Emissions per Unit Activity (Passenger-km and Tonne-km)



These results emphasize in a quantitative way the challenge of this work: for CO_2 emissions to fall significantly, energy intensities of each mode must decline; the CO_2 content of energy in most modes must decline, and transport activity must also decline for North America, and grow much more slowly in Latin America, relative to GDP, than in the past. Only in the Globalization scenario is there a decline in CO_2/mj of energy, about 40 percent from the 2005 and BAU values for passenger travel and slightly less decline for freight. This is the greatest decline the ICCT could foresee consistent with their review of technologies projected to the middle of this century.

In the Glocalization scenario, policies were presumed not to focus on CO_2 as a main problem, hence the specific push for low-carbon technologies and fuels is much weaker than in Globalization. The energy intensities of air, light duty vehicles, and trucking still fall 60-75 percent between the scenarios, in part because cars are smaller and less powerful and aircraft are slightly more filled and run fewer short-haul routes. However, a key element of lower fuel intensities of light duty vehicles in the Glocalization is our assumption that these become significantly smaller, which is reflected in the ICCT estimates accompanying this work. Still, only with a decline in the absolute level of car travel and air travel in the Glocalization scenario in North America can the low levels of emissions be achieved. In addition, when comparing with the "targets", in North America, the results in Glocalization winds up being 5.4 times the targeted level and Globalization almost five times more than the "targets". For Latin America, the projections yield results in each scenario that are about 50 percent over the "target".

POLICY RECOMMENDATIONS

This section of the study explore four main groups of polices that will successfully reduce transportation CO_2 emissions. One group of policies is aimed primarily at fuel and CO_2 emissions and receives strong emphasis in the "Global" scenario. A second group is focused on changes in land uses (particularly in urban areas) and other measures relatively independent of energy and CO_2 or even transportation. The third group focuses on public transportation development, while the fourth group contains fiscal measures and shifts that affect both transport activities and emissions. Each of the two scenarios we have developed has relied on measures from each group, but with important varying emphasis.

The scope of these policies covers transportation demand management measures, alternatives to private automobile oriented use and development, and both private initiatives and regulations that expand the use of advanced vehicle technologies and alternative fuels. The impact of each policy option has not been quantified individually, but the collectively implementation of the policies is assumed to achieve the reduction of CO_2 emissions in the scenarios. Some policies are more influential than others, but all policies were selected based on existing research studies that have documented positive results for the policies (Table 19).

Ultimately, both CO_2 intensities and travel fall relative to BAU; CO_2 intensities fall more in the Globalization scenario, while the levels of travel and freight activity decline more in Glocalization. These two main types of change are reflected in the assumptions and calculations, in terms of energy intensity and km traveled, and shown in Table 19. Some of the policies in Pricing Instruments could result in both impacts, as they increase energy efficiency through longer term technology innovations by creating a pricing incentive, but reducing vehicle kilometers traveled through increasing the cost of travel. Transportation technologies and strategies will most likely increase energy efficiency, while land use planning could either increase energy efficiency through mode shifts or reduce vehicles km traveled or both. Pricing instruments or transportation demand management could increase energy efficiency or in some cases encourage modal shift and reduce vehicles km traveled.

Table 19: Policy Implementation for Latin America and North America

Policy	Changes in the Calculation	Scenario
Transportation Technologies and Strategies		
Fuel Economy Standards	Increase efficiency of light duty vehicles and certain classes of trucks	Globalization and Glocalization
Taxes to promote smaller, less powerful vehicles	Decrease fuel intensity of cars	Globalization
Advanced Vehicle Technology	Increase energy efficiency	Globalization
Alternative Transportation Fuels	Reduce CO_2 content of fuels in combustion and over life-cycle	Globalization
Intelligent Transportation Systems	Reduce impact of congestion and irregular speeds on fuel use	Globalization
Public Transportation Development		
Investment Increase	Shift from cars to less CO_2 intensive public transport	Glocalization
Improve Operational Efficiency and Integrated Modes	Increase speeds with dedicated lanes, improved station access, off board paying, smart cars and other cost-decreasing and speed-increasing measures	Glocalization
Improve Technology and Pricing Structure		Glocalization
Land Use Planning		
Transit-Oriented Development	Increase Energy Efficiency, Reduce Distance Traveled	Glocalization
Jobs-Housing Balance	Reduce Distance Traveled	Glocalization
Influential Urban Design	Increase Energy Efficiency,	Glocalization

Policy	Changes in the Calculation	Scenario
	Reduce Distance Traveled	
Pricing Instruments Design		
Fuel Taxation	Increase vehicle energy efficiency, decrease vehicle size and distance driven somewhat	Globalization
Carbon Emission Taxation	Shift incentives away from carbon intensive fuels, reduce driving somewhat	Globalization
Differentiated Vehicle Taxation	Change acquisition and yearly registration taxes and fees to reflect new vehicle fuel efficiency.	Globalization
Tax shift to VKT: Collect taxes for using transport system in proportion to kilometers traveled (all vehicles) and vehicle size/weight/footprint	Reduction in veh-km traveled, possible shift to smaller private vehicles. Can be accompanied by reduction in fuel-related taxation	Glocalization
Road Pricing: Charge for specific stretches such as expressways	Promote shift to other long-distance modes	
Congestion Pricing Scheme	Mode Shift and Some Reduction in Distance Traveled within congested regions at congested times.	
Parking Pricing Strategies	Reduce use of individual vehicles	Glocalization

This section addresses broad policies that could and should underlie the two scenarios discussed in this report. The scenarios, Globalization and Glocalization, illustrate how different levels of CO_2 will be reached in 2050, given the different policies and regulations implemented today. Four major groups of policy recommendations are included, ranging from vehicle and fuel technology innovations (covered more thoroughly by the ICCT) and land use planning to public transportation development and transportation pricing instruments design. Each group of policy recommendations is analyzed in this chapter for North America and Latin America, based on their current transportation conditions and existing transportation/climate policies.

As noted above, North America and Latin America represent two poles of a very car-centered “new world” the former with more cars than drivers, the latter with much lower car ownership on average, albeit high for its GDP/capita. Yet the streets of Latin American cities are dominated and often clogged by cars and other light duty vehicles, despite their relatively lower car ownership rate. Transport policies aimed at CO_2 emissions in North American must include a significant reduction in car use from present levels, at least in urban areas, while in Latin America, an opportunity exists to slow the growth in ownership and use significantly by restoring balance to the streets and roads towards collective transport and non-motorized modes. There may be no reduction in the absolute level in car ownership in Latin America, but it could still avoid many of the problems of urban sprawl that North America has seen.

The changes in both CO_2 emission intensities and levels of travel and freight activity in both the back-casting exercise and projections are very large when compared to the BAU projections provided by the SMP model. While it might be tempting to calculate "what levels of fuel or transport costs" would cause these changes we have avoided this calculation, because price changes alone, while necessary, would not induce all the impact on emissions reductions. Technological improvements and innovative land use planning, as well as changes in freight haulage volumes required are expected to occur simultaneously. The policies discussed in this section would move both travel and freight activity in the direction required to reduce CO_2 emissions, acknowledging only strong measures and market signals together could establish enough momentum to induce radical technological and behavioral changes over the next 40 years. We emphasize the obvious, that the policies have to be set in motion soon, as it takes decades to influence vehicle design, fuel type and patterns of travel and freight. At the same time, we acknowledge that there is no guarantee that these policies alone will usher in the large changes proposed in the study, nor is there any guarantee that politicians and voters will accept those policies and their consequences.

Policy Analysis

This section will discuss four groups of policy recommendations that will help reduce transportation CO_2 emissions in North and Latin America, based on previous studies and results generated from the Globalization and Glocalization scenarios. The findings from both sets of scenarios require a combination of different polices to achieve the ultimate reduction in CO_2 emissions. Globalization scenarios portray a world where international cooperation and compliance play a larger role in unifying standards and agreements.

There will also be higher levels of international trade and transaction in goods and labor, with the assumption that access to energy supply will not be restricted. On the other hand, in Glocalization, there is a greater sense of identity, self sufficiency, trading within regions, and higher levels of local production for local consumption. There will be restrictions on access to energy supply, hence, consumption, and as a result, travel distance is assumed to be lower than in Globalization.

Different types of policies, with the goals of improving energy efficiency and reducing total distance traveled and vehicle km traveled, have to be introduced in order to complement each other and to lower CO_2 emissions effectively. Most of the proposed policies will be implemented in the two scenarios and in both regions to some extent. The policies are not mutually exclusive in either scenario, but some will play a stronger role in Globalization than others and some will be assumed to be more influential in Glocalization.

I. Transportation Technologies and Strategies

Assumptions for technology advancements and improvements in emissions standards form the basis for the changes in transportation emissions as shown in the scenarios and further described by ICCT. However, technology alone will not solve the carbon problem in 2050. Transportation technology will increase energy efficiency and affect the emissions factor of vehicles, but not influence transportation activity patterns, distance traveled and mode choice. Nevertheless, this section will summarize the role technology plays in our scenarios and in reducing future emissions levels, particularly through the application of strict emissions standards and the use of advanced vehicles.

Technology advancement over the past two decades has not only improved vehicle efficiency, but has also increased fossil fuel efficiency for transportation and expanded the options available for alternative transportation fuel. Improving energy efficiency is one of the more straightforward ways to reduce CO_2 emissions, as it reduces emissions per unit of distance traveled directly. This could be done through vehicle and fuel technologies, and as long as there is a market for such technologies, policies that encourage the use of these cleaner technologies will be relatively easier to implement compared to the other types of policy described below. In North America, innovations in engine and vehicle technologies have been studied extensively proving their benefits, and the use of advanced vehicles has penetrated the market share of passenger vehicles. The same technologies could be transferred to countries in Latin America by creating a market for more energy efficient vehicles and cleaner fuels, which will also reduce local air pollution at the same time. Innovative vehicles have to be introduced ultimately, but advanced vehicles can no longer be focused on higher power or speed. Instead, development must focus on reducing fuel consumption and increasing fuel economy instead (Cheah et al., 2008).

The following transportation technologies and strategies should be further developed in both North America and Latin America, with the former focusing on enforcing stricter emissions and fuel standards, while the latter creating a market for a fleet of energy efficient vehicles. Although transportation technology will continue to play a role in reducing the impact of climate change, it is important to note that it is only one of the many solutions. Policies addressing vehicle technology and alternative fuel will be discussed in greater detail by an accompanying ICCT report.

Reduce Energy Intensity of Road Vehicles by Fuel Economy Standards and Other Measures

Reducing vehicle energy intensity is the first step to reduce CO_2 emissions from the transportation sector, and improving fuel economy standards is the most direct way to do so. Current fuel economy standards in the United States (U.S.) take the form of the Corporate Average Fuel Economy law (CAFE), which was first enacted in 1975. Although CAFE standards have been updated in 2007, mandating all new vehicles to have 35 mpg fuel efficiency by 2020, it is still relatively weaker when compared to Europe and Japan, which is a result of the greater weight, size and power of the average vehicle sold and driven in the U.S. (Schipper, 2009). New vehicles sold in Europe and Japan today already have lower fuel intensities than what CAFE has mandated for the U.S. in 2020; the new U.S. standards will bring the entire U.S. fleet to the present on-road level of Europe by 2035. This difference arises largely because U.S. vehicles are heavier and more powerful. In particular, a third of new cars sold in Japan are mini cars (<660 CC displacement) and only a very small share of new household passenger vehicles in either region are SUV, compared to nearly 40 percent in the U.S. Stricter CAFE standards will trigger greater fuel efficiency, as American motor vehicle manufacturers would have to comply with the standards by designing more efficient vehicles and to redefine the size and horsepower of a normal automobile. Therefore, there should be a stronger policy to raise the proposed CAFE standards beyond what is now law.

Canada's fuel economy standards are called the Company Average Fuel Consumption (CAFC) standard, and they are similar to U.S. CAFE standards, implying that they are equally weak standards. The only difference between the two standards is that CAFC has been a voluntary program. However, with a large share of cars and light trucks made in Canada bound for the U.S. market, "compliance" has not been difficult. In fact, new light duty vehicles sold in Canada during the past two decades tend to be 10 percent less fuel intensive than those sold in the U.S., probably a consequence of both higher fuel prices in Canada and lower real household incomes (when adjusted for purchasing power).

Countries in Latin America do not have fuel economy standards, even though Mexico is planning to implement one in the near future (Lacy, 2009) and Brazil has moved to label the fuel economy of new cars (CONPET, 2009). New cars sold in Latin America tend to be significantly smaller than those sold in North America, although new vehicle size has tended to grow over time with increasing incomes. Stringent fuel economy standards have to be imposed on new vehicles in North and South America as soon as possible, not simply to ensure higher fuel efficiency and push vehicle manufacturers to be as innovative as they can in producing efficient vehicles, but to offset the impact of increasing vehicle size and weight that happened in North America. An additional factor in Latin America is poor traffic, which appears to raise fuel use compared to tests by at least 33 percent (Schipper et al., 2009), compared to a more moderate 25 percent increase in the U.S.

II. Improve Transportation and Land Use Planning

The relationship between transportation and land use planning has been studied extensively in North America, showing that historical trends in urban land use changes are strongly related to changes in transportation. Urban land use patterns have changed drastically over the past century in North America as transportation costs have decreased over time due to technological advancements. The distance between household location and workplace therefore has increased as a result of lower transportation costs (Pickrell, 1999) and lower property values and higher housing affordability in areas beyond city centers, leading to urban sprawl with residential areas and employment centers in suburban areas.

In developing Latin American cities, crowded central cities are also slowly pushing people out to suburban areas, despite the relatively lower road density than North America or other parts of the world. Nevertheless, rapid urbanization in Latin America has resulted in approximately 77 percent of its population living in cities and towns, including the urban poor (Fay and Morrison, 2007). Therefore, unlike cities in North America, central cities are mostly still heavily populated and filled with different transportation activities. Without appropriate land use and transportation planning in place, they are likely to follow the wave of suburbanization North America has experienced, especially as the relative cost of transportation to income decreases and when more transportation infrastructure investments are made over time.

Land use planning has been found to influence travel patterns in several ways and is a long-term strategy that will achieve lasting CO_2 emissions. The broader urban system, which includes land development and patterns of activities, has to be considered in key transportation policies.

This section has selected four different land use policies that have the potential to regulate travel demand and reduce CO_2 emissions in the long term. Although future changes in land use planning could experience a different magnitude of change in transportation and vice versa than before, their impact on each other is still undeniably interrelated (Cervero and Landis, 1995; Randall, 2000).

Promote Transit-Oriented Development in Neighborhoods with High Density

In addition to encouraging public transportation use, transit-oriented development (TOD), which is a type of land use planning that creates centers filled with mixed-use activities around public transportation nodes, should also be encouraged along dense transit corridors. Potential benefits of TOD include reduction in congestion, improved air quality, a vibrant transit corridor filled with housing, jobs and commercial activities, and a path to sustainable cities. Cities in North America are largely auto-oriented, and if TOD projects are to succeed in such an environment, transit corridors have to be parallel to auto travel corridors, in order to create travel demand along transit corridors (Cervero, 2007).

The impact of urban design discussed in the previous section will play an important role in successful TOD projects, by creating a built environment that provides advantages to transit users, and inconvenience to automobile users. Not providing ample parking or locating parking garages relatively further away from commercial activities, workplaces or even housing development than the distance between transit stations are two examples.

Future TOD projects in either North or Latin American cities should therefore include elements of greater convenience for transit users, which will increase their incentives to switch from driving to transit ridership.

Land use policies should also allow appropriate land-use rules or zoning and encourage public private partnerships that will lead to mixed-land uses around transit corridors (Moore and Thorsnes, 2007). Together with improved transit services, TOD can lead to sustainable regional development, when taking the needs of transit users into account. Because private automobile ownership is still not as high in Latin America, there are still opportunities for more successful TOD projects to take place in Latin American cities well before 2050. A crucial step for both regions is the organization of TOD through work with real estate and housing developers, both public and private.

Urban sprawl in both North and Latin American cities has been growing within the past two decades, more rapidly in the former than latter. Sprawl has been found to occur because of lower transportation cost and the desire to live in larger residences, as well as the availability of jobs outside of city centers (Alonso, 1964; Cervero and Wu, 1998; Randall and Chatman, 2003; and Real Estate Research Corporation, 1974). TOD measures could be used as one of the solutions to reduce urban sprawl but greater changes in land use planning have to be introduced to serve as complementary policies. The following sub-section on jobs-housing balance is one such policy.

Match Jobs and Housing Locations with Regard to Employment Type and Housing Affordability

The relationship between jobs-housing location decisions and travel pattern is complex and controversial. Some argue that having jobs-housing balance, where the number and type of jobs match the number of employees and their skills, as well as the type of housing available and its affordability for the employees in a community, will lead to a decline in travel time, which will subsequently decrease congestion, air pollution, traffic accidents, and other transportation externalities (Cervero, 1989; Levine, 1998; Sultana, 2002). Others believe this is improbably because cities are dynamic and in any event it is well understood that travel cost is only one factor in location choice (Giuliano, 1991; McFadden, 1977; O'Regan and Quigley, 1999, and Wachs et al., 1993). Hence, they might not always minimize travel time by choosing to live close to where they work (Hamilton and Röell, 1982).

Consumer housing location decisions are made based on various reasons, and the most direct of all is often related to transportation cost. According to microeconomics theory, when transportation costs are high, travel demand will decrease, leading to shorter commuting distances, less congestion, and even changes in housing location patterns. However, in reality, transportation costs might not have a strong impact on housing location decisions, reducing distance travelled or other transportation externalities because of the many other non-cost related factors that are being considered when such decisions are made. Commuters are willing to pay for higher transportation costs when they place higher values on other factors influencing their decisions on where to live and work. Similarly, transportation costs could also be perceived as an insignificant cost when compared with other socio-economic costs. As a result, achieving jobs-housing balance or efficient commuting could reduce transportation externalities in circumstances where transportation cost is of higher significance than other social-economic benefits or of equal importance.

As the supply of affordable housing grows in areas where there are employment opportunities, it might seem logical to assume that these neighborhoods will be filled with households whose members work in the same area. Travel distance and time will therefore decrease accordingly when there is a good match between housing and the type of employment available. This assumption could be true when residential location is based solely on the choice of a single employed member of a household with a long-term workplace and on travel cost alone. With the growing number of job mobility and more than a single worker in a household, residential location decisions are no longer simple. How much jobs-housing balance can reduce commuting distance will thus depend on varying household preferences (Levine, 1998). However, wide areas of both North and Latin American cities have jobs in locations where housing is not affordable to the middle or lower classes, creating important segregation that leads to long commutes (Cervero, 1989; Scott, 1994).

There have been numerous studies on the relationship between jobs-housing balance and commuting distance, as well as travel time over the past two decades, each showing how effective jobs-housing balance can be in influencing travel behavior, and hence, reduce travel distance or time, traffic congestion and air pollution. This study has identified three main transportation changes that can indicate the relationship between jobs-housing balance and transportation. They are, namely changes in commute distance, changes in commuting time and changes in traffic congestion eventually. Cervero's study has shown that having jobs-housing balance will increase walking and cycling trips (Cervero, 1989). Two other studies on Atlanta (Sultana, 2002; Yang and Ferreira, 2008) have generated similar findings. Both studies concluded that in Atlanta, the location of jobs and housing strongly determines commuting pattern and supports the growth of housing in areas close to communities with plenty of job opportunities. In Sultana's study (2002) on commuting patterns in the Atlanta metropolitan area, increases in traffic volume, commuting distance and time have been found to be a result of jobs-housing imbalance. The jobs-housing imbalance is found to be the most significant factor contributing to long commuting time in Atlanta, followed by the cost of housing and housing affordability (Sultana, 2002). Although Yang and Ferreira (2008) applied a different approach in their study, their finding for Metropolitan Atlanta is similar to Sultana's. Commuting time and distance have increased over a period of 20 years in Atlanta, even though it is a region with relatively lower density compared with other cities in the United States. Commuting behavior in Atlanta is affected by local jobs-housing location, which suggests that policies that will improve local jobs-housing balance will reduce commuting distance and hence, congestion (Yang and Ferreira, 2008).

However, there are also studies showing how in certain cities, jobs-housing balance might not have a significant environmental impact. For example, jobs-housing balance does not have a strong impact on commuting distance and time in Boston (Yang and Ferreira, 2008). Although commuting distance and time have increased over time in Boston, such increases are not due to local jobs-housing imbalances, but by greater regional wide job and housing dispersal. When compared to the findings for Atlanta, Boston has shown a weaker link between jobs-housing balance and commuting pattern, and hence, implementing policies that will encourage jobs-housing balance in order to reduce commuting distance or time and to decrease traffic congestion will not be as effective in Boston than in Atlanta.

A specific case study on employees of Kaiser Permanente in Southern California (Wachs et al., 1993) has shown that employees are willing to pay for higher commuting costs if they can afford to purchase a house. Despite no evidence in increasing jobs-housing imbalance in the study sample area or increases in commuting distance over a period of six years, there has been an increase in average commuting time due to congestion as a result of growing traffic in the area. This study has therefore concluded that even in a situation where jobs-housing balance is established, people will still not choose to live close to where they work. They value non-transportation related factors, such as housing costs, quality of neighborhood and schools, crime rates, and other amenities over commuting time, even when faced with daily congestion.

The impact of jobs-housing balance on the environment could therefore vary depending on the type of cities, employment, skills required and possessed, housing cost, and access to automobiles. Cities in North America and Latin America, where jobs-housing balance could make a positive impact should be identified and developed accordingly. However, Latin American cities are still developing more rapidly than those in North America, presenting more opportunities for changes that would reduce travel needs and travel distances between the present and 2050.

Support Urban Design that Will Improve Travel Patterns

The built environment, which includes buildings, transportation infrastructure and everything else in between, can influence travel patterns through its design. Studies have shown that certain urban designs can affect trip frequency, average trip length, total distance traveled, modal share, travel time, and even automobile ownership. Travel distance can be reduced through agglomerations, by narrowing the distances between activities and clustering activities together within smaller areas. The design and appearance of buildings and neighborhoods can also affect travel patterns by either encouraging non-motorized transportation modes through the planting of street trees for example. Good design need not be related to travel speed or distance, it should contribute to the quality of travel and allow a trip to be more pleasurable. The built environment can therefore influence the quality of travel, the quantity of travel, and the cost of travel (Crane, 1996). Few North American or Latin American cities have emphasized on the design of the built environment as a way to reduce CO_2 emissions.

It is important to note that design matters from a transportation perspective because it not only shapes the attractiveness of a location, but it also affects the feasibility and attractiveness of travel options there. Both land development patterns and street design are at issue. For example, land development that is not oriented toward the sidewalk, with large setbacks or blank walls along the pedestrian ways, or that is low density and scattered, can create an unappealing, inconvenient, or even hostile environment for pedestrians, regardless of the presence of sidewalks and transit services. Development laid out with a limited number of through streets is likely to require long, circuitous walks to get to destinations in the area including transit services, and if the streets are also multi-lane, crossing them may be a deterrent to walking.

By 2050, urban design that will trigger a decrease in travel distance and cost, as well as increase in travel quality should be incorporated in every transportation or land use project in both North and Latin America. This will not only ensure efficient transportation infrastructure, it will also enable all users of different transportation modes to share available road space equitably. The built environment surrounding public transportation links and nodes should be particularly designed to maximize clustering and density, and to decrease waiting, walking and transferring time. Urban design should also ensure travel accessibility, providing convenience and comfort for all users of different transportation modes.

III. Expand Public Transportation Development in Urban Areas

The role of public transportation has to be strengthened in North American cities where there is high urban density and further enhanced in Latin American cities by 2050, in order to help reduce CO_2 emissions. Public transportation in areas with high urban population density and user demand is a way to reduce congestion, and by having the capacity to hold more passengers than a private automobile, it can help reduce CO_2 emissions. Given the current level of vehicle efficiencies, this assumption will hold true if public transportation systems have sufficient demand and can attract enough passengers to offset the energy consumed by their buses or trains. Public transportation provides transportation services at a lower cost to the user and with its higher capacity; it can transport a substantial larger number of people over the same distance than an automobile. Although rail transit is significantly more costly than buses to implement, if ridership is available, rail transit will be a good alternative to driving, provided it is more efficient than driving.

Strengthening public transport means three things: greater speed (lower travel times) compared to individual modes, greater security, and an improved fare system. Speed comes from both dedicated bus-ways, as well as better transfers between vehicles or among modes. An improvement in fares, which might not make an individual trip less expensive, means integrated fares and modes so that travelers get better service for what they pay. As the speed of vehicles increases, they serve more passengers daily, which will then keep fares down and pay the drivers well. For Latin America, these improvements must come in the context of a continent where "public transport" is dominated in most cities by "colectivos" or paratransit, which ranges from small shared taxies, often as mini-buses on semi-fixed routes, to large buses run by mostly independent operators.

In Latin American cities, current private automobile ownership is still much lower than in North America. This implies that most trips are still made by public transportation, dominated by mini buses and other smaller vehicles variously called colectivos in Spanish (Schipper et al 2009). Larger, buses, or trains, could be a more desirable way to travel, especially if they are more efficient and can avoid the congested roadways or routes that automobiles have to encounter, as the recent success of many bus rapid transit systems has demonstrated (Hidalgo and Grafiteaux 2008). As congestion increases in densely populated cities, there will be more opportunities for public transportation to be developed and invested. For North America, which is already car-oriented, it would be costly to reinvest in public transportation on a large scale and harder for modal shift to occur. Although the options are different for North America, public transportation could still play an important role as an alternative mode of transportation in cities that are densely population and in cities where it is expensive and inconvenient to drive.

Underpinning the strengthening of public transport is changing the way individual drivers pay to use their cars - fuel, parking, scarce road space, etc., making collective transport less costly and more frequent is useful, but without real changes in the conditions car drivers see, transit likely will lose share continually in Latin America and gain very little share in North America. Although public transportation plays a more significant role in Latin American cities than in North America, private automobile ownership is expected to grow over the next few decades in Latin America (Schipper et al., 2009), assuming that economic development will continue to increase. Any attempt to stabilize or increase the share of public transport must come to grips with this trend, which has characterized Latin America for many decades.

Increase Public Transportation Efficiency and Ridership through Investment

Investment in public transportation will lead to economic benefits through high economic rates of return in dense cities (Cambridge Systematics Inc. and Apogee Research, 1996), especially in growing dense cities. The benefits of public transportation will therefore, not be constrained within improving traffic conditions but could also provide greater advantages to the economic growth of the region in some cases. Yet, public transportation has long been associated with urban poverty in the U.S., where it serves as an appealing reason for the poor to remain living in central cities, while the rich move further away as they could afford to live and/or work in the suburbs (Glaeser et al., 2006). Public transportation will therefore not always contribute to the economic growth of a region. Nevertheless, without public transportation, cities such as Toronto, San Francisco, New York or Boston might not be able to attract as many business developments or employment opportunities.

Policies that will encourage better transit efficiency should be implemented in both North and Latin American cities. Some examples include exclusive guideways, better feeder bus service, attractive stations, park-and-ride facilities, and transit oriented development (Galicia et al., 2009). For Latin America, where some kind of collective transport provides roughly 50 percent or more of all trips in and around urban areas (Schipper et al., 2009), maintaining or increasing this share would have beneficial results by reducing growth in individual auto travel._

It is therefore crucial to ensure the quality of public transportation in Latin America and to sustain its ridership over the next few decades. Incentives to shift automobile drivers to transit should be introduced in cities where there are existing transit infrastructure and framework. The general appeal of transit use would have to be improved and policies that will give right-of-way to transit should be implemented, in order to decrease users' travel time when compared to private automobiles. Transit stations also have to be safe and attractive to users, who need to have quick and easy access to all stations (Moore and Thorsnes, 2007). Second, there should be better coverage of the city, while waiting time and transfers should be minimized, and third, transit services have to be reliable (Moore and Thorsnes, 2007). Without these improvements, it will be hard to convince riders to use public transportation and to increase its modal share, especially in North American cities.

Increase Public Transportation Efficiency and Ridership through Improved Operations and Integrated Modes

The operations of public transportation could directly affect the optimization and efficiency of transportation networks. The various modes used for public transportation usually have different sets of operation standards, yet when different modes could be integrated seamlessly and efficiently, transit would then be proven to be a good transportation alternative. Transit systems with better services have to be created in order for them to stay competitive and to increase if not maintain ridership,

In addition to regular bus and train (above and underground) systems, an emerging type of public transportation, bus rapid transit (BRT) has been slowly developed throughout cities in North America and Latin America. Although the definition of BRT varies city by city, the impressive record of BRT systems in Latin American cities developed since the early part of the last decade (Hidalgo and Grafiteaux, 2008), while not without problems, has clearly shown that as many as 10 percent of total riders in BRT gave up cars for the faster and more comfortable BRT service. While the initial 19 km stretch of Metrobus of Mexico City only saves less than ½ kg of CO_2 per rider, those savings work out to around 40,000 MT of CO_2 per year from the transport outcome of BRT, replacing a large number of smaller, disorganized buses, the resulting smoothing of parallel traffic, and the switch of up to 10 percent of the ridership from cars. When the success of a single system leads to establishment of a network, as seen in Curitiba and Bogota and is now happening in Mexico City, the growth in car travel appears to be reduced permanently. What remains to be seen is whether the emergence of a dense BRT network in Mexico City leads to even greater abandonment of cars for BRT (as in Bogota) or the low level of car use seen in Curitiba.

Increase Public Transportation Efficiency and Ridership through Technology and Pricing

Modest investment in technology can lead to substantial improvements in transit experience. The flow of public transportation operation could be further enhanced through technology that would provide seamless travel within and across systems. Such technologies include smart cards that contain computer chips for processing data, synchronized arrival times, transit management or traveler information system have the potential to increase ridership on existing transit vehicles as they could make public transportation use more convenient.

Pricing structures that discriminate according to travel times will also influence transportation patterns. For example, peak and off-peak fares will create incentives to travel during off-peak hours for users who do not necessarily need to travel during peak hours. This will complement policies that have the potentials to increase the cost of driving. Shirley and Winston (1998).have argued strongly against heavy subsidies for transit systems in the U.S. without congestion pricing and other alternative measures.

When buses or trains are not occupied, they could be as CO_2 intensive as private cars during non-peak hours on average. Indeed, this was the case for the U.S. in the late 1980s and 1990s when urban buses are compared with cars and light trucks on an annual average (Davis and Diegel, 2009). Therefore, ridership has to be increased on existing transit vehicles in order for public transportation to be a solution in reducing emissions and not another contributor.

IV. Pricing Instruments Design

Pricing and related economic instruments are important to both scenarios. A key dilemma for reshaping transportation and land use patterns to encourage lower CO_2 emissions is that neither the value of fuel saved nor the value of CO_2 reductions, even if monetized at a high CO_2 price tend to dominate the balance of costs and benefits compared with congestion and time, pollution and accidents, and other transport and land-use variables. The high social cost of transportation includes externalities associated with automobile use, local and global air pollution, ecosystem degradation, oil dependency, traffic congestion and accidents (Levinson et al., 1998). A recent study on the cost-benefit analysis of the introduction of Metrobus in Mexico City by Schipper et al. (2009; see also INE 2006) has shown that the reduction in CO_2 emission has saved U.S. $15million per year. The same study has also presented the various types of externalities associated with driving in the U.S. (Table 20), showing how the external cost of climate change is relatively lower than other social costs.

As shown previously in Table 19, pricing instruments that have been found to be effective in regulating transportation demand can be divided into different forms of taxation or shifting the current pricing structure from fuel tax to vehicle miles traveled, which can better capture the externalities of transportation and provide a more flexible policy option. Externalities when measured are significant costs inflicted upon the society and should be reflected in transportation policies for greater reductions in the negative climate change impact associated with transportation activities. Imposition of strong pricing signals to correct transport and land use distortions can have large co-benefits as the reduction of CO_2 emissions that come from shifts away from individual cars as well as less travel in general. If such policies are combined with those that strongly encourage the use of lower carbon fuels and more efficient vehicles, then the synergies among these two, particularly less congestion and fuller mass transit vehicles add important savings in emissions to those from vehicle/fuel technology and mode-shift itself.

Current pricing policies focus on charging road or infrastructure users through fuel consumption. Other associated costs are considered as fixed and will not change according to how much distance is traveled, at what place and at what time. Therefore, in order to capture externalities, which are usually proportional to distance driven, pricing policies have to focus on the variable cost of transportation. This section will introduce the different types of variable costs charging and how can they help to reduce congestion, CO_2 emissions and other transportation externalities.

Table 20: External Costs (U.S. Cents/Mile) per Mile of Driving in the U.S.

Externality	Low	High	Range	Comments
Air Pollution	1	14	2.3	Values are probably higher for Latin American cities because of higher levels of air pollution, even after adjusting for quality-adjusted value of life. See Vergara et al. (2002) and Harvard School of Public Health (2003). Important to both scenarios
Climate Change	0.3	1.1	0.3-3.5	Value widely disputed (Nordhaus, 2008; Stern, 2006) and certainly dependent on national and local situation. More relevant in the Globalization scenario
Congestion	4	15	5-6.5	Does not apply to all travel, or all times and places. Depends on value of time and wage rate. More relevant in the Glocalization Scenario
Accidents	1	10	2-7	Depends on valuation of accidents and life. See INE (2006) for MC perspective. Important for both scenarios
Energy Security	1.5	2.6	0-2.2	Values depend on local energy supply situation, which has greater emphasis in the Glocalization scenario

Sources: Parry et al. (2007) for range and Schipper et al. (2009)

The underpayment is not small. Studies that have measured the externalities of transportation have shown considerable social costs that are unpaid for (Keeler and Small, 1977; Parry et al., 2007) (Table 20). Most importantly, the estimated costs per km of car use for congestion, air pollution and accidents are larger than those for CO_2 valued at $85/tonne at the level of fuel economy found in the U.S. in 2000. Note that important fixed costs that are related to distance traveled, such as insurance, are not included in the table above, nor do fuel tax revenues necessarily even cover the costs of maintenance and expansion/upgrading of the road system. It is fair to say that the average driver does not pay for his/her external costs, but as Table 20 suggests, the actual underpayment is a matter of debate, and in some cases, such as for air pollution or congestion, specific to the time and place.

Were such costs to be charged to distance driven, one might see the kinds of reductions illustrated by our Glocalization scenario for North America. If such costs were to be imposed on all drivers in lower-income Latin America, one might avoid the continued spiral of sprawl and motorization that has gridlocked some Latin American cities for two or more decades, as typified by Sao Paulo (Vasconcellos, 2005). We do not ignore the distributional and equity impacts of major reforms in transport pricing, but note that it is primarily the well to do and middle class in Latin America who have access to cars, not the poor. Surely countervailing economic policies can accompany transport pricing reforms that leave the overall disposable incomes of all citizens constant by lowering other taxes while raising fees and taxes on transport services, and above all, on the use of private automobiles. It is important that such costs are related to km traveled, because in either of our scenarios, fuel use per km falls by 60-75 percent, which means that fuel costs per km will fall over time.

Policies that fall under the pricing category are mostly targeted at decreasing the externalities associated with transportation activities by charging for the "true cost" of driving inflicted upon the society through various means. Only when this marginal social cost is included in market prices, can markets allocate resources efficiently (Moore and Thorsnes, 2007). Current market prices do not reflect marginal social costs in transportation, especially highway transportation. Road tax is one of the few taxes implemented on road users, through taxes on fuels, but these are insufficient to cover all the social costs generated and in the case of North America, do not even cover the costs of the highway and road system itself (Mackerowiz et al., 2010; Frankel, 2009; Transport Canada, 2008). Non-road users are paying for users through taxes and higher costs of goods and services in cases where parking is available at no cost (Shoup, 1999). Transportation externalities are unpaid for, yet non-road users would have to bear the negative consequences of transportation congestion and pollution. This is a common phenomenon in both North and Latin America.

The policy recommendations below are aimed at reducing distance traveled and the number of trips made by increasing the current cost of driving through efficient pricing and costs allocation, charging users what they are willing to pay for. Appropriate taxation and pricing policies based on the variable cost of driving or owning a vehicle are described below. Since institutional structures and political barriers vary depending on region, the implementation method of pricing policies should be tailored accordingly.

Impose Higher Fuel and Carbon Taxes to Reflect Real Transportation Costs

Taxation on fuel use would increase the cost of owning and using a vehicle and could then manage transportation demand. However, current tax policies are underpriced, as they do not take social marginal costs into account, but only charge taxes at average prices. There should therefore be an increase in current fuel tax and vehicle use tax, or removing subsidies for automobiles, which could be equivalent to the latter. Similarly new vehicle taxes and yearly fees that are independent of how much a vehicle is used should be revised to rely more on vehicle use for revenue.

Using fuel taxation as a policy instrument can recover part the variable costs of driving by charging vehicle users for transportation infrastructure indirectly through individual use. Since fuel is one of the highest and most visible variable costs of vehicle use, fuel taxes encourage drivers to make more efficient use of their vehicles, reduce trip frequencies and even switch to less fuel-intensive vehicles. The level of fuel taxes imposed should be enough to abate vehicle emissions and serve as revenue for transport infrastructure operation and maintenance purposes. An increase in fuel taxes will also lead to a higher demand for advanced vehicles and alternative fuel vehicle technologies. However, a fuel tax is a self-defeating revenue source if it is successful and leads to declining revenue. Therefore, some of the present fuel tax should be shifted to vehicle use.

The social costs of CO_2 emissions generated by autos and other vehicles are not insignificant, yet usually untaxed. The Nordic countries represent an important exception. Current pricing policies are not structured for drivers to pay the total cost of vehicular emissions. There are no strong incentives to reduce auto emissions and as described in the preceding subsection, efficient policies require the implementation of a tax per unit of emissions by the type of emission. In other words, CO_2 emissions should be taxed separately from other types of emissions and differentiated according to the level of emissions, and not in the form of a fixed annual tax. This would thus encourage drivers to drive less or purchase less polluting vehicles. Although the impact of such a tax might not be as significant as some of the other policies described in this section, it is a direct way to increase fuel efficiency and create more efficient vehicles and will serve as a complementary tax to fuel tax.

A dilemma for authorities here is that even a CO_2 tax of $85/tonne (Stern et al., 2006), which works out to $26/bbl is still small compared to present taxes in much of Europe and small compared to a world oil price of $80/barrel. By the time crude oil becomes gasoline, it still costs roughly $80/bbl before taxes. Thus, a CO_2 tax by itself will not change automobile characteristics, yet when applied all through the economy, such a tax will discourage production of gasoline from high-CO_2 sources, such as coal or advanced sources of liquid fuels, such as shale or tar sands (Farrell and Brandt, 2006).

A recent simulation for the U.S. (Morrow et al., 2010) makes the point that the impact of the combination of strong fuel economy standards and high fuel/carbon taxes far exceeds that of standards bolstered mainly by various tax subsidies for low carbon vehicles. In fact, such subsidies may be very expensive per unit of CO_2 saved. Experience from the increased penetration of so-called "efficient" diesel cars in Europe gives similar results (Schipper and Fulton, 2009; Bonilla, 2009). With diesel fuel taxed below gasoline in most European countries (and new diesel cars exempted from vehicle excise duty in the UK where fuel prices are at parity), new diesel cars are heavier and more powerful than their gasoline counterparts, and the average new diesel emits only 5 percent less CO_2/km than the average new gasoline car. Indeed Kaageson (2009) questions whether the various "green car" (i.e., low emissions vehicle) subsidies in Sweden really lead to significant results, as do Morrow et al. (2010).

Removing hidden subsidies, like light taxation of company-bought cars for employees, is also important. Such cars are typically also heavier and use more fuel/km than cars purchased privately. Sold off after two or three years, they provide private buyers with larger and more fuel consuming cars than otherwise, too, bloating the fuel intensity of the entire stock (Schipper and Price, 1994; Schipper et al., 1993; Kaageson, 2009). Thus, there is no question that to reduce CO_2 emissions in particular from light duty vehicles a significant carbon tax is required, while policies that offset the impact of the tax must be eliminated.

A carbon tax should be implemented on passenger and freight vehicle use in both North America and South America as soon as possible if impacts are to be significant by 2050. For vehicles using fossil fuels, the tax is paid directly when fuel is purchased. The technological barriers and practicality of the implementation of such a tax on electrically driven vehicles could be reduced when ITS technologies are used to charge the externality cost of CO_2 when fuel is purchased (Moore and Thorsnes, 2007) or when the vehicle is driven over a certain level of distance per week. This would then make paying an additional carbon tax more convenient and visible to electric vehicle users, creating incentives to shift travel patterns in order to save on carbon tax. The level of carbon emission tax could be set according to the desired level of CO_2 emissions in a defined region, and revised periodically using the data and information collected on the impact on travel patterns and emissions level of such a tax.

Most economists, however, argue that the tax should be set at the marginal value of the damages. Nordhaus (2008) argues for a tax around $15 US/tonne CO_2, while the Stern Report (2006) pushes for a much higher value of around US$85/tonne, which is about U.S. $0.22/liter of gasoline. Such a tax would be small, compared to much higher prices of fuel in some Latin American countries, but it would be more noticeable in Mexico and North America. In our scenarios, we have assumed that carbon taxation will play a more important role in globalization, even though it is not the only measure used to reduce CO_2 emissions. On the other hand, it will not be as significant in a Glocalization scenario, where international regulations will not be strictly complied with.

Shifting Transportation Pricing from Fuel Consumption to Vehicle Use

The current transportation pricing structure for driving is based mostly on the cost of fuel and the fixed cost of vehicle ownership, including acquisition cost and annual registration fees. Vehicle taxation is usually not based on vehicle type, vehicle size, or emission and noise levels, in North America nor South America. By adopting a different approach to price the cost of vehicle ownership, there will be greater incentives for vehicle manufacturers to design less polluting vehicles for consumers who are unwilling to pay more vehicle taxes. Unlike fuel taxation, vehicle taxation does not increase the variable costs of owning a vehicle and has less impact on travel patterns as soon as the vehicle has been paid for.

Therefore, shifting a part of vehicle use taxes that are based on fuel consumption to vehicles miles traveled will create a more direct demand management strategy and better reflect the impact of each vehicle on the infrastructure it uses. Paying for road usage can reduce demand for roads, which in turn reduces maintenance or replacement costs and can alleviate the need for significant and expensive capacity expansion, particularly on bottlenecks such as expressways or bridges and tunnels. A pilot study of such a shift has been successfully conducted in the state of Oregon in the U.S. and results have shown that congestion pricing or vehicle miles traveled pricing could be an efficient way to fund transportation systems and reduce emissions (Whitty, 2007). France has variable tolls on expressways that rise at peak times, which both smoothes out demand surges and reduces the need for adding lanes.

Pricing based on vehicle miles traveled includes road pricing, which is a broad concept that encompasses different kinds of pricing strategies that charge motorists directly according to where they drive and at what time. This could include congestion pricing, road toll charges, cordon area tolls, HOT lanes, and road space rationing.

Congestion pricing is different from other road tolls as it is specifically targeted at reducing congestion and travel time, by discouraging vehicle use during peak travel time periods and shift demand to less congested times or other travel routes. Congestion charges should therefore change according to location and time of the day. Peak hour travel, which has higher levels of congestion, should be charged at a higher rate than non-peak hour travel, hence, encouraging motorists to shift to other transportation modes where available or to carpool. The application of ITS on congestion pricing will increase the practicality of collecting such a fee and gathering necessary data and information for future updates on charges. Some European cities in France, Italy and Norway have also successfully implemented various forms of road pricing policies, some related to congestion pricing. For example, France has been implementing road tolls for intercity travel, and implementing varying toll rates according to peak and off-peak traveling periods to regulate demand (Burris, 2003).

Congestion pricing has been shown to be more effective at reducing vehicle use during congested times than increases in fuel tax (Menon, 2000) where it is applied. However, in most countries, it is only applicable to a fraction of overall distance traveled. It is a policy that should be implemented as soon as there is a wider recognition of its benefits and the existence of a strong political will together with stakeholders' support. Most of the technological barriers of electronic congestion pricing have already been solved and it would be relatively easier to transfer the ITS technology across cities as long as there is an interest for congestion pricing. Revenue collected from congestion pricing could then be used locally for roadways maintenance or be added to a central fund for the city government. The implementation of congestion pricing in North America would relieve congestion in metropolitan areas and reduce pollution, and encourage modal shifts to public transportation, innovative car sharing or car pooling schemes. Congestion in Latin

America would discourage car ownership and provide more incentives for people to use public transportation especially in high-density areas.

Apply Parking Pricing Strategies to Accurately Reflect Pricing Cost

Implementing parking pricing policies is another method to allocate land resources efficiently. Parking is free or charged at a subsidized rate in many countries (Breithaupt, 2002), even though it is not free at all. The cost associated with the land developed for parking is trickled down from land developers to retailers or employers and ultimately to consumers or employees, in the form of higher retail prices or lower wages (Shoup, 2005). The costs of on-street and off-street parking should thus be distributed to people who use the parking spaces.

Parking charges collected should be kept within the local city and used for transport infrastructure maintenance or other projects that would benefit the local residents. For privately-owned parking lots, taxes can be assessed on parking. This could then generate local support for such a proposition. The implementation of parking fees will increase the cost of driving in urban areas, which will make private car use less appealing. For high-density cities in North and Latin America, this will certainly influence future patterns of car use, cruising behavior, subsequent congestion, and emissions levels. Raising parking fees to reflect the real costs and value of land, while enforcing existing parking rules, will discourage the use of cars in congested zones.

In North America, where parking is readily available in suburban residential and commercial areas, city streets, parking structures, and workplaces, parking is not charged at an amount at which it should be charged. By 2050, parking policies should eliminate all free on-street parking to reducing cruising, which contributes to unnecessary congestion and CO_2 emissions. Regulations should be imposed to prevent developers from over providing parking whenever new developments are built, and minimum parking requirements requested by city governments, which are common in North America, should be abolished. If parking prices would be charged to reflect the real cost of parking, the variable cost of driving would increase and there would then be additional incentives to shift to other transportation modes or change travel patterns. Employees should also be discouraged to provide free parking to their employees and retail developers should start charging consumers for parking. The space used for parking should then be reduced and be replaced by other uses that would benefit people who do not drive. For example, replacing parts of a parking lot with green space and tree-lined streets could encourage people to walk to a shopping mall from a transit station and make their trip more pleasant.

In Latin America, car ownership is still relatively lower than in North America and even though there is no extensive public land use devoted to parking space, parking policies should still be in place to act as an additional cost to driving. Former mayor Enrique Penalosa of Bogota installed bollards at the edges of sidewalks to prevent cars parking there during his term, only to be impeached. He had survived that political storm, but the affair served as a good demonstration of the political sensitivities of parking[i]. A high parking price will discourage unnecessary trips and provide a parking space to people who value that space at a particular time and are willing to pay the most. The revenue collected from parking could then be used for local city improvements. ITS can again be used to collect parking fees and with the use of a smart card (electronic chip), parking fees can be paid with the same card used to pay congestion charges, road tolls or even emissions tax.

No single transport demand measure by itself is expected to have a large impact. But a combination of higher charges to use cars, greater coverage and frequency of collective modes, increasingly more compact and transit oriented development, reinforced by strong pricing signals, could move the transport system, particularly in urban regions, in a significantly different direction by 2050. This is particularly true for Latin America, which has not all of the sunk costs of a very automobile dominated society that North America has.

Policy Discussion

The success of each type of policy recommended is determined by how much travel demand and transportation emissions can be reduced, and how will each type of policy affect total travel distance, time and cost. The implementation of each policy has to be complemented by one other in some cases to provide efficient transportation policies. For example, ITS, which is a technological advancement, should be applied in pricing policies for cost efficient results. In the long term, all three different types of policy discussed in this report have to be implemented in North and Latin America, but depending on the region, different policies could be given different priorities and timeline for execution.

North American cities have to strengthen existing transportation regulations and emissions standards, develop vehicle and fuel technologies that can be widely distributed and create a larger market for affordable clean technologies. The integration between transportation and land use planning should also be improved, and various pricing policies should be implemented incrementally by 2050. In the long term, transportation and land use policies should aim to change travel behavior. Latin America will have a slightly different emphasis, because of its lower automobile ownership and less auto-oriented cities. In Latin America, there should be a stronger focus on sustaining its public transportation modal share and implementing supporting policies to discourage a rapid growth in private automobiles. Most importantly, every transportation and land use planning policy should be attached with its associated carbon co-benefits. The targeted levels of CO_2 emissions can only be obtained if a combination of policies, which will enhance each other, is implemented in a timely manner.

Out of the three sets of policy options, pricing instruments related to vehicle use or transportation demand measurements might seem to be the weakest in terms of reducing CO_2 emissions. Yet such changes could reduce vehicle use (from a case with no changes in pricing) by large amounts, depending on how large the pricing changes were. Such changes would reinforce measures related to land-use planning and TOD, and complement technological improvements to vehicles, in part by making up for the loss of fuel-tax revenues. Indeed, very efficient vehicles with low fuel costs per kilometer, even in a world of expensive fuel, would certainly not discourage somewhat greater use. Higher costs to use cars would offset this potential rebound. Other pricing measures that are not described in this section but should also be considered include pay-as-you-drive car insurance, road tolls, charging by vehicles km traveled, and increasing freight carrier's registration fees.

FUTURE STUDIES

Many issues are important to improving the approach we have used in future work. The first is improved transport activity and fuel use data, particularly for Latin America and for the urban/non-urban split for both regions. We noted how we modified input assumptions for trucking and maritime shipping and bus and air travel significantly for Latin America, as well as fuel used for air and maritime. For Canada, official sources include bunker fuel for Canadian ships departing Canada for international destinations, as can be seen noting that according to the official Canadian data we used, Canadian shipping is 5-6 times more fuel intensive than U.S. shipping. Canadian officials also stopped publishing a breakdown of domestic passenger-km and fuel consumption for air travel. Such details may seem unimportant, yet they can cause large errors in our BAU and cloud judgment of how great a deviation from this BAU.

The second priority is more research on how much change a given policy, price change, or regulation really causes. For example, what is the price elasticity of car fuel? The literature has a wide range of short and long-range answers (Basso and Oum, 2007), and within a set of findings, differences in how car ownership, car use, and car fuel economy might change (Johansson and Schipper, 1997). However, for very large price increases, say bringing Mexico and North America to European levels of taxation, or for shifts of some fuel tax or insurance costs to taxes on distances driven, there is very little experience with such changes. Similarly, there are many estimates of how changes in urban population density would affect how much people travel, but little careful quantification with measurements over time. So while it is fair to say that land-use changes that increase residential density, or populate regions around transit nodes (transit-oriented development), the actual size of the effect varies according to the situation. How much urban congestion pricing, or tolling of intercity highways at peak times can be estimated, but how much change would making such practices universal cause, how would family and real estate developer choices on where to live or to build change? How would higher fuel prices affect the long-term development of supply changes for agriculture, manufacturing, and consumer purchases? One can speculate or estimate formally some of these effects. But moving into a world of relatively high carbon taxes, higher taxes for vehicles to use roads, and shifts in vehicle insurance to where a large share of the total is paid according to distance driven is beyond most forms of analysis, even if our scenarios illustrated a possible outcome. Conversely, what kinds of urban forms would significant increases in moving in automobiles bring about to reduce the overall number of kilometers driven? These are questions that need further exploration.

A related set of questions is political. As noted above, Canada had a very large increase in its road fuel taxation in 1981, and some European countries have had significant and lasting increases as well, notably Sweden and the United Kingdom (Makerowicz et al., 2010). Such tax increases are politically impossible in the U.S. (at least at present) and not an easy matter for Latin American countries either. Implementation of mandatory fuel economy standards in Canada took many decades, and is only slowly occurring in Mexico and Brazil. Thus, better understanding both the current political feasibility of strong policies that would reduce CO_2 emissions and how to raise that feasibility is important.

One important step that goes back to Schwartz (1996) is the use of scenarios as a tool of engagement. The present study could be presented in a way that required active involvement of leaders from all key agencies and other groups shaping transport and CO_2 policy. The senior author once did this to the leaders of the Swedish "Transport and Climate" Commission in 1994, asking spokespeople for the vehicle industry how low they thought emissions/km could actually be brought, asking city planners and road authorities how much they thought car use could be reduced, and asking representative for urban-region mass transit how much market share their bus and rail services might gain. None of the answers were consistent with the low-carbon future the Commission was seeking.

Still, discussion with these leaders provided insights on why the answers were disappointing: long lead times required to improve fuels and vehicle technologies, uncertainty over whether fuel prices and taxes would support such improvements in the market place, unwillingness (at the time) to impose congestion charging in urban areas, and so forth. A carefully constructed scenario of the kind Schwarz has helped develop often helps lead to breakthroughs in policy, or at least identification of the factors thought hindering the implementation of bolder and stronger transport, land-use, and CO_2 policies.

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