As If Kyoto Mattered: The Clean Development Mechanism and Transportation

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DRAFT: 1 Dec 2006
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Comments welcome

Submitted for presentation consideration:
World Conference on Transportation Research (WCTR), Berkeley, June 2007

To be submitted for publication consideration:
Energy Policy

Key words: Clean Development Mechanism, Transportation, Greenhouse Gases, Chile

Abstract

Transportation is a major source of greenhouse gas (GHG) emissions and the most rapidly growing anthropogenic source. In the future, the developing world will account for the largest share of transport GHG increases. Four basic components drive transportation energy consumption and GHG emissions: Activities (A), Mode Share (S), Fuel Intensity (I) and Fuel Choice (ASIF). Currently, the Kyoto Protocol's Clean Development Mechanism (CDM) serves as the main international market-based tool designed to reduce GHG emissions from the developing world. Theoretically, the CDM has the dual purpose of helping developing countries achieve "sustainable development" goals and industrialized countries meet their Kyoto emissions reductions commitments. This paper reviews overall CDM activities and transportation CDM activities to date and then presents findings from three case studies of transportation CDM possibilities examined in the ASIF framework in Santiago de Chile. The analysis suggests that bus technology switch (I) provides a fairly good for the CDM, while options aimed at inducing mode share (S) to bicycle, or modifying travel demand via land use changes (ASI) face considerable challenges. Finally, the implications of the findings for the CDM and the "post-Kyoto" world are discussed.

1 Introduction

Transportation is a major source of greenhouse gas emissions (GHGs) related to potential global climate change. The sector currently accounts for one-quarter of the world's energy-related carbon dioxide (CO_2) emissions and is expected to be the most rapidly growing source over the next 30 years, increasing at an annual rate of 2% to 3% (Price, et al., 2006). The largest share of this growth is expected to come from the so-called developing world, with forecasted growth rates between 3.5% and 5.3% per year (as compared to 1.2% to 1.4% in the OECD). Given these forecasts, the developing world will shift from accounting for roughly 35% of world transportation GHG emissions in 2000 to 52% to 63% by the year 2030 (Price et al., 2006).

If we are interested in modifying these growth trajectories, we will likely need a suite of technology, policy and pricing approaches, focusing on both passenger and freight transportation at both the urban and inter-urban levels. Passenger transportation cannot be ignored: based on estimates from the International Energy Agency, passenger transportation consumes roughly two-thirds of transportation energy today, a share which is expected to remain fairly stable over the next 50 years (IEA, 2004). The metropolitan developing world cannot be ignored either: according to the United Nations, the developing world's urban population will double by 2030, representing 95% of net global population growth, or 1.94 billion additional people (UN, 2001).[1] As such, an urban (or metropolitan) focus in the developing world will be important in any efforts to reduce transportation greenhouse gas emissions.

The near-term burden of climate change mitigation clearly falls on the shoulders of the world's industrialized nations, which account for the overwhelming share of the accumulated anthropogenic GHG emissions to date. Nonetheless, in the face of rapid growth, efforts to mitigate future GHG emissions from the developing countries will be unavoidable if atmospheric GHG concentrations are to be stabilized and, eventually, reduced. To date, the main international instrument to deal with mitigating climate change emissions in the developing world has been the Clean Development Mechanism (CDM). The CDM has the dual purpose of providing industrialized countries with the opportunity to achieve cost-effective emissions reductions while also contributing towards developing countries' sustainable development goals. Essentially, the CDM is a market-based mechanism, allowing industrialized countries to meet their emissions reductions commitments by investing in emission reduction possibilities in the developing countries.

As of November, 2006, 386 CDM projects have been registered – not one has been a transportation project (UNFCCC, 2006). In the face of transportation's large and growing share of global GHG emissions, the increasing importance of the developing countries in transportation GHGs, and the fundamental role of transportation in sustainable development – the need for bringing the CDM to bear on the transportation sector seems readily apparent. Can the CDM play a meaningful role in reducing developing countries' transportation GHG emissions *and* in meeting these nations'

[1] To put this in perspective, during the latter half of the 20th Century, the industrialized world urban population doubled, adding "just" one-half billion people.

development needs? If not, can the CDM be effectively modified to match the transportation GHG challenge, or are entirely new approaches necessary for the sector?

This paper aims to answer these questions via an examination of three different passenger transportation-oriented project types in a single setting: the Santiago de Chile metropolitan area. The remainder of this paper includes five additional sections. The next section presents a framework for understanding the major factors influencing passenger transportation energy use and greenhouse gas emissions. After that, a brief background on the Clean Development Mechanism (CDM) is presented, including a discussion of transportation CDM activities to date. The following section provides a brief overview of the case study context, Santiago de Chile, and then summarizes three different passenger transportation case studies, analyzed according to their CDM potentials. Finally, the conclusion ends with a discussion of the challenges to applying the CDM to transportation – as illuminated by the case studies – and of possible alternative mechanisms in the "post-Kyoto" world.

2 Transportation Energy Use and Greenhouse Gas Emissions

All forms of transportation consume energy. We use calories to walk, gasoline or diesel (or, occasionally, other fuels and/or electricity) to drive motor vehicles, electricity to move subways, and aviation fuel to fly planes. Concerns about transportation's use of energy are, naturally, not at all new. In the last few decades, these concerns have derived principally from the sector's dependence on petroleum. The first "oil crisis" of the early 1970s spawned a range of policy, research and technology activities, focusing on vehicle efficiency standards, driving patterns and speed limits, alternative fuels, "alternative" transportation modes, and changes in urban forms and settlement patterns (e.g., Gilbert and Dajani, 1974). Interest continued during through second "oil crisis" of the early 1980s; oil importing nations naturally were concerned about balance-of-payment effects and economic and national security. Environmental and social concerns – related to oil spills, seepage into groundwater supplies, tailpipe emissions and local pollutant concentrations, and oil exploration and drilling in environmentally sensitive and/or indigenous people's lands – received increasing attention. By the late 1980s, increasing evidence of a climate change risk due to growing concentrations of atmospheric greenhouse gas emissions led to worries about fossil fuel consumption more broadly. Today, these wide-ranging concerns with transportation energy use remain.

2.1 The ASIF Framework

When it comes to transportation energy use and greenhouse gas (as well as local pollutant) emissions, Schipper et al (2000) offer the "ASIF" framework, which provides a useful optic through which the contributing components of transportation energy use and emissions can be understood. Essentially, transportation energy use is a function of total activity (A), mode share (S), fuel intensity (I), and fuel type (F) (thus, ASIF). Multiple factors influence each of the ASIF components (see Fig. 1) and, many of the influencing factors effect more than one of the components, as discussed briefly below. While the discussion (and Fig. 1) below focuses on passenger transportation, the ASIF framework applies analogously to the freight case.

Activities (A) form the underlying force driving transportation emissions: to carry out many activities, we make trips, across distances. The number of trips are influenced by: the total number of people, clearly; demographic factors such as age and gender; income factors, as trip rates tend to rise with income (e.g., Schafer, 2000); the economy and economic composition, which may influence, for example, the demand for different trip types; and urban form, which affects the distribution of activities (potential origins and destinations), and size, which influences total travel distances (e.g., Cameron et al, 2003).

Mode share (S) influences transportation energy use and emissions because different travel modes have different emission rates, with human-powered transportation, for example, producing no direct emissions. Multiple related factors influence mode choice. Income again plays a role, affecting, for example, people's value of time and thus demand for speed, as well as demand for comfort and privacy. Income also influences the motorization rate (e.g., automobile ownership), which plays a role in determining the availability of different mode choices (household vehicle ownership may also impact trip rates and distances, by increasing possible trip departure time and destination choice flexibility). Infrastructure provision can affect the willingness to, for example, choose walking or bicycling options, dictate the availability of certain fixed-transit options (e.g., rail), and influence attractiveness through effects on reliability (e.g, dedicated lanes for bus rapid transit). The quality of services provided also logically plays a role, as do the relative out-of-pocket (and perceived) costs. Finally, urban form and design characteristics may well play a role (beyond their effect on travel distances) – Rajamani et al (2003), for example, find local land use diversity and cul-de-sac street patterns have an effect on walk mode choice (in Portland, OR), while Zhang (2004) finds population density to increase the likelihood of walk, bike or public transport for work trips (in Boston, MA). Both of these cases control for the relative costs among competing modes.

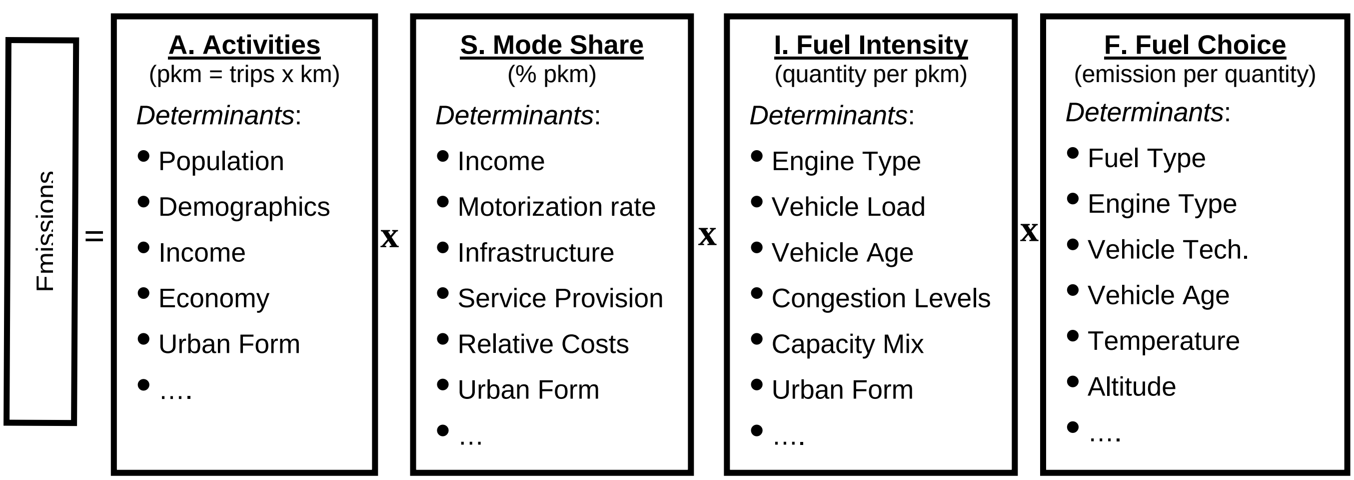

Fig. 1. "ASIF": Determinants of Urban Passenger Transportation Energy Use/Greenhouse Gas Emissions. *Sources*: Schipper et al, 2000; Pargal and Heil, 2000. *Note*: pkm = passenger kilometers.

In terms of fuel intensity (I) – that is, the consumption of fuel per work (passengers moved) – a range of technological factors play a role, including engine type, technology, and vehicle age. Vehicle technological improvements have long been a focus of research and development, spurred in part by government standards. In the US, for example, in response to the oil crises of the 1970s, the national government established fuel economy standards for new light duty vehicles in 1975. The ensuing 15 or so years witnessed important improvements in average fleet fuel economy (Davis and Diegel, 2006); although by the end of the 1980s, researchers were suggesting considerable more room existed for commercially viable gains (e.g., Bleviss, 1988). Falling fuel prices, automaker pressures on regulators, and changing consumer demand (for larger and more powerful vehicles) combined to produce very modest vehicle fuel economy improvements in the US since the mid-1990s (Davis and Diegel, 2006). Driving conditions also affect fuel intensity (e.g., stop-and-start travel conditions worsen fuel consumption per distance traveled), as do initiatives aimed at increasing vehicle occupancy. Some evidence suggests that urban form and design may play a role in this last point; Zhang (2004), for example, detects an influence of the share of cul-de-sacs streets on the likelihood of people driving alone to work in Boston, MA.

Finally, fuel choice (F) will influence greenhouse gas emissions because a fuel's chemical composition will determine the greenhouse gases produced at combustion. Natural gas has different GHG emissions than diesel, than gasoline, and so on. In the case of electricity-powered transport, GHG emissions depend on the fuel source(s), combustion technologies, and transmission and distribution losses. "Renewable" fuels offer some promise for reducing net GHG emissions, but the impacts depend critically on the feedstock used, production processes, etc. Moreira and Goldemberg (1999), for example, present analysis suggesting that sugarcane-derived ethanol in the Brazilian case indeed has a net GHG reduction, even after considering the fossil fuel utilization in agro-industry. Patzek et al (2005), on the other hand, examining the case of corn-derived ethanol in the US case, estimate that it takes approximately 3.8 liters (1 gallon) of gasoline to produce 5.7 liters (1.5 gallons) of ethanol, translating into no net impact on GHGs. Hydrogen has attracted considerable attention in recent years as a promising solution to the GHG (and petroleum dependence) problem; however, the technological (and financial) challenges to harnessing hydrogen power as a transportation fuel remain considerable and the net effects on GHG emissions remain dependent on the hydrogen source.

The latter discussion regarding fuel choice (F) hints at an important, but sometimes overlooked issue quite crucial to a thorough treatment of the GHG issue: the need to consider lifecycle GHG emissions. Unlike local pollutant emissions, the ultimate impact of concern (potential climate change) of GHG emissions is relatively time and place independent. In other words, a gram of CO_2 will have the same ultimate effect of concern whether emitted in the hinterland or a densely populated city. As such we should be concerned about emissions not only at the point of combustion, but also throughout the entire fuel extraction and processing procedures (e.g., Hackney and de Neufville, 2001) – sometimes called "well-to-wheels." Even more rigorously, we should include the embedded energy and GHG emission implications of the necessary infrastructures, such as the roads, tunnels, and rails, and the vehicles (see, for example, Delucchi, 2003). Note that this is not solely an issue for rail- and road-based vehicles and infrastructures: energy use and GHG emissions are embedded in bicycles (and shoes, for that matter) and the energy demanded (i.e., food) for human-powered transportation nearly always has some related GHGs in the production and distribution process. Finally, in rigor we need to account for all GHG emissions (e.g., methane, etc.) and their relative impact on potential climate change – this is sometimes stated in terms of CO_2-equivalent or global warming potential (GWP).

Ultimately, depending on the perceived need to slow the growth rate of, and/or reduce the total magnitude of, transportation GHG emissions, we may well need interventions in each of the "ASIF" components. In the short- to medium-term, at least, technological fixes (i.e., in the I and F components) alone will most likely not provide the hoped-for "silver bullet." Heywood et al (2003) provide a sense of the relevant challenges through a recent assessment of plausible vehicle technological improvements in the U.S. private passenger vehicle market. After accounting for the existing vehicle stock and turnover rates, they find that a combined strategy of slower annual growth in new vehicle sales, a decline in light-duty truck market share, a 50 per cent market share of hybrid vehicles, and no growth in VKT would result in: a 13 per cent increase in fuel consumption between 2000 and 2010; a return to 2000 levels by 2020; and a reduction to 1970 levels by 2030. This assessment leads them to the "sobering overall conclusion" (p.15) that technology and demand growth options together will be required. In other words, we will likely have to work on all ASIF components. Can the CDM play a role?

3 The Clean Development Mechanism (CDM)

In February 2005, the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) entered into force for signatory countries. The Protocol contains several market-based mechanisms, including the Clean Development Mechanism (CDM), which allows industrialized (so-called Annex 1) country governments or private entities to invest in developing country emission reductions. The industrialized country project "proponent" earns emission reductions – known as Certified Emission Reduction units (CERs) – towards their reduction commitments (also specified in the Protocol), while the developing country project "host" advances its development goals. Indeed, the Kyoto Protocol specifies that CDM projects must help host countries achieve "sustainable development," although the Protocol does not specify a definition of the concept. Projects undertaken through the CDM must produce "real, measurable, and long-term" climate change mitigation, through reductions that are "additional to any that would occur in absence" of the project (so-called additionality) (Kyoto Protocol, 1997).

The Kyoto Protocol also identifies supervisory responsibility for CDM activities (an executive board) and requires that each project activity be certified by officially "designated operational entities" (DOE). Subsequent meetings of the "Conference of the Parties" (COP) of the UNFCCC (the 12th COP meeting was held in Nairobi in November 2006) as well as meetings of the CDM Executive Board (EB) further detailed the operating procedures of the CDM. The CDM project cycle includes five basic steps: (1) project design and formulation, which includes establishment of the project baseline (according to approved methodologies) and additionality, and culminates in a project design document (PDD); (2) national approval (by host country designated National CDM Authority); (3) project validation (by a DOE) and registration (by the EB); (4) project monitoring and verification/certification (by a DOE); and, (5) CER issuance (by the EB) (UNCTAD, 2003; UNEP, undated). Stages (1) through (3) take place before project implementation, while monitoring, verification and CER issuance happen over the course of the project lifetime. Project proponents can opt for a single 10 year CER crediting period or for a seven year period, which is renewable up to two additional times (i.e., for a total of 21 years). The market value of a CER varies according to the prevailing carbon price and can be influenced by factors such as country and project risk. Over the past few years the price per tonne of carbon in Europe has ranged from US$10-20. The price range of CERs has been on the order of US$3 to $8, with a lower cost associated with buyer (as opposed to seller) assumption of project registration risk (Ellis et al, 2007).

Sector	Registered or Request for Registration			At Validation		
	Number of Projects	**Total CO_2/Year (KT)**	**Average CO_2/Year**	**Number of Projects**	**Total CO_2Yr (KT)**	**Average CO_2/Year**
Biomass energy	103	5843	57	179	10267	57
Hydro	72	3388	47	138	11678	85
Agriculture	60	4003	67	82	1165	14
Wind	49	3666	75	106	9608	91
EE industry	40	4055	101	106	10664	101
Landfill gas	39	10177	261	57	11662	205
Biogas	33	600	18	41	2092	51
Cement	11	1522	138	12	1302	109
HFCs	11	56104	5100	4	11316	2829
Fossil fuel switch	9	406	45	38	5058	133
EE supply side	5	591	118	11	4526	411
Geothermal	5	1463	293	2	136	68
Fugitive	4	2484	621	6	6902	1150
N_2O	4	17228	4307	5	2566	513
Solar	4	4	1	3	141	47
EE households	3	42	14	1	45	45
EE service	2	15	7	9	48	5
Reforestation	1	26	26	2	396	198
Tidal	1	315	315			
Transport	1	247	247	1	7	7
Coal bed/mine methane				13	7041	542
PFCs				1	86	86
Totals/*Average*	457	112177	*245*	817	96704	*118*

Table 1. CDM Projects Registered, at Registration, or at Validation: By Sector. *Source:* Derived from Fenhann, 2006. *Notes*: KT: kilotons; EE: energy efficiency; HFCs: hydrofluorocarbons; N_2O: nitrous oxide; PFCs: perfluorocarbons.

Currently, of the eligible CDM project sectors, over one-half of the 457 projects registered or with registration requests (as of November 2006) has focused on the energy supply industries (biomass, hydro, wind, etc.) (Table 1). Less than 10 percent of these projects has explicitly focused on energy demand (45 energy efficiency projects in industry, households and services), and only one (with a request for registration) has focused on transportation (as of November, 2006) (UNFCCC, 2006; Fehnann, 2006). In terms of actual GHG reductions, however, most of these have come from the non-energy sector: HFCs, N2O, and landfill gas capture. With respect to the regional distribution of registered CDM project activities (Table 2), the East Asia and Pacific region – which accounts for the largest share of the developing regions' CO_2 emissions (as of 2002) – accounted for over one-half of the total estimated annual emission reductions from CDM projects.[2] The next largest share of estimated reductions comes from Latin America,[3] whose reductions comprise one-quarter of the global CDM-derived emission reductions. South Asia follows, with roughly 12 per cent of total reductions.[4] Relative to total annual regional CO_2 emissions (in 2002; World Bank, 2006), the Latin America and the Caribbean region has, to date, registered the greatest share of tonnes-reduced, follow by East Asia and the Pacific. Central and Eastern Europe, the Middle East, and Africa have as of yet reduced a very small share of their regional emissions via CDM projects. Overall, considering that countries in the six developing regions emitted approximately 48% of global CO_2 in 2002, the estimated annual reductions in CO_2-equivalents produced via the CDM (as of November 2006) account for just 0.41% of total annual CO_2 emissions. The CDM has provided a start, but as yet, a modest one.

Developing Region	**CDM Projects**	**Estimated Annual Reductions (tonnes of CO_2-e)**	**Total Annual Emissions (tonnes of CO_2)**	**Reductions as Share of Total**
East Asia & Pacific	66	60,456,432	4,504,511,200	1.34%
Latin America & Caribbean	179	25,617,402	1,265,709,106	2.02%
South Asia	126	12,111,331	1,371,179,740	0.88%
Middle East & North Africa	6	1,752,310	927,357,765	0.19%
Eastern & Central Europe	5	245,175	3,141,962,226	0.01%
Sub-Saharan Africa	4	156,613	513,964,854	0.03%
Total	*386*	*100,339,263*	*11,724,684,891*	*0.86%*

Table 2. Registered CDM Projects, Annual Reductions, and Total $C0_2$ Emissions by Region
Sources: Total CO_2 derived from World Bank, 2006; CDM projects and reductions derived from UNFCCC, 2006. *Notes:* Countries aggregated to developing regions, as defined according to the World Bank's operational regions; estimated reductions of CO_2-equivalent are as stated by the project participants; total regional CO_2 emissions are for 2002 (the last available year for which complete data were available) and are not presented as CO_2-equivalent, since the necessary information was unavailable – as such, the Table presents an overestimate of reductions as a share of 2002 annual GHG emissions. Figures presented based on CDM project registrations as of Nov., 2006.

[2] Two countries – China and the Republic of Korea – accounted for the overwhelming share, 94%, of the region's estimated emission reductions.
[3] Four countries – Brazil, Mexico, Chile, and Argentina – account for 92% of the region's estimated reductions.
[4] India accounts for 92% of the region's reductions.

3.1 Challenges to and Problems with the CDM

The CDM, in its current incarnation, faces of host of practical challenges (e.g., Ellis et al, 2007; Sterk and Wittneben, 2005). For example, the CDM implies complex, costly and quite lengthy transactions. According to Fehnann (2006), there is a 200 day average time lag between PDD submission and project registration (this does not include the time to prepare the PDD and related documentation). Project development costs typically begin at $100,000; with current CERs valued in the US$3.50 to $5.00 range, this means that a project must achieve at least 20,000 tonnes of GHG reductions just to cover project development costs (Ellis et al, 2007). In addition, the entire concept of "additionality" remains controversial, although the recent CDM EB (2005) additionality "tool" should help improve this.

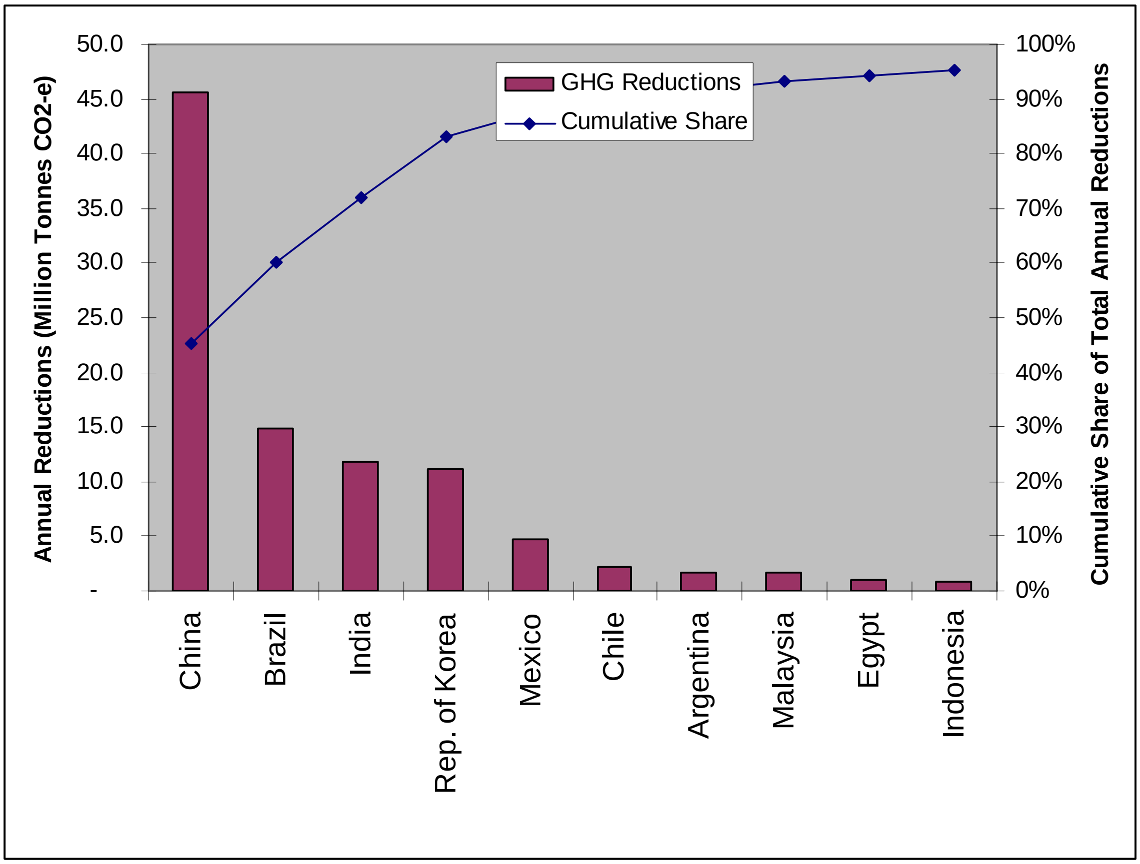

Fig. 2. Top Ten Countries, by Total Annual Emissions Reductions for Registered CDM Projects. *Source: Derived from UNFCCC*, 2006. *Note*: As of Nov., 2006.

Questions have also been raised about the CDM's effectiveness in fulfilling its "dual purposes" of reducing GHGs and achieving sustainable development. On the GHG front, although the overall reductions have been modest, a large share of the reductions has come from relative high impact GHGs: of the 457 projects registered or at request for registration, 75% of the total CERs come from HFCs, N_20, landfill gas (methane) projects (Table 1). In one sense, this represents good climate value for money. From a sustainable development perspective, however, the local development dividends from such projects are likely to be low. Furthermore, evidence suggests that currently a high geographic concentration of CDM activity exists: just 10 countries account for 95% of CERs from registered projects (Fig. 2). In general, these countries could be characterized as fairly high on the development scale, or at least fairly well situated in terms of their ability to attract foreign direct investment (FDI), etc. In fact, Ellis et al (2007) suggest that there is a high correlation between FDI and CDM activity. Might the CDM further exacerbate global development inequities?

3.2 The CDM and Transportation

We saw above that the transportation sector accounts for a large and growing share of global energy-related GHG emissions, with the developing world expected to account for a large share of future growth. Transportation also plays a key role in sustainable development – the mobility provided enables access to jobs, education, social opportunities, etc. and allows for the trade of goods and services; this same mobility can, however, produce negative effects, including local air and noise pollution, death and injury risks from accidents, etc. The CDM, with its ostensible "dual purpose" of promoting sustainable development *and* reducing GHG emissions, must, then, seriously consider the transportation sector. The sector, however, poses important challenges to the CDM, in no small part due to its highly dispersed emissions sources (i.e., individual vehicles) with few readily available, less carbon-intensive energy substitutes.

As seen in the previous section, few transportation projects have formally entered into the CDM process, as recorded by the official UNFCCC channels at the registration or validation stage. Only when a PDD has been submitted for registration to the CDM EB can formal CDM project activity be recorded – thus, marking the beginning of the CDM "pipeline."[5] According to this marker, and based on the CDM project compilation by Fenhann (2006), nine transportation-related projects are at some formal CDM PDD-or-beyond stage (Table 3). These include the Bogotá BRT (Transmilenio) project, for which project registration has been requested, and the Doom Dooma road-to-rail freight transport mode shift project (for a specific firm's freight transport), which is at the validation stage. The latter was submitted as a small-scale project. Seven other projects remain in various stages of PDD revision. The overall amount of estimated annual emissions reductions from these nine projects equals 970,000 tonnes of CO_2 per year, less than 0.2 percent of the developing world's estimated transportation CO_2 emissions (530 million tonnes; Price et al, 2006) in 2000.

Returning to the ASIF framework (Fig. 1), we can see that the majority (five) of the transportation projects in the CDM pipeline entail fuel choice (F): an ethanol and two biodiesel projects in Thailand and a biodiesel and a liquefied petroleum gas (LPG) project in India. These projects do not have a sub-sector (i.e., freight or passenger) focus, per se. The other four propose mode shift and/or a change in fuel intensity (via increased passenger or freight load factors) – two of these are freight transport projects and two are

[5] A non-governmental organization (NGO), CDM Watch, maintains an on-line CDM project database (http://cdmwatch.org/search_project.php) allowing for a search by sector, including transport. The database includes projects in various stages of development (e.g., methodology approved, feasibility study completed, etc.). As of 19 November, 10 transport projects were listed, three of which have had methodologies submitted to the CDM EB (according to Fenhann, 2006). For five of the projects (in Bangladesh (2), Brazil, India, and Indonesia) no additional information was available. Details on the generation of this project database were also unavailable.

urban passenger transport projects, involving so-called BRT systems (Transmilenio in Bogotá and Metrobus [Insurgentes] in Mexico City). In the freight transport projects, the principal emissions reductions come from shift to road to rail (India) or road to sea (Brazil); there are also some changes in load factors implied as well as a necessary fuel switch. For the two BRT systems, the Transmilenio project achieves most of its claimed emissions reductions through improvements in vehicle utilization (I), system efficiencies (I), as well as some mode share effects (S); the Metrobus also claimed its emissions reductions from improved vehicle utilization (I) (higher capacity vehicles, improved network performance, etc.) as well as a modest assumed mode shift (S) from auto to the new bus system.

Project Title	Project Description	Host Country	ASIF	CO_2/ Year (KT)	Status
Modal shifting in industry for transport of product/feedstocks	Freight transport (pulp factory) mode shift from road to sea	Brazil	SI(F)	6	New PDD requested (Nov 05)
BRT System for Bogotá, Colombia: TransMilenio Phase II to IV	Expansion of BRT system	Colombia	SI	247	Registration requested (Jul 06)
AutoLPG in India - A road transport sector fuel-switching project	Establish 1500 retail outlets for LPG for 2-,3-, and 4-wheelers	India	F	363	New PDD requested (Feb 05)
Andhra Pradesh biodiesel production and fuel switch	Biodiesel from oil seeds on Jatropa and Pongamia trees & waste oil	India	F	26	Changes to PDD requested (Sep 05), decision pending
Shift to low greenhouse gas emitting vehicles for materials	Shift from road to rail for goods transport to and from Doom Dooma plant	India	SI(F)	7	At validation
Mexico City Insurgentes Ave. BRT Pilot Project	Creation of a pilot BRT corridor	Mexico	SI	26	New PDD requested (Jan 06)
Khon Kaen fuel ethanol project	Production of sugar cane based anhydrous bio-ethanol for transportation	Thailand	F	40	Preliminary recommendations sent to project developers by Meth Panel (Oct 06)
Palm Methyl Ester - Biodiesel Fuel production and use for transportation	10% Palm oil methyl ester added to diesel	Thailand	F	218	Preliminary recommendations sent to project developers by Meth Panel (Feb 06)
Sunflower Methyl-Ester Biodiesel Project in Thailand	Methyl-ester biodiesel from sunflower on unused land	Thailand	F	33	Changes to PDD requested (Nov 05), decision pending

Table 3. Transportation CDM Projects in the "Pipeline". *Source:* Derived from Fenhann, 2006. *Notes*: KT: kilotons; BRT: bus rapid transit; ASIF refers to the Activities (A), Mode Share (S), Fuel Intensity (I), Fuel Choice (F) framework (see Fig. 1); LPG: liquefied petroleum gas.

4 The Santiago de Chile Case

The transportation sector in Chile accounts for 24% of the country's 81 million tonnes of (2001) CO_2 emissions (or almost 30% of energy-related CO_2) (DICTUC, 2004). By modes, nearly 80% of Chile's transportation GHG emissions come from the road sector, with the remainder coming from shipping (13%), air (9%), and rail (1%); by sector, urban transport accounts for 45% and inter-urban 55%; finally, by purposes, passenger movements account for 65% of total transport CO_2 (O'Ryan et al, 2002). Depending on future economic growth, and policy and intervention scenarios, the transportation sector's GHG emissions could increase by between 50 and 120% over the period 2000 to 2020 (O'Ryan et al, 2002).

Chile offers a relevant case for exploring transportation and the CDM, for a range of reasons. As can be appreciated from Fig. 2, Chile has been active on the CDM front. As of November, 2006, the country has 6 registered CDM projects – four landfill gas projects, one hydroelectric project, and one fossil fuel switch project – totaling approximately 1,195 kilotonnes of CO_2-e (Fenhann, 2006), or approximately 1.5% of the nation's 2001 GHG emissions (from all sources, including biomass; DICTUC, 2004). The country has sustained strong economic growth over nearly the last 20 years, making it, to some in the region and beyond, a "model" for other countries to follow. In the transportation sector, the country has strong institutional capacity, exhibited, for example, by government-sponsored development of world class travel and land development forecasting models (see, e.g., Boyce and Bar-Gera, 2004; Martínez and Donoso, 2001) and consistent efforts to develop the necessary data (e.g., SECTRA 1992a, 2004; Ampt and Ortúzar, 2004).

Source	**PM_{10}**	**CO**	**NO_x**	**VOCs**	**SO_2**	**NH_3**
Buses	27.6%	3.2%	37.9%	3.1%	8.8%	0.0%
Trucks	18.5%	1.8%	17.1%	3.0%	5.2%	0.0%
Light Duty Vehicles	9.3%	87.9%	30.7%	24.5%	10.2%	3.1%
Off-Road Vehicles	1.0%	0.8%	1.6%	0.3%	0.1%	0.0%
Mobile Sources Total	*56.4%*	*93.8%*	*87.3%*	*30.9%*	*24.3%*	*3.2%*
Point & Area Sources	43.6%	6.2%	12.7%	69.1%	75.7%	96.8%

Table 4. Annual Pollutant Emissions Inventory by Source (% of Total): 2000. *Source*: CONAMA, 2003. *Notes:* PM_{10} – respirable particulates; CO – carbon monoxide; NO_x – nitrogen oxides ; VOCs – volatile organic compounds; SO_2 – sulfur dioxide ; NH_3 – Ammonia.

Within Chile, Santiago provides a fairly logical geographic scope to examine CDM applicability. The Greater Metropolitan Region of Santiago concentrates a large share (40%) of the highly urbanized nation's residents and accounts for nearly 50% of national Gross Domestic Product (Zegras & Gakenheimer, 2001). Due to a relatively energy intensive inter-urban transportation sector, however, Santiago accounts for only about 20% of Chile's transport GHG emissions.[6] Notoriously, Santiago suffers serious air pollution problems. The transportation sector accounts for 56% of PM_{10} and 87% of NO_x, a precursor to ozone (transport is responsible for 31% of VOCs, the other ozone

[6] According to O'Ryan et al (2002), interurban travel in Chile accounts for 55% of the nation's direct CO_2 emissions; Santiago's transportation CO_2 emissions are estimated for 1994 (from Zegras & Litman, 1997).

precursor) (Table 4) – the two most serious problems of air pollution in the capital city. Like any large urban area, the city suffers from other negative transportation-related impacts, including accidents, time loss from congestion, etc. (see, e.g., Zegras & Litman, 1997). As such, potential "sustainable development" (or so called "co-") benefits of CDM activities in the sector could be large. In 1994, cars and light trucks accounted for a slight majority (52%) of the city's transportation CO_2 emissions, followed by taxis and fixed-route shared taxis (18%), buses (16%), trucks (13%), and the Metro (1%) (Zegras & Litman, 1997).

Category	Item	1977	1991	2001	AAGR (91-01)
Socioeconomics	Avg. HH Income (US$ 2001)	n.a.	$4,700	$9,000	6.5%
Demographics & Motorization	Households	649,820	1,162,845	1,484,903	2.4%
	Persons	3,483,084	4,502,099	5,325,193	1.7%
	Auto Fleet	208,263	414,798	748,007	5.9%
	Vehicles per 1000 Persons	59.9	93.6	140	4.2%
	Vehicles per Household	0.32	0.36	0.50	3.5%
Trip Making	Trips per Person	1.04	1.69	2.39	3.5%
	Work Share All Trips	n.a.	39%	27%	-3.7%
	School Share All Trips	n.a.	28%	19%	-3.5%
	"Other" Share All Trips	n.a.	1.3%	22%	28%
Aggregate Mode Share	Private Transport Mode Share	11.6%	19.7%	39%	6.8%
	Public Transport Mode Share	83.4%	70.5%	51.8%	-3.1%
	Other	5	9.8	9.3	-0.5%

Table 5. Evolution of Basic Socioeconomic & Travel Characteristics in Santiago. *Sources*: Derived from SECTRA, 1992a,b; 2002; 2004. *Notes*: Only data for the jurisdictions common to the 1991 and 2001 surveys are used. Travel information is for comparable observations (i.e., trips over 200 m, by individuals over five years old) for the normal work week. AAGR: average annual growth rate; n.a: not available.

Driven by rapid economic growth – including an estimated 6.5% average annual growth rate in average household income over the period 1991-2001 – Santiago's transportation system is under rapid transformation (Table 5). The motorization rate (vehicles per 1000 persons) increased by 4.2% over the same period (although it still stands at only 20% of the US level and just 30% of Western European levels), while private motorized travel demand increased even more rapidly. The overall trip rate increased at 3.5% per year, with a large growth in non-work, non-school trips as a share of total travel. The government has embarked on major interventions in the sector over the past decade, including: aggressive expansion of roadway infrastructure, including through Chile's highway concessions program; urban heavy rail (Metro) expansion; and important reforms Santiago's bus-based public transport (Santiago's bus operations are operated exclusively by the private sector, with no explicit public subsidy). Public transportation reform has been implemented under the umbrella "Transantiago" plan, encompassing a re-organization of bus services, bus priority infrastructure, service and fare integration, among other initiatives. Authorities originally developed a CDM PDD for "Transantiago," which was originally submitted in 2004; authorities later determined not to pursue the Transantiago PDD for undisclosed reasons and are currently redefining potential strategies for linking the plan to climate change financing (personal communication with Iván Jaques, Transantiago, 29 November, 2006).

4.1 Background to the Case Studies Selected

Towards the end of 2002, under support from the Canadian government, a coalition of organizations undertook a project to "build capacity" for the CDM within Chile's transportation sector. As part of the project, several case studies were selected to elaborate on their CDM possibilities. The cases selected for further analysis were drawn from a range of candidate cases, with the ultimate selection carried out in collaboration with a local steering committee comprised of relevant government authorities and local non governmental organizations (NGOs). Selection was based upon CDM eligibility (e.g., additionality, etc.), potential sustainable development impacts, replicability, demonstration effects relative to the various ASIF components (Fig. 1), among other factors. Browne et al (2005) provide further details. The final case studies selected were: bus technology switch, bicycle promotion, and location efficiency, as detailed below.

The bus technology switch focuses specifically on an aspect of the proposed "Transantiago" Plan that was not being explicitly detailed in the plan: the potential role of advanced vehicle technologies in a Transantiago feeder area. Transantiago, while entailing a range of transport system interventions in the city, rests on a fundamental change – the restructuring of the road-based public transportation system, oriented around dedicated bus trunk lines (i.e., BRT) (and the Metro lines), serviced by 10 different feeder areas (distinct zones) in the city, with service and fare integration and intermodal transfer stations. The choice of examining fuel switch options in the feeder areas was driven by the facts that: government authorities were also planning to submit the Transantiago plan to the CDM (as discussed above), the feeder zones basic characteristics were already defined (routes, vehicle characteristics, etc.) with no advanced technologies (beyond traditional diesel vehicles complying with emissions standards) formally called for.[7] As such, the feeder area focus implied a fairly clear case of additionality, and a straightforward definition of project boundaries and baseline (as service characteristics were defined by authorities). The technology chosen for analysis was hybrid diesel-electric; in the ASIF framework, the bus technology switch aims at the fuel intensity (I) component.[8]

The bicycle promotion case study examines the possibility of increasing bicycle mode share in the city. As a human-powered transportation mode, bicycle use produces no direct greenhouse gas emissions,[9] so a switch to this mode from motorized modes can reduce GHGs. Santiago enjoys favorable conditions for bicycle use: most of the urban

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[7] Except for the feeder area in the central business district (CBD), for which "clean technologies" are called for.
[8] The fuel choice does not change; energy still comes from diesel fuel, which is used to either provide direct power to the wheels or to power electric motors which power the wheels. The net effect, then is to improve the efficiency (fuel consumption per km), an effect that is enhanced by the vehicles' performance in stop-start driving conditions.
[9] In rigor, the potential increased caloric intake to power the mode should be considered, along with the related upstream emissions (i.e., fossil-fuel intensity of diets).

area rests in a relatively flat river valley, with a slight 3% grade towards the Andean foothills[10]; the city has a relatively dry climate (average 346 mm precipitation/year), with summer monthly temperatures averaging 19-21 degrees Celsius and winter monthly temperatures averaging from 7 to 10.[11] Currently, bicycle facilities are limited to some unpaved routes in urban parks, and a small number (approximately 20 total kms) of bikeways and bike lanes along a few major roadways. In recent years, authorities – in part through support from the Global Environment Facility (GEF) – have increased their efforts to implement more widespread bicycle infrastructure (and related promotional activities) in Santiago, and several Municipalities have networks under development (e.g., Graftieaux et al, 2003). As of 2001, bicycle use remains low, overall, at approximately 1.9% of all trips on a normal workday; during the summer months, this mode share increases to 4%; the majority of bicycle trips (54%) are for non-work, non-school trip purposes (SECTRA, 2004). The bicycle promotion case study examined two different options: development of an individual, hypothetical, 4.5 km bikeway; and development of comprehensive bicycle network, consisting of approximately 600 km of bikeways and 600 kms of on-street bikelanes. In the ASIF framework, bicycle promotion aims at the mode share (S) component.

Finally, the location efficiency case study examines the possibilities for influencing land development patterns – the location of urban development projects within Greater Santiago – as a means for changing individual travel demand (modes used, distances traveled) and thereby reducing transportation greenhouse gas emissions (GHGs). Similar to many other metropolitan areas the world over, Santiago has been undergoing rapid urban expansion in recent years. For example, from 1985 to 1995, the urban area expanded 70% more rapidly than population growth (Zegras and Gakenheimer, 2000). Multiple, often inter-related factors play a role in this urban expansion, including income growth (and subsequent motorization and demand for space), land speculation and large-scale real estate projects, transportation infrastructure development, low income housing demand, etc. A number of public policies have produced somewhat countervailing effects, such as an urban renovation subsidy program, designed to increase residential housing demand in the central city since 1992; major changes in 1997 to the metropolitan land use regulatory plan, opening up to development almost 20,000 hectares on the northern urban fringe; the introduction of transportation impact fees; among others (Zegras and Gakenheimer, 2000). In part through GEF support, authorities have been looking to develop land use incentives to reduce motorized travel (Graftieaux et al, 2003), although the concept remains in initial stages of development. The location efficiency case study analyzed a range of different scenarios for future land development, including location of future educational facilities, changes to future non-residential land uses, and a future sub-center pattern of development. In the ASIF framework, location efficiency aims at: activities (A), by modifying trip distances; mode share (S), by inducing shifts to lower emitting modes; and fuel intensity (I), by inducing changes in vehicle occupancies.

[10] In the foothills, the grade increases precipitously. Approximately 15% of the city's area (and much less of the population) is actually in the foothills.

[11] The three winter months account for nearly 70% of annual precipitation (MOP, 1997).

4.2 Analytical Approaches

Each of the cases involved fundamentally different analytical approaches, due in part to the components of the ASIF identify addressed, as well as data availability. The bus technology switch involved a straightforward cost-engineering, incremental cost approach, whereby the performance and costs of the baseline vehicle technology (diesel buses meeting EURO III emission standards) is compared to the alternative (hybrid diesel-electric). The specific feeder area analyzed, Area 3, was chosen as the case study because the vehicle specifications for this area (12 meter buses) most closely matched the hybrid diesel electric vehicles for which technical data were available. The baseline analysis assumes: compliance over a ten-year project life with the operating requirements (fleet size, routes, frequencies, etc.) as specified by authorities, and subsequent implications for mean bus travel speeds; and fuel consumption for the EURO III baseline vehicle based Santiago drive cycle-derived function.[12] The "with project" case used vehicle procurement and operating cost data drawn from Electra, a Brazilian manufacturer of diesel and hybrid buses; fuel consumption for the hybrid case is corroborated by de Almeida D'Agosto and Kahn Ribeiro (2004). The analysis considered only CO_2 emissions due to vehicle fuel consumption, based on diesel carbon content; i.e., upstream emissions are not considered (such as potential variations in energy-intensity of vehicle production), nor are other GHGs, such as nitrous oxide or methane. The financial analysis is based on an incremental additional cost for the hybrid technology of $25,000 per vehicle, lower operating costs for the hybrid of roughly US$0.01 per km, in addition to the fuel savings for the hybrid (see Browne et al [2005] for more details). In this analysis the greatest uncertainty comes from the lack of actual hybrid vehicle performance data, including on fuel consumption and operating and maintenance costs. Wright and Fulton (2005), for example, estimate incremental purchase cost of hybrid electric vehicles on the order of US$65,000 to US$100,000, increased operating costs for hybrid electrics on the order of US$0.02 per km, and fuel savings of 5% to 20%.

The bicycle promotion case study entailed a "sketch planning" method, utilizing fairly basic scenarios of estimated mode share changes induced by bicycle infrastructure development. Resource constraints and lack of empirical data regarding bicycle choice and influencing infrastructure characteristics were the primary reasons for the choice of the scenario-based sketch planning approach. One empirical precedent for Santiago exists; Ortúzar et al (2000) used a stated preference survey of 1917 individuals in 612 households to estimate a mode choice model for bicycling, based on a scenario of a dense city-wide bicycle network (3.2 km per km^2 of the city) as well as an expanded and improved Metro and bus system network (roughly along the lines of the Transantiago plan). Based on this analysis, they estimate bicycle mode share for all trips could increase to nearly 6% by 2005 (from the 1.9% 1991 baseline), including almost 5% among people over 14 who currently drive or take bus, shared-taxi, Metro or mixed-modes. The case study analysis utilized the following basic assumptions: an emissions factor of 165 g of CO_2 per auto passenger-km avoided and 42 g of CO_2 per bus

[12] Fuel consumption factor (gram/km) = $1{,}391.325 * V^{(-0.4318)}$.

passenger-km avoided;[13] construction costs of US$80,000 per km for the individual bikeway and an average of US$58,000 per km for the comprehensive network (combining segregated bikeways and on-street bikelanes); the bicycle infrastructure will only meaningfully induce a mode shift for trips under 3 kms.[14] For the bikeway project, 1,000 users per day for 260 days per year were assumed; it was further assumed that these users would come from other modes in direct proportion of the future (2015) mode share (Table 6). For the bicycle network, several different future scenarios were analyzed, estimating a range of effects on future bicycle mode share relative to the 2015 baseline, as discussed further below.

Mode	**2001**	**2015 Estimate**
Bikes	2.5	2.5
Bus	9.1	6
Auto	17.5	27
Walking	62.2	56.3
Metro	1.9	1.7
Taxi/Shared-Taxi	6.3	6
Other	0.5	0.5

Table 6. Baseline Mode Share (% of all Trips) Assumption for Trips under 3 km.
Source: 2001 mode share for trips under 3 kms derived from SECTRA, 2002.
Note: 2015 values represent "best guess" estimate.

Finally, the location efficiency case study employed an integrated travel demand and land development model to assess (1) the transportation demand and related greenhouse gas emissions of alternative land development scenarios and (2) estimate the interventions in the land market (via subsidies) required to achieve the land development scenarios. The transport demand model consists of a set of discrete choice models (multinomial logit models) of trip generation, distribution, and mode choice. The model was specified for and estimated on AM peak period, work day travel, since available transportation level of service information was only available for that period. The modeling approach does not consider route assignment, due to limitations in available resources and time, although the framework allows for expansion to include route assignment. This simplification also implies that average speeds – derived from observed data and independent of route, zone, or time of day – were used to calculate GHG emissions.[15] Despite its simplifications, the model performs fairly well: the model has a tendency to overestimate the number of longer distance trips and GHG emissions, which

[13] The auto emission factor is based on average passenger loading of 2 persons/vehicle and the bus emission factor is based on the same base-case emission factor used in the bus technology switch case study and an average load factor of 30 persons per bus. Both of these loading factors should produce conservative estimates of emissions reduced from mode shifts from these modes; however, attributing any emissions reductions due to attracting bus passengers may still be problematic as the most likely short- to medium-term outcome would not be a reduction in bus GHG emissions.
[14] Again, a conservative assumption.
[15] Emissions factors for 30 different vehicle types were included, utilizing average speed emissions factors developed by local authorities.

would result in conservative estimates of total GHG emissions reduced. A second model, based on the urban equilibrium theory used in MUSSA (the Santiago land use model; see Martínez and Donoso, 2001), calculates the subsidies required to make households and firms locate according to the land use scenarios developed. As such, travel distances and the spatial distribution of activities are modeled in an integrated fashion, accounting for relevant factors influencing residential and non-residential location decisions. Donoso et al (2006) provide more details on the modeling approach. Several different scenarios were modeled, including: an "education-oriented" scenario, which located educational facilities directly proportional to residential location patterns; a "non-residential-oriented" scenario, which redistributed non-residential land uses proportional to residential location patterns; and a "sub-center scenario," which concentrated a high share of residential and non-residential land uses into defined sub-centers on the urban edge. The baseline is defined as a linear extrapolation of current land uses driven by exogenously defined household growth rates.

4.3 GHG Emissions Impacts and CDM Potentials

As would be expected given the range of project scales and ASIF component intervention, the case study projects produce a range of GHG emissions (Table 7 provides a summary). In the case of the Area 3 feeder bus technology switch, the 10-year project results in almost 12,000 tonnes per year, just 0.3% of Santiago's estimated 2000 transport CO_2 emissions. At US$5 per CER, this would generate roughly US$60,000 per year. In theory, the project could be replicated – with modifications – across eight other feeder areas (not including the CBD, for which "cleaner" technologies are already specified), which might produce reductions of up to 2.7% percent of 2000 CO_2, and proportionally larger CER flows ($500,000). Based on the technological and cost assumptions, the Area 3 emissions reductions are achieved at a savings to the bus operator – in other words, the cost per tonne is negative (-US$80), the investment should be attractive irrespective of development within the CDM. This raises an important additionality question. If financially attractive, should this project be considered "additional"? In November, 2005 the CDM EB (2005) produced a tool which provides a step-by-step approach to demonstrate and assess additionality. In the case of financially attractive projects, additionality can still be shown based on other barriers, such as technological (e.g., lack of properly trained operations and maintenance labor). Meeting this need, proponent must complement the barrier analysis with a "common practice" analysis, assessing the degree to which the project has "already diffused in the relevant sector and region." For the case of diesel hybrid electrics, this condition is clearly met. While a full additionality analysis extends beyond our scope, we can reasonably assess that the project has a good chance of meeting the additionality requirement. Finally, in terms of the monitoring and verification protocol, the Transantiago plan includes a global positioning system (GPS) based operations control unit, which will enable verification of travel distances, derivation of mean speeds, etc. Such information can be used to establish the dynamic baseline (for the "without project" counterfactual); actual fuel consumption data for verification purposes can be obtained from fuel purchase billing data. Although not trivial, the project faces relatively modest institutional challenges in terms of CDM applicability.

Looking at the two different bicycle promotion cases, we see considerably larger challenges in terms of CDM applicability. The cases face significant uncertainties regarding demand projections and emissions offsets (i.e., mode shift from where?). Fairly conservative estimates suggest a single bikeway would produce very low CO_2 reductions (roughly 700 tonnes per year); at US$5 per CER, this would generate less than $400 per year – enough perhaps for annual maintenance. The cost per tonne of CO_2 reduced is over US$200 (ignoring transaction costs and project renewal costs over the 21 year assumed project life). In the case of the city-wide bicycle network, the estimated reductions per year depend on the scenario – a "conservative" scenario of 3% bicycle mode share (versus an assumed baseline of 2.5%) for trips under 3 km results in 27,000 tonnes CO_2 reduced per year (roughly 0.7% of year 2000 levels) a "moderate" scenario of achieving 6% bicycle mode share (roughly in line with the Ortúzar et al [2000] forecasts) would amount in almost 100,000 tonnes per year reduced (2.4% of year 2000 levels). The estimated cost per tonne in these two scenarios ranges from US$30 to US$111. In these cases, CERs generate a not insignificant share of annual revenues, on the order of US$137,000 to almost 500,000 per year, although these would still account for only a fraction (0.2% to 0.7%) of estimated construction costs. For either the bikeway or the bike network project the question of additionality is not straightforward. Several bikeways already exist in the city and a pilot bike network in a small area of the city is under development. It might be argued that certain links – i.e., those not included in existing plans – are additional; furthermore, while authorities are developing plans for a comprehensive bicycle network, no regulations or dedicated financing exist for the network such that additionality could well be defended. As for monitoring and verification, surveys would likely be the only defensible option (possibly supplemented by automatic bicycle counting technology); for the individual bikeway this is fairly straightforward, while for the bikeway network a more ambitious survey implementation would be required. It might be possible to link such survey requirements with government plans for a continuous survey instrument (Ampt and Ortúzar, 2004). Finally, in terms of institutional challenges, a single bikeway would face modest challenges, most likely involving a single municipality. The comprehensive city-wide network, however, would be more challenging, not only in terms of infrastructure implementation (multiple municipalities), but also regarding the ultimately responsible authority.

For the location efficiency case, potentially large emissions reductions can be achieved. While several scenarios were tested, only two seemed reasonable in terms of the degree of modification to urban structure required and costs per tonne of CO_2 (see Donoso et al [2006] for additional details). The education-oriented scenario, evaluated over a 21 project life, produces on average 500,000 annual tonnes of CO_2 reductions, 13% of 2000 emissions, with the potential to generate US$2.0 to $2.6 million per year in CERs. The estimated cost per tonne of CO_2 reduced – calculated as the present value of the subsidies to residential and non-residential land users (locating agents) – is a competitive US$2 per tonne. For the non-residential scenario, nearly 1 million tonnes of CO_2 per year can be reduced (23% of 2000 emissions), generating $3.9 to $4.6 million per year in CERs. But, this comes at a high cost – an estimated US$91 per tonne. As for additionality, while the government has been exploring the "location efficiency" concept and also has been looking at school relocation possibilities, little formal programmatic activity on this front has been taking place – in fact development patterns continue which in general seem to be moving against the principle of "location efficiency." Again, further additionality assessment would be necessary, but the location efficiency project should be able to surmount this barrier. Monitoring and verification, on the other hand, would likely be a major challenge. Household surveys, supplemented by traffic counts, are one possible approach. In the case of the education-oriented scenario the challenges may be somewhat less, as stratification could be possible based on specific schools. Again, the possibility exists to use monitoring and verification activities to supplement existing government plans for a continuous survey instrument. Finally, the institutional challenges in the location efficiency scenarios are quite high. These might be slightly lower in the education-oriented scenario, as ostensibly one government agency, the Ministry of Education, manages school location policies. In the broader non-residential scenario, the large number of decision-making agents and the lack of any single metropolitan-level authority controlling land use regulations, transportation investment decisions, etc. pose as major practical challenges to deploying the CDM.

4.4 Contributions to Sustainable Development

As discussed above, a criticism of the CDM to date has been its marginal contribution to helping developing countries achieve "sustainable development." Detailed analyses of the sustainable development benefits (so called "co-benefits") of the various case studies were not carried out. However, a rough qualitative assessment provides a general indication of effects. Table 7 presents such an assessment in five different categories: health promotion (i.e., promoting "active living"), pollution reduction (both air and noise), accessibility (defined as the potential to reach desired activities/destinations), equity of that accessibility, and technology transfer (which includes capacity building and data collection efforts which might aid in more general planning efforts). According to these categories, the CDM options analyzed here confirm the findings from CDM activity elsewhere (discussed above): the most attractive CDM option (bus technology switch) offers fewer co-benefits (although the neighborhood-level air and noise pollution benefits could well be important). The location efficiency options provide likely the highest degree of co-benefits (without considering possible benefits from habitat preservation, reduced infrastructure investment requirements, etc.) yet are the most difficult options to pursue under the current CDM framework.

Project	ASIF Components	Project Scale	Analytics		Project Life (years)	GHG Impacts			CDM Issues		"Co-Benefits"[‡‡]					Institutional Challenges
			Analytical Approach	Main Challenges		CO_2 per Yr (KT)[†]	% of Transport CO_2 (2000)[‡]	US$ per tonne[*]	Annual CERs ($US)[††]	Monitoring & Verification	Health (activity)	Pollution	Accessibility	Equity	Tech. Transfer	
Area 3 Feeder	I	462 buses, ~1/10th city	Cost-Engineering, Incremental Cost	Lack of vehicle performance data	10	11.7	0.3% (up to 3%)	-80	$59,000	Easy (firm)	0	M	0	0	M	Modest
Bikeway project	S	4.5 km (1000 cyclists)	Sketch Planning, simple demand variations	Little direct empirical evidence available	21	0.07	Negl.	212	$368	Modest (survey)	M	L	L	M	0	Modest
Bike Network		1,200 km			21	27.3 to 99.6	2.4%	30 to 111	$137,000 to 498,000	Hard (survey)	M	M	M	H	0	High
Location Eff.: Schools	A S I	Greater Santiago	Integrated, micro-economics-based land use transport model	Modeling complexity, uncertainty	21	520	13%	2	$2.0 to 2.6 million	Hard (surveys)	M	M	H	M	L	High
Location Eff.: Non-Res.					21	920	23%	91	$3.9 to 4.6 million	Very Hard (surveys)	M	M	H	M	L	Very High

Table 7. Summary of the Case Studies. *Source:* derived from Brown, et al. (2005), Donoso et al (2006), and author's own judgment. *Notes*: [†]For bike network the range represents the different scenarios. [‡]The year 2000 transport CO_2 is estimated at 4 million tonnes (O'Ryan [2004] estimates 4 million tonnes for 2005; Zegras and Litman [1997] estimate roughly the same value for 1994). [*]Based on 10% discount rate over project lifetime (not including transaction costs). [††]At US$5 per CER; for location efficiency the range is due to the fact that emissions reductions increase in time. [‡‡]Qualitative estimates – 0=none; L=low; M=medium; H=high; U=unknown; health here refers to promoting human activity, pollution includes air and noise, accessibility refers to the potential to reach desired activities/destinations, equity refers to impacts on lower income groups accessibility, technology transfer includes knowledge transfer (including data generation).

4.5 Shortcomings to the Analyses

The case studies analyzed here are intended to be illustrative. As such, numerous shortcomings exist, although in most cases these most likely influence only the relative magnitudes of effects, not necessarily the overall lessons. For one, only tailpipe CO_2 emissions are considered in the analysis; the CDM requires lifecycle GHG emissions including those resulting from construction, etc. Incremental emissions from construction costs could be quite challenging to estimate in the location efficiency case. Furthermore, as noted above, both the bicycle promotion case and the location efficiency case have numerous analytical shortcomings, despite the somewhat ambitious integrated land use-travel demand modeling carried out in the latter case. Also, as discussed in each of the cases above, additionality was examined fairly superficially. In addition, the indicative, qualitative assessment of potential "co-benefits" should be more rigorously carried out – these may be especially large in the location efficiency case (and not insignificant in the bicycle network promotion case) and could therefore create further justification (and social and economic substantiation) for the interventions. Finally, the complex issues of project boundaries and "leakage" have been essentially ignored. While this should not be a problem in the bus technology switch – since the scope of the project is extremely well-defined – this becomes a potentially large problem in both of the more behaviorally-based projects. As an example: in the case of location efficiency it is impossible to determine (given available data and modeling capabilities) what the second- (and third-)order effects might be of location efficiency – what if households (or firms) chose to locate beyond the existing spatial area of analysis (Greater Santiago); what if persons "invested" their travel time (and cost) savings into additional inter-city or international travel?

5 Conclusions and Future Outlook

The developing world's transportation demand must increase. Much of the developing world remains mobility and accessibility poor; mobility will both increase development and be increased by development. The high forecasted growth in these nations' travel represents a good degree of "catching up" – even after a forecast three percent average annual increase in per capita light duty vehicle kilometers traveled (VKT) over the next 50 years in Latin America and the Caribbean, North America's per capita VKT will still be three times higher (IEA, 2004). Absent a technological "silver bullet" (and none seems to be on the medium-term horizon), this worldwide business-as-usual growth in demand will lead to large increases in transportation GHG emissions. We are, then, left with four basic options to meet the climate change threat: (1) aggressively pursue zero-carbon transportation technologies for motorized fleets (i.e., IF in the ASIF framework); (2) aggressively pursue changes in activity patterns and mode choices (AS in the ASIF framework); (3) aggressively pursue the full suite of technology and non-technology options (ASIF); and/or (4) aggressively pursue mitigation options in other sectors, recognizing the transportation sector as "too difficult" in terms of finding meaningful global GHG reductions.

For the developing countries, the primary international mechanism for mitigating GHGs is the CDM: an ostensibly "dual purpose" instrument aimed at helping developing countries meet their sustainable development goals, while allowing Annex 1 countries to find possibly cost-effective means of meeting their emissions reductions commitments. To date, the CDM has been marginally effective in meeting these dual purposes: the great share of CERs (thus investment flows) have focused on projects with marginal development impacts and have been generated from just a handful of countries. Furthermore, the total GHG reductions achieved to date have been modest – less than one-half of one percent of global anthropogenic CO_2 emissions. In the transportation sector, one project has made it to the "request for registration" stage of the CDM, the Transmilenio BRT expansion, an important milestone for a project which proposes to achieve reductions through both mode share (S) and fuel intensity (I) improvements. Another project – a small-scale project in India, also targeting mode share (S) for freight – is at the CDM validation stage. At least seven other projects have not made it through the CDM approval process and an unknown number have been abandoned or are at some stage of development. The CDM and transportation have proved, so far, to be a difficult fit, in part due to project boundary and leakage issues, analytical and project baseline issues, among others.

The Santiago de Chile case studies presented above provide a glimpse at some of the possibilities for and challenges to applying the CDM to the urban passenger transportation sector. A technology switch project – examining diesel hybrid electric vehicles as a substitute for traditional diesel buses in a bus system feeder area – improves fuel utilization (I). The project appears to be attractive from a CDM perspective and, in fact, should be financially attractive irrespective of the CDM – the lack of empirical vehicle performance data adds uncertainty to this bottom line, however. While modest in total GHG impact due to the small project scale, the project could be replicated in other feeder areas and produce reductions an order of magnitude greater.[16] In fact, the methodology (and the technology) could be replicated for other urban fleets, especially those for which hybrid technology offers a distinct performance advantage (taxi fleets, commercial fleets, etc.). The projects aiming to shift (S) motorized travel towards bicycle use – either through development of an individual facility or a large-scale network – face greater challenges under the CDM: GHG reductions seem modest at fairly high cost. Finally, at least one of the location efficiency projects – that aimed at school relocation, and addressing travel distances (A), mode share (S) and vehicle loadings (I) – appears to be theoretically attractive from the CDM perspective: achieving fairly large emissions reductions at a cost (if fully financed by a CDM investor) that is competitive at current carbon prices. Nonetheless, the project faces major hurdles, including uncertainties regarding the transportation and land use modeling, institutional difficulties relating to responsibilities for implementation, monitoring and verification challenges, and boundary and leakage problems. Qualitatively, those projects with greater sustainable development benefits seem to have a lower CDM attractiveness.

5.1 Whither (or Wither?) Transportation and the CDM?

Almost two years into the formal existence of the Kyoto Protocol, we are already looking towards the post-Kyoto (i.e., 2012) world. What role can the CDM play in the

[16] Replication would raise the question though: by demonstrating technology feasibility in one feeder area does one not then eliminate any arguments to overcome the additionality barrier? One way around this would be to implement at once, in all feeder zones, the project.

transportation sector up until 2012 and, perhaps, beyond? A good possibility exists that the CDM will best serve as a "niche" instrument in the transportation sector: effectively aiding in the implementation of discrete project types, such as fuel switching, or well-bounded system interventions. This modest expectation perspective may actually be too modest, particularly in light of the first approved project, Transmilenio, which successfully claims S- and I-oriented emissions reductions. This approval bodes well as potential support for the BRT "revolution" underway in much of the developing world. Yet, even BRT will only get transportation part way towards effective emissions reductions. Ultimately, a suite of ASIF approaches must be taken.

In looking "beyond Kyoto," considerable attention has been given to "sectoral approaches" – which aim to create incentives for countries to adopt GHG intensity targets for different sectors. In one proposed variation (Schmidt et al, 2006), countries would establish a baseline along with a voluntary "no lose" GHG intensity target below that baseline. Any emissions reductions achieved below that "no lose" pledge would be available for sale to Annex 1 nations. The approach would still face considerable challenges relating to baseline establishment, etc. However, such a sectoral approach would enable governments to effectively pursue a suite of options (vehicle technology standards, policies to promote mode shifts, etc.) and sell the combined effects to the carbon market. Given the inherently "leaky" nature of the transportation market, it seems that a sectoral target for transportation would have to be national (for example, a metropolitan-scale sector would likely leave too much room for leakage into the inter-city travel market). Finally, however, examining the CDM leaves one wondering: are we avoiding the obvious, a carbon tax? Of course, taxes imply some welfare losses, however, it would be worth exploring how these losses compare to the transaction costs, institutional opportunity costs (negotiations, etc.) and even the GHG emission costs (travel to COP meetings, etc.) of the CDM…

Acknowledgements

This paper is based, in part, on the project, "Building the Capacity of Chile's Transportation Sector for Sustainable Development through the Clean Development Mechanism," supported by the Government of Canada, through the Canadian International Development Agency Climate Change Development Fund. The author owes a large debt of gratitude to Jodi Browne, Erin Silsbe, Steve Winkelman, Eduardo Sanhueza, and José Luis Barías who carried out the analyses on the bus technology and bicycle promotion case studies summarized here. The author, however, retains sole responsibility for all interpretations and conclusions as well as any errors contained herein.

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