solutions

Transportation

in Developing Countries

Greenhouse Gas Scenarios for Chile

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PEW CENTER ON Global CLIMATE CHANGE

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by

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Foreword *Eileen Claussen, President, Pew Center on Global Climate Change*

Worldwide, transportation sector greenhouse gas (GHG) emissions are the fastest growing and most difficult to control. In Chile, where the transportation sector is growing even faster than the rest of the economy and accounts for one-third of the nation's energy use, per capita GHG emissions are relatively high and car and truck ownership rates continue to increase.

Until recently, the environmental consequences of Chile's rapid development received little scrutiny. GHG emission levels continue to be a low priority for policymakers, but severe air pollution and traffic congestion are raising awareness of the need to address transportation-related environmental problems. As one of the world's most sophisticated countries at transferring transportation infrastructure and services provision to the private sector — most are now owned or managed by private companies, and market principles are being widely used in providing traditional public services — Chile could pioneer market-based approaches to transportation and environmental challenges.

This report creates two scenarios of GHG emissions from Chile's transportation sector in 2020. It finds:

- Greenhouse gas emissions increase 117 percent in the high, "business-as-usual" scenario but only 42 percent in the low scenario.
- Urban transportation strategies driven by concerns over air quality, traffic congestion, and the high cost of road infrastructure investments would also have climate change benefits. Examples of these strategies are:
    1. *Introducing new and enhanced technology,* such as converting urban buses from diesel to hydrogen fuel cell and using natural gas and small battery-powered electric cars.
    2. *Improving public transportation,* such as integrating bus routing and fare structures, establishing exclusive bus lanes and rights-of-way, offering more comfortable buses, and significantly expanding Metro and suburban rail services.
    3. *Encouraging smaller cars and alternatives to car use,* e.g., by implementing parking restrictions, charges, and road fees, and eliminating tax incentives for larger and inefficient cars and light trucks.
- For interurban transportation, the main problem is inadequate road, rail, port, and airport infrastructure. Supporting rail infrastructure will restrain GHG emissions.

Transportation in Developing Countries: Greenhouse Gas Scenarios for Chile is part of a five-report series on transportation sector GHG emissions in developing countries. The report's findings are based on a Lifecycle Energy Use and Emissions Model (LEM) developed by the Institute of Transportation Studies at the University of California at Davis. It estimates CO_2-equivalent GHG emissions from the transportation sector.

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Executive Summary

Chile is a lightly populated country of 15 million that has undergone major economic transformations. Over the past 25 years, the economy has evolved from a slow-growing, state-directed one into a fast-growing, market-oriented one. Chile's South American neighbors imitated this transformation during the nineties. In the transportation sector, as in other areas of the economy, the private sector took over many traditionally state-managed activities. Chile has undertaken more structural changes in this sector in the past two decades than perhaps any other developing country.

This report addresses changes in transportation, energy use, and greenhouse gas (GHG) emissions and other environmental impacts resulting from economic growth and transportation choices. It includes interurban transportation and the urban system in the capital city, Santiago. Chile is an especially interesting case study because of its enthusiastic embrace of market competition in all aspects of transportation. In particular, it has developed a franchising system by which the private sector has been encouraged to finance infrastructure development. However, during this period of economic transformation and growth, Chile has not addressed many environmental problems, including GHG emissions. The expected increase in emissions in the next twenty years is significant, and any reductions would result from indirect efforts intended to address other urban, environmental, and congestion problems.

Chile's transportation sector is growing even faster than the rest of the economy, especially in Santiago. Between 1985 and 1998, the Chilean economy increased by 2.5 times (7.4 percent per year on average) and the transportation sector by about 3.5 times (over 10 percent per year on average). Between 1977 and 1991, cars increased their share of passenger travel by more than 60 percent, while the bus share fell by 27 percent. These shifts are motivated by the strong urbanization process, with over 85 percent of the population now living in cities, and strong growth in car ownership, with one in ten persons now owning a car. Cars now account for 26 percent of travel within cities (measured as passenger-kilometers) and 41 percent between cities. Public transportation has been losing market share for decades.

The transportation sector is responsible for about 28 percent of GHG emissions in Chile. Of the total GHG emissions from transportation, 45 percent are from cars and taxis, 22 percent from trucks, 13 percent from ships, 9 percent from airplanes, 10 percent from buses, and less than 1 percent from trains. Passenger transportation accounts for about two-thirds of transportation sector GHG emissions, while about one-third is from freight. Interurban transportation accounts for over half of total emissions.

Chile's policymakers at the national, sectoral, and local levels have largely ignored the environmental consequences of rapid development. A policy of "grow first, clean up later" was pursued until 1990, after which a few local environmental concerns did reach the policy agenda. Lack of interest in GHG emission reductions continues, stemming from growth-oriented thinking as well as the general understanding that Chile's impact on the global climate is small compared to major industrial nations. With only 15 million people, each using on average less than one-sixth as much energy as each U.S. resident, and with large carbon dioxide (CO_2) sinks due to natural regeneration in abandoned lands and forest plantations, Chile's relative net contribution to global climate change is small. Concern for global climate change is not likely to motivate domestic policy action.

But other concerns, especially acute air pollution and worsening traffic congestion, are already motivating actions that will have a side effect of reducing growth in GHG emissions. Intensifying policy debates over motor vehicles will play a central role in determining Chile's impact on climate change. Prospective international incentives, for example from the sale of emission credits under the Kyoto Protocol's Clean Development Mechanism (CDM), would serve to support such domestic initiatives, with potentially large climate change benefits.

This report develops high ("business-as-usual") and low emission scenarios for GHGs for the next two decades. The scenarios are based upon interviews with experts and policymakers, and extensive analysis of transportation and energy data gathered from a wide range of Chilean sources. Both scenarios are premised on strong continued economic growth (5.8 percent annual GDP growth).

Under the business-as-usual scenario, it is assumed that no strong actions are taken to curb GHG emissions or restrain motorization. The result, over the next twenty years, is a doubling of energy consumption and GHG emissions by the transportation sector.

In an alternative low emission scenario, changes include policies to improve public transportation and introduce cleaner and more efficient vehicles. The net effect is a 42 percent increase in GHG emissions, significantly less than in the high scenario.

It is clear, given Chile's strong economic growth, that overall national GHG emissions will increase. It is also clear that the potential exists to substantially restrain the growth in transportation emissions. This study illustrates the opportunities and benefits of laying a foundation now for a more fundamental strategy shift toward the low GHG emissions scenario. The national experience using market-based approaches to finance transportation sector infrastructure development could prove to be a useful model for implementing additional market-based initiatives that reduce GHG emissions, including international mechanisms. Indeed, policymakers and private sector partners in Chile may have the capacity to develop cost-sharing projects in which domestic goals – e.g., better transportation and local air quality – and international GHG goals can be attained.

I. Introduction

Chile, a country of 15 million people and 756 square kilometers, has undergone a major economic transformation over the last two decades. It is now widely regarded as having the most open, stable, and liberalized economy in Latin America. With a market-based system in which exports and the private sector are the main engines of growth, economic performance in Chile in the last decade has been quite extraordinary. Per capita income has reached almost U.S.$5,000, placing it among the world's upper middle-income countries.[1] This economic development has come at a cost, however, as pressures on the environment have led to the deterioration of many resources. The changes have been especially great in transportation, where the private sector has taken over many traditional public sector roles, and vehicle use has soared as income levels increased.

This report addresses Chile's transportation sector as it relates to energy use and greenhouse gas (GHG) emissions. Both urban and interurban transportation are considered, the former because most environmental initiatives in the foreseeable future will be focused on urban centers, and the latter because it accounts for over half of the sector's total GHG emissions. Because the capital city, Santiago, accounts for a large share of the nation's economic output and energy consumption, and because data and analysis are less available for other cities, the urban sections below primarily focus on Santiago.

A. Economic Development

Chile is a long, narrow country squeezed between the Andes Mountains and the Pacific Ocean (see Figure 1). It stretches more than 4,200 kilometers from Peru, Chile's northern neighbor, to the southern tip of South America. The climate ranges from arid desert in the north to subarctic in the far south. The main economic activities are mining and fishing in the north, agriculture in some northern valleys, and a variety of industries based on natural resources in the southern strip. Most of the population and business centers are concentrated in the temperate valleys and along the coastline of the central part of Chile *(zona central)*. Urban centers in the north and south are few and located far apart from one another. Administratively, Chile is divided into thirteen regions.

Santiago, located in the zona central, dominates the country. It produces 42 percent of Chile's Gross Domestic Product[2] (GDP) and is home to almost 5.5 million inhabitants, 37 percent of the nation's population.[3] Santiago's population tripled between 1960 and 1990. Only about 2 million people in Chile, out of 15 million total, live in rural areas, and no other city in the country exceeds one million inhabitants. The rural population is static, while the urban population, in Santiago and elsewhere, continues to increase.

Between 1960 and 1987, Chile exhibited relatively modest economic growth, with GDP increasing at less than 4 percent per year.[4] Between 1988 and 1998, however, the Chilean economy accelerated to 7.9 percent annual growth. As a result, Chile's income per capita is now one of the highest in Latin America. Compared to the rest of Latin America and the Caribbean, Chile's economy is quite strong, as indicated in Table 1. Poverty levels have also fallen dramatically, from almost 40 percent of the population in 1990, to just over 20 percent in 1998.[5] Income distribution, however, is highly skewed in favor of the rich, with the wealthiest 10 percent representing almost 30 times higher income than the poorest 10 percent. This situation has not changed in decades.

This rapid growth followed "two decades of radical changes both in development models and political regimes."[6] A democratically elected socialist government was pushed aside in 1973 by a military

Figure 1

Map of Chile

Lucidity Information Design, LLC

dictatorship which embarked on a path of radical economic change. The socialist government had closed the economy, nationalized enterprises, and controlled most prices. The military replaced this with a free-market system in which the private sector played an increasingly dominant role. The changes, realized between 1973 and 1982, included privatization of almost all state-owned firms and banks, introduction of market forces in most sectors and services, price liberalization in most markets, and the reduction of tariffs to 10 percent for almost all products.

Table 1

Indicators of Economic Performance

	Chile	Latin America and Caribbean
GNP per capita (U.S.$)	4,590	3,670
Poverty (percent)	21	-
Urban Population (percent)	85	75
Life Expectancy at Birth (years)	76	70
Infant Mortality (per 1,000 live births)	10	29
Access to safe water (percent of population)	99	93
Illiteracy (percent of population over age 15)	4	12

Source: World Bank, World Development Indicators Database, July 2001.
See *www.worldbank.org/html/estdr/offrep.lac/*

The wide shifts in government policy, first by socialists and then by military leaders, resulted in poor economic performance between 1970 and 1985.[7] Since 1985, the economy has experienced strong growth, led by large increases in exports (see Table 2). Between 1985 and 1998, total output increased by 250 percent. International observers, such as the World Bank, expect that Chile will maintain this new, high growth path in the future. Growth rates for Chile are expected to be around 6 percent per year in the years to come, and exports in particular are expected to grow at a rate above 11 percent per year.[8] The economic slowdown around 2000, however, illustrates the level of uncertainty associated with these forecasts.

The economic sectors with the highest growth in recent years have been transportation and communications, and fisheries. In only 15 years, the economic importance of the transportation and communications sector more than tripled, growing at a much faster rate than almost all other sectors of the economy. The growth of transportation is especially relevant from a global warming perspective since it is responsible for significant GHG emissions.

The impact of this growth is also reflected in the increasing importance of the transportation sector in terms of total energy consumption. Total energy consumption doubled between 1985 and 1996, while energy use by the transportation sector increased 2.4 times. Consequently the importance of energy consumption by the transportation sector, relative to total final energy consumption, increased from 29 percent in 1985 to almost 35 percent in 1996.

Table 2

GNP Growth by Economic Sector (1985=100)

Sector	1985	1990	1995	1998
Agriculture, Forestry	100	152	196	196
Fisheries	100	156	285	350
Mining	100	118	155	205
Manufacturing, Industry	100	138	195	209
Electricity, Gas, Water	100	99	193	215
Construction	100	159	239	279
Commerce*, Hotels	100	149	247	312
Transportation, Communications	100	157	255	356
Financial Services	100	148	237	282
GDP	100	138	210	251

*Includes wholesale and retail sales.
Source: Banco Central, Anuario de Cuentas Nacionales, 1999.

B. Environmental Strategies

The environmental consequences of Chile's development process have been largely overlooked by policy-makers, both at the sectoral and national levels. Rapid growth has placed great stress on the environment. Recently, a State of the Environment report highlighted the following problems:[9] uncontrolled fishing; inadequate management of water resources; danger of extinction of some native forest species due to deforestation; air and water pollution problems related to mining (mostly of copper and gold) in the north and south; air pollution and contamination of rivers and coastal waters due to industrial pollution and urban waste in the central part of the country where Santiago is located.

Before 1990, Chile had promulgated a considerable number of environmental regulations and standards, but these policies were fragmented and not coordinated. Generally, they were adopted *ad hoc* in reaction to specific environmental problems, not as part of a coherent policy. As a result, some regulations were not effectively enforced.

In the last decade, however, environmental quality has gained increased attention. By 1990, the severity of environmental deterioration was becoming widely recognized, particularly in Santiago, accentuated by criticism from the United States and elsewhere of “ecological dumping” — that Chilean exports were benefitting from the absence of domestic environmental controls. The newly elected democratic government in 1990 initiated significant changes. A month after coming into office, it established the

Special Commission for Metropolitan Region Decontamination,[10] and a few months later, the National Commission for the Environment (CONAMA), a coordinating body charged with establishing policies to protect the environment. In 1994, the General Environmental Framework Law (GEFL) was passed. It strengthened and formalized the powers of CONAMA and created the foundation for a stronger and more integrated national approach to environmental protection.

The GEFL requires that large private and public sector projects undergo an environmental impact assessment, for which unified procedures have been laid out. These new laws cut through the large and sometimes contradictory set of sectoral rules that had previously been in place. The GEFL also requires that environmental quality be improved, based on objective indicators, using environmental quality standards and emission standards as the primary policy instruments. If a zone fails to achieve a given standard, it is designated a non-compliance ("saturated") zone, and is required to develop a "decontamination plan."[11]

As a result of implementing the GEFL, eight saturated zones were designated for failure to comply with one or more of the air pollutant standards. Most saturated zones have decontamination plans in place, including Santiago, whose plan is addressed below. In other saturated zones, emissions from copper smelters have been regulated. National water discharge standards were also put in place. Legislation is currently being developed for both fishing and forestry.

Additionally, Chile has subscribed to international environmental agreements related to Antarctica, wetlands, international trade of endangered species of wild flora and fauna, protection of the ozone layer, transboundary disposal of hazardous waste, coordination of environmental protection with Argentina, climate change, biological diversity, desertification, persistent organic pollutants, and the international trade of dangerous chemical components and pesticides.

In short, during the 1990s, Chile has made significant progress regarding environmental stewardship. There has been important institution building, coordination of relevant legislation, and concerted efforts to improve environmental quality.

However, significant inadequacies remain, and there is a long way to go before recent economic improvements can be considered sustainable. The development of a comprehensive approach to environmental management in Chile is just beginning. To date, environmental policies have been aimed at "visible" and immediate problems such as air and water pollution. Medium- and long-term problems are usually brushed aside. Issues such as the destruction of native forests, management of water resources, soil degradation, loss of biodiversity, regulation of toxic substances, and abandoned mines have been largely ignored in deference to other more urgent priorities. Climate change is very low on the environmental agenda.

An important barrier to improving environmental quality in Chile is the poor integration between environmental, sectoral, and economy-wide policies. Though debated, no systematic effort has emerged to develop and evaluate a consistent national energy management system on either the demand or supply side, nor to integrate energy policy with environmental and transportation policy. Similarly, there has been little effort to integrate urban development, transportation, and environmental policies. Decontamination plans and air quality standards, the primary environmental policy instruments, are not robust enough to address these broader and more complex relationships and issues.[12] As a result, transportation policies are not coordinated with environmental policies, even though transportation is a principal source of air pollution and noise.

As discussed below, the lack of concerted and integrated environmental policies, particularly with the transportation and energy sectors, will clearly exacerbate the difficulty of controlling GHG emissions.

II. Chile's Transportation Picture

In the past quarter century, both urban and interurban transportation activities in Chile have been transformed. Changes include: the introduction of a franchising system to finance interurban road construction, now also being used in some urban settings and being explored for the expansion of train service; nearly complete privatization of the public transportation system; and deregulation of interurban freight and passenger transportation. All transportation services are now privately owned and/or operated with the exception of interurban passenger trains and the urban railways (Metro). Certain trends – in particular increased vehicle ownership – have continued, and the overall environmental impacts of the transportation sector are increasing.

The governance and institutional structure for management of the transportation sector in Chile is quite decentralized. At the local level, relatively autonomous municipalities (*comunas*, about 300 nationally) are responsible for maintaining local roads and facilities for public transportation (e.g., bus stops), along with controlling local land use. The Undersecretary of Transport and Telecommunications is responsible for the operation of both urban and interurban passenger and freight transportation. The provision of infrastructure for interurban transportation – and some urban roads – is the responsibility of the Undersecretary of Public Works.[13] The Urbanism and Housing Ministry is responsible for providing most of the urban roads and for planning and managing urban development, including zoning policies and setting city limits. These ministries and the Interministerial Secretariat for Transport Planning (SECTRA),[14] together with the Planning and Finance Ministries, participate in the Commission for Investment in Transport Infrastructure that determines major transportation investments. Though this coordination helps to define major investment decisions – including those to do with urban railways and urban and interurban roads – in general, most policies, priorities, and specific policy instruments are created and pursued independently by the various ministries and within the comunas.

In the private sector, there are two important trade associations, the National Confederation of Truck Owners and the Metropolitan Guild Association of Passenger Transport, that are both vocal defendants of the specific interests of transportation providers. These associations request higher bus tariffs, lower taxes on diesel fuel, and lower road tolls for trucks.

A. Urban

Chile is becoming a highly urbanized country. Residents of cities with over 100,000 inhabitants increased from 46 percent of the total population in 1970 to 61 percent in 1992. As the country urbanizes, transportation becomes increasingly important – and problematic.

Buses are still the primary mode of transportation in cities, but cars are playing an expanding role. Table 3 summarizes the transportation modal splits for major cities in Chile. Bus riding and walking together accounted for 65 percent or more of total trips in all major cities during the 1990s.

Table 3

Travel Mode in Major Cities of Chile (percentage of total number of trips)

Mode	Santiago 1991	Valparaíso 1996	Concepción 1996	Temuco 1996
Bus	49	49	31	43
Walking	20	26	34	24
Car*	16	18	12	17
Train/Metro	5	1	-	-
Colectivo**	2	2	4	7
Other	8	4	18	8

*Includes taxis.
**Taxis with a pre-specified and fixed route.
Sources: "Diagnóstico del Sistema de Transporte Urbano de la ciudad de Curicó, Chillán, Temuco, Valdivia y Punta Arenas," SECTRA, 1996; "Análisis de la Red Vial Básica del Gran Concepción," SECTRA, 1999; "Actualización de la Encuesta Origen – Destino de Viajes del gran Valparaíso de 1986," SECTRA, 1996; "Encuesta Origen Destino de Viajes en la Gran Santiago," SECTRA, 1991.

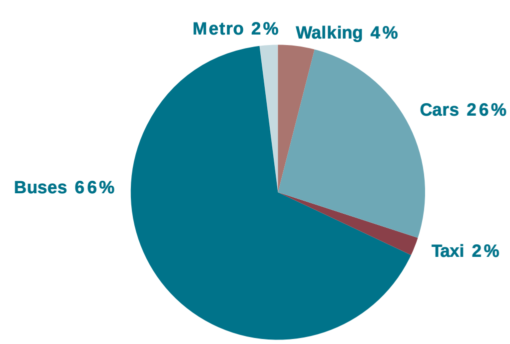
Buses account for 66 percent of all urban travel, measured in terms of passenger-kilometers traveled, as indicated in Figure 2. Travel by car represents 26 percent of total passenger-kilometers, and all other modes only 8 percent.

The car population has been increasing rapidly in the last quarter century. As indicated in Table 4, the number of cars and light trucks, mostly in urban areas,[15] increased over fivefold from 1975 to 1995, an average increase of 8.6 percent per year. More than one in 10 people in Chile now owns a car. In Santiago the rate is about one in eight.

Figure 2

Urban Travel in Chile (1997)

(passenger-km traveled)



Source: O'Ryan R. and T. Turrentine, *Greenhouse Gas Emissions in the Transport Sector 2000-2020: Case Study for Chile*, University of California, Davis, Institute for Transportation Studies Working Paper UCD-ITS-RR-00-10, November 2000.

Table 4

Urban Buses, Cars, and Motorization Rates in Chile (1975-1995)

Year	Urban Buses	Cars and Light Trucks	Motorization Rate (Vehicles per 1,000 people)
1975	16,563	255,717	30
1980	20,734	448,492	40
1985	21,491	624,884	50
1990	28,730	906,626	70
1995	33,970	1,330,376	110

Source: "Parque de Vehículos en Circulación," years 1975, 1980, 1985, 1990, and 1995, INE; and "Población Estimada al 30 de Junio de cada año," INE. Rural vehicles are included in the table, but are less than ten percent of the total.

Even with this high growth, car ownership rates are not particularly high compared to other countries with similar income levels. In Table 5, motorization rates of Chile and Santiago are compared to other countries and cities. An important difference with Asian cities is the virtual absence of motorized two-wheelers in Chile (and most of Latin America and Africa). Car ownership in Santiago and Chile is much higher than in Shanghai, but Shanghai has extraordinarily high densities and aggressive restraints on vehicle ownership and use. Santiago's car ownership rate is double that of Delhi, which is much poorer, and Chile's motorization rate is similar to South Africa's, despite South Africa's lower per capita income. Car ownership will undoubtedly continue to expand in concert with the country's expanding income.

Table 5

Vehicle Ownership and Other Characteristics of Selected Cities and Countries

Region	Year	Population	Income per Capita*	Motor Vehicles per 1,000 People**	Passenger Cars per 1,000 People***
London	1990	6,679,699	$22,215	356	288
Paris	1990	10,661,937	$33,609	383	338
Tokyo	1990	31,796,702	$36,953	266	156
Chile****	1998	14,821,714	$4,930	137	109
Santiago	1998	5,332,100	$5,200	183	129
Delhi	1998	13,400,000	$850	200	63
Shanghai	2000	13,000,000	$4,000	69	22
South Africa	2000	43,700,000	$3,050	141	100

Sources: Kenworthy and Laube, *An International Sourcebook of Auto Dependence in Cities 1960-1990*, 1999. Data for Delhi, Shanghai, and South Africa are from other reports in this series on transportation in developing countries published by the Pew Center on Global Climate Change (2001 and 2002). Chile and Santiago data are referenced elsewhere in this report.
*For cities in this table, gross city product per capita is used as a proxy for income and gross domestic product per capita for nations. Income is in nominal terms for the years indicated.
**For Delhi and Shanghai, data include motorized two-wheelers but exclude mopeds (two-wheelers with engine capacity of less than 50 cc).
***Includes light trucks used for private transportation.
****Chile figures include Santiago.

Chile's three largest metropolitan areas (Santiago, Greater Concepción, and Greater Valparaíso) have serious congestion problems. Additionally, smaller cities such as Temuco and Valdivia are beginning to experience significant traffic congestion, and these and other cities (including Arica, Iquique, Antofagasta, and Rancagua) are also experiencing air pollution.[16]

Santiago's Transportation Picture

Greater Santiago officially includes 34 communas spread over 2,000 square kilometers, and now includes another three for planning purposes. The population density of Greater Santiago is about 8,000 residents per square kilometer,[17] which is much less than in large Asian cities, but much more than in U.S. cities. Densities range from 17,000 inhabitants per square kilometer in Lo Prado, a poor community near the center, to 10,250 in the central business district, and fewer than 5,000 in affluent neighborhoods. Residents of poor shanty towns *(poblaciones)* on Santiago's periphery have particularly long trips, especially when measured in time.

The principal motorized transportation modes in Santiago are cars, taxis, *colectivos,*[18] buses, and the Metro. As indicated in Table 6, of 8.4 million trips per workday in 1991, 49 percent were by bus,

Figure 3

Designated Bus Lanes in Alameda, a Major Transportation Corridor in Santiago

Photo by Raúl O'Ryan, Universidad de Chile

Table 6

Passenger Travel by Mode in Greater Santiago (percentage of trips, 1977-1991)

Mode	1977	1991
Car	9.8	15.9
Bus	66.4	48.7
Metro	3.3	5.0
Walking	16.4	19.8
Colectivo	N.A.	2.1
Other	4.2	8.5

Source: SECTRA, "Encuesta Origen Destino de Viajes en la Gran Santiago 1991," Comisión de Planificación de Inversiones en Infraestructura de Transporte, 1991.

16 percent by car (including taxis), 5 percent by Metro, and 9 percent by other means. (Note that these travel percentages are for the number of trips, while Figure 2 percentages are for passenger-kilometers.) Motorcycles, scooters, and even bicycles are virtually absent. Another 20 percent of trips are non-motorized, mostly walking.[19]

Table 6 shows that in just 14 years, cars' share as a percentage of the total number of trips rose by more than 60 percent, while the share of travel by bus fell by 27 percent. Additionally, the number of trips per person increased from 1.14 to 2.12 in the same period, due to the increase in income and urban expansion. While use of the Metro and colectivos has increased, the overall trend is toward greater reliance on private cars and lesser reliance on public transportation.

Mass Transportation in Santiago

The provision of transit services is problematic worldwide. As affluence increases, demand for residential space and personal transportation also increases. As trip origins and destinations become more diffuse, mass transit becomes less attractive economically and the desire for personal vehicles accelerates. To ensure affordable access to all segments of society, governments almost everywhere have felt the need to subsidize transit services. Santiago faces those same pressures. However, Santiago has taken a path different from most, and now relies on private transit providers to a far greater extent than most megacities. It has invested far less public money in buses than most, and its rail transit system is one of the few worldwide that receives no operating subsidy.

The first motorized transit in Santiago began in 1902 with electric streetcars that ran on rails. These were later supplemented with conventional buses and, in 1953, by rubber-tired electric trolley buses powered from overhead wires. Electric streetcars disappeared by 1967 and the electric trolley buses soon followed in 1978.[20] Buses now dominate, supplemented by colectivos, taxis, and an expanding modern rail transit system.

The bus industry has been transformed in recent decades. Until 1975, the State exercised total control over bus routes, fares, and service frequency. Routes and fares evolved through difficult negotiations between operators and authorities. The result, according to most, was poor service, high fares, and a sparse network of routes.[21] In 1975, bus markets began to be liberalized – part of the sweeping "free market" transformation of Chile. The result was total freedom of routes and fares by 1988.[22] The number of buses and smaller 21-seat "taxi-buses" rose 50 percent and 75 percent, respectively, between 1978 and 1985. (These 21-seat vehicles are included in estimates of the number of buses in this report.) Network coverage improved and waiting times dropped. Fully 93 percent of users are now within walking distance of bus stops,[23] and the mean waiting time is estimated to be only 3.7 minutes.[24]

Deregulation was not all positive, though. More service did not lead to more passengers. Bus occupancy (percentage of seats filled) fell by over 50 percent between 1978 and 1985.[25] The result was lower income per bus. Bus operators compensated by raising fares almost 200 percent in real terms between 1979 and 1990.[26]

Not only did deregulation lead to shrinking market share and higher bus fares, it also led to poor safety conditions, increased air pollution, and heavy traffic congestion. Safety deteriorated due to aging vehicles, deferred maintenance, and fierce competition between operators to pick up passengers. Air pollution increased in part because of deferred maintenance and use of older diesel buses. Traffic congestion worsened as a result of the additional buses and their often erratic jockeying for passengers. Overall, the image of the bus system deteriorated and, consequently, the popularity of cars increased. According to one observer, bus service

> had fallen entirely under the control of an entrepreneurial cartel that controlled prices and governed competition. Excess capacity had developed, estimated in the range of 35-40 percent, while large and small buses displayed a scandalous level of obsolescence and deterioration. Visible exhaust emissions were so notorious that the urgent need for strong intervention by the Ministry of Transport was clear.[27]

Local authorities responded in 1990 with a new innovation: route tenders. In areas with serious congestion or pollution, transit operators had to apply for concessions to operate with specified frequencies on designated routes. The authorities grant exclusive service rights to operators for a given period of time (three years, for example). In return, concessionaires contract to meet operating requirements, technological standards, and management procedures established as part of the public tender. There is no financial bid offered; assignment is based solely on fares and service level commitments. The authorities determine the point of origin and destination of tendered routes. Outside of the regulated areas, competition is open to all, and operators are allowed to determine the routes and frequencies that they prefer. Bus service dropped dramatically on affected routes, as intended. Along Avenida Libertador Bernardo O'Higgins, Santiago's main street, the number of buses dropped from 1,200 per hour in March 1990 to 550 per hour after the tender.[28] To date, there have been four tenders in Santiago: in 1990, 1992, 1994, and 1998.

In 1997, the bus system consisted of 354 bus routes, of which 311 were tendered, plus another 22 tendered Metrobus routes (buses connecting to the Metro).[29] In 1999, there were about 9,000 buses, of which 8,700 ran along tendered routes, all using diesel engines. The average age for buses within the tender system is now only four years. The tender process required an additional private investment of over U.S.$500 million, with no state subsidies. It has resulted in a modern bus fleet with a uniform appearance, better working conditions for drivers, and improved safety conditions for users. The tender process also ended political conflicts associated with fare increases. With the introduction of a transparent fare calculation formula, fares came to reflect real transportation costs more closely. The only apparent downsides to the tender process are reduced frequency of service in the targeted areas and increased congestion resulting from a concentration of buses along some routes just outside the areas with tendered routes.

The principal government investment in buses has been in dedicated bus lanes. In 1995, five kilometers of segregated bus lanes were built. In 2000, substantial bus-only lanes were established along some important transportation corridors, in particular Alameda, the most important transportation corridor in the city.

Santiago is also served by a modern rail transit system. Construction of the first Metro line began in 1969. It was inaugurated in 1975, followed by two more, the most recent completed in 2000. The Metro system now includes 40 kilometers of rail lines and 52 stations. Ridership continues to increase, reaching almost 200 million passengers in 1998.

Modern rail systems are expensive and often criticized as extravagances, even for very dense cities. Indeed, the stretch of rail built in the 1990s cost over U.S.$370 million, and was the largest public infrastructure project carried out in Chile during the decade.[30] However, the Santiago Metro is among the more successful in the world. While construction was paid for by the government, the system is now one of the world's few rail passenger systems that does not require government subsidies to operate.

No modern Metro system, including Santiago's, is known to have recovered construction and capital costs through its operating revenues. Few recover even operating costs, though Santiago does. Others include Hong Kong and Manila. The financial success of Santiago's system is due to a variety of factors. First, there is a deliberate policy to keep fares relatively high to recover costs, rather than keeping them low to serve the very poor. Second, Santiago maintains a limited network that serves mostly densely populated areas. Third, the Santiago system is apparently well managed and entrepeneurial, e.g., making agressive efforts to generate revenue by selling advertising on the trains and in stations.[31]

Connecting to the Metro are twenty-two Metrobus lines with a fleet of over 600 buses. They are intended to serve as feeders to the Metro. The Metro sells discounted Metrobus tickets and shares the income with Metrobus operators. This program has been relatively successful at the stations located at the end of rail lines, but less so at stations along the line. In most corridors, buses continue to operate in competition with the Metro system. The Metro rail system serves 5 percent of total urban trips[32] and the Metrobus another 1 percent.[33] Regular (non-Metrobus) buses serve almost half of all trips.

Colectivos and Taxis in Santiago

Colectivos and taxis serve the gap between private cars and fixed-route, fixed-schedule transit (i.e., buses and rail transit). Santiago has a large number of taxis. Until 1978, the number of taxis was regulated by the Ministry of Transport and Telecommunications. In 1978, as part of the economic liberalization plan, limits on the number of taxis were lifted. In 1984, Greater Santiago had over 25,000 taxis, one for every 160 inhabitants.[34] By 1996, it had over 50,000 taxis, one for every 100 inhabitants. In 1997, at the suggestion of CONAMA, the number of taxis in Greater Santiago was frozen to allow time to review their impact on urban pollution problems. The taxi fleet remains frozen at that number.

Colectivos are a taxi-like, paratransit service that operates along fixed routes, using cars that carry up to five passengers (see Figure 4). Colectivo services began as an experiment in 1967, with 380 vehicles covering 19 routes. Since then, they have continued to expand, providing an intermediate service between taxis and buses. They offer faster travel than buses at about twice the price. Colectivos tend to connect underground Metro stations with residential neighborhoods. In 1996, there were about 150 colectivo routes, all privately owned and operated.

In February 1991, the Transport Ministry banned colectivos from Avenida Libertador Bernardo O'Higgins in an attempt to reduce traffic congestion along this congested route. An implicit goal of this

Figure 4

A Colectivo and Driver in Santiago

Photo by Raúl O'Ryan, Universidad de Chile

measure was to demonstrate that the route tender system begun in 1990 was not directed solely at buses.[35]

Cars in Santiago

The ownership and use of cars in Santiago has increased substantially in the last 30 years.[36] In 1966, less than 50,000 cars were owned by the 2.4 million residents of Greater Santiago – roughly 20 per 1,000 inhabitants. This rate was relatively low, even when compared to other developing country cities of that time, including Teheran (44 per thousand) and Manila (77 per thousand). That year, just 7.6 percent of total trips were made by car. Car ownership was low in large part because of the heavy import taxes in effect at that time. But even with heavy taxes, the car population steadily increased. By 1977, Santiago had 208,000 cars, roughly 60 per thousand inhabitants, with cars representing 9.8 percent of all trips.

High import taxes remained in place as a means of supporting Chile's ultimately unsuccessful attempt to build a domestic auto industry. A number of local companies imported parts and car kits and assembled them in Chile during the 1960s and 1970s. When the economy was opened in the late 1970s, these nascent companies largely disappeared. No cars are produced today in Chile (though some are assembled from imported kits).

Import restrictions on cars were eliminated during the late 1970s and early 1980s, resulting in access to cheaper and better cars. From 1977 to 1991, the population rose 30 percent, while the number of cars increased by 94 percent, resulting in 90 cars per thousand inhabitants. This trend has continued, with Santiago's rate reaching 129 cars per thousand in 1998. This motorization rate is low compared to cities in developed countries, but the number of vehicles has continued to increase at a rate close to 10 percent per year in recent years.

B. Interurban

The principal modes of interurban passenger transportation in Chile are car, bus, rail, and airplane; and the principal interurban freight modes are truck, rail, and ship. Data are sparse and uneven for interurban transportation, but it is clear that major transformations have occurred over the past few decades. At present, cars transport about 61 million interurban passengers per year (49 percent), followed closely by buses (42 percent), with trains (6 percent) and air travel (3 percent) accounting for the remainder.[37]

Table 7 presents overall trends in intercity passenger transportation using available data during the last decade.[38] As indicated in the table, the mode share of bus travel has been steadily decreasing as the car increases in importance. Between 1990 and 1998 the number of cars passing through interurban toll booths increased by 88 percent, reflecting the increase in total passengers transported by this mode. The number of passengers on buses and rail stagnated in the same period. The largest percentage increase was in domestic airline travel, with average increases of over 18 percent per year in domestic flights. While data are unreliable, it appears that in the mid- to late-1990s cars caught up with buses in the number of passengers transported, and are now becoming steadily more important.

Reliable freight transportation figures are generally lacking and numbers are not readily comparable. Also, good historical data are not available for tonnes and tonne-kilometers transported by trucks, the most important mode.

Table 7

Interurban Travel in Chile, passengers per year (1990-1998)

				Airplane	
Year	**Cars***	**Bus****	**Rail****	**Domestic**	**International*****
1990	7,716,063	47,257,664	8,822,537	855,579	1,053,599
1994	10,679,462	59,977,479	10,202,513	1,789,851	1,888,710
1995	12,223,193	56,930,005	10,085,973	1,997,029	1,067,979
1998	14,501,392	51,173,921	7,305,354	3,326,589	1,517,588

*Number of vehicles passing through the following tollbooths: Cristo Redentor, Las Vegas, Quinta, Quepe, Angostura, Zapata, Lampa, Perquilauquén, Lo Prado, Chaimávida and Chacabuco.
**Tickets sold each year.
***Only considers national enterprises; information not available for other international carriers.
Sources: "Anuario Estadístico," years 1990, 1994, 1998, INE.

With these caveats, available information suggests that trucks are by far the most important mode of interurban freight transportation. According to the Ministry of Public Works, 86 percent of total cargo is transported by trucks, almost eight times more than ships, the second most common freight carrier.[39] The remaining freight is handled by rail and air transportation.

Table 8 presents some important trends. Coastal shipments within the country have been relatively constant at around 16-20 million tonnes per year. The same is true for trains. Air cargo shipments are increasing sharply, but the absolute quantity shipped is small.

Table 8

Freight Transportation by Mode (1960-1998)

		Air (tonne-kilometers)**		Domestic Ships (tonnes)
Year	Rail (tonnes)	National	International*	Total
1960	9,868,000	–	–	19,891,000
1970	13,967,000	–	–	–
1980	16,961,000	–	–	20,282,117
1990	19,134,000	–	–	16,686,676
1996	18,215,482	23,359	181,766	16,156,786
1998	20,634,277	29,709	229,910	17,037,094

*Includes cargo loaded and unloaded.
**Data are not available before 1996. International air cargo is transported by domestic and foreign airlines.
Source: Instituto Nacional de Estadísticas, 1999, "Anuario de Transporte y Comunicaciones," Santiago; and Instituto Nacional de Estadísticas, 1998, "Compendio Estadístico 1998."

Freight and Passenger Railroads

Though railroads were important both for passenger and freight transportation in the middle of the 20th century, their role declined as cars and trucks became more important.

The first trains in Chile were privately owned and used for mining in the north of Chile, beginning in 1851. When various mines stopped or slowed production during the first half of the 20th century due to low international commodity prices, the state acquired the lines and created the state-owned system, *Ferrocarriles del Estado*. The government used the rail system for political, economic, and social objectives to integrate the country and catalyze development of remote regions. By the 1920s, it connected Iquique in the far north to Puerto Montt in the south. Though initially most of the train system was private (60 percent in 1890), by 1975 almost 88 percent was in state hands.

Even with government subsidies for the railroads, road transportation continually increased its share of both passenger and freight travel. The state-owned rail company did not operate like a business. For example, Ferrocarriles del Estado served remote locations in the north, operating passenger trains until the 1970s, well after privately-owned cargo trains had ceased service to these areas. It had 25,000 employees, and owned its own hospital, funeral parlor, and a variety of other ancillary services for employees. Even with substantial subsidies, the quality of rail service steadily declined under state-operated management.

During the period of market reforms by the military government (1973-90), rail maintenance and capital investments were deferred, operating subsidies were reduced drastically, and 22 passenger routes were eliminated. By 1990, only a few profitable passenger routes remained. The number of freight lines was also reduced, but considerable cargo continued to be shipped by rail. Rail shipments of minerals in the north and a variety of products in the center and south were still profitable, despite deteriorated track and equipment.

The democratic government elected in 1990 was more sympathetic to rail transportation. Their policy was to maintain state ownership of passenger rail systems (understanding that privatization was not possible without large public subsidies estimated at U.S.$140-150 million) and to privatize freight rail lines.

The government spent U.S.$28 million to improve tracks close to Santiago and between two other cities, and additional funds for modern suburban (Metrotren) passenger services. On targeted routes, the deterioriation of the passenger train system was reversed, with significant increases in ridership. In freight transportation, by 1997, the government had sold the train network just north of Santiago and, in the south, had sold the right to use the tracks (rather than the tracks themselves). Freight traffic stabilized in the north and passenger travel increased in the south. It is widely viewed that the decline in rail service has been halted, and that both passenger ridership and freight service are starting to expand, albeit slowly.

Along with an extensive domestic rail network, five international rail lines have connected Chile with Perú, Bolivia, and Argentina, with varied degrees of success. The only line to Perú is not profitable and is maintained for political reasons, as is a line to La Paz, Bolivia, built in 1913.[40] A line to Argentina from central Chile ended passenger transportation in 1979 and freight in 1984. However, a line carrying minerals to Bolivia is highly profitable, and a line linking the north of Chile and Argentina is still active and transporting cargo.

Interurban Passenger Buses

In the 1970s, the bus system was transformed from a heavily regulated sector to a competitive, deregulated service.[41] Until the mid-1970s, the government controlled the bus sector through three principal instruments: the granting of a specific concession for a specific bus service, the setting of passenger fares, and rigid control of the import and sale of buses. Holders of concessions were free to increase the frequency of their services, and maximum passenger fares were fixed nationally, based on the class of service, route length, and road condition (paved or unpaved). In August 1978, the government eliminated fare controls and in November 1979 it opened the market to new companies.

The interurban bus sector in Chile has been dominated by large companies. Their large size and financial resources enabled these companies to survive economic downturns, such as that of 1982, even under deregulation. They offer diverse services with relatively stable fares. The industry has remained relatively stable as a result.

Trucking

The trucking industry has been less stable than interurban buses. Trucking became increasingly important in the 1960s as highways expanded and were upgraded. Like bus services, trucking was heavily regulated until the mid-1970s. In 1977, the military government began a process of deregulation and encouraged imports of trucks. Trucking boomed. Between 1977 and 1981, the number of imported trucks increased 450 percent.

This boom was also favored by an overvalued peso that resulted in fairly low investment and operating costs. In 1982, Chile (and the rest of Latin America) went into a severe recession. Growth had been dependent on significant inflows of foreign capital that suddenly stopped as investors began seeking more secure countries (i.e., those with lower foreign debt) in which to place their money. The Chilean peso was severely devalued. As a result, the dollar-denominated debts of truck owners doubled in a short period, and domestic fuel and parts prices increased substantially. Due to the magnitude of the recession –

a 14 percent fall in GNP in 1982 - demand for trucking fell an estimated 70 percent for trucks of more than 11 tonne capacity. Consequently, thousands of truckers were unable to meet their financial obligations. The government intervened in 1984, creating a credit agency that helped reschedule debts. However, the excess capacity was not addressed and truck operators continued to operate at a loss in many markets. After 1984 and especially during the 1990s, strong economic growth eased the problems of the trucking sector, though many operators are still burdened by old debt payments that they continue to renegotiate.

Truck operators and their vehicles have become more specialized and dedicated to specific services, such as the transportation of fruit or forestry products. Larger, better organized, and more professional trucking companies have emerged. However, the sector is still atomized. On average, operators own fewer than three trucks, and many own just one.

The net result of these events has been a large increase in trucking activity. The number of large long-haul trucks passing through toll booths nearly tripled between 1985 and 1998 – from 359,000 to 1,077,000 – and the number of smaller trucks doubled.[42]

Ocean Shipping

Foreign trade represents a large fraction of Chile's GDP. Since most Chilean exports consist of natural resources and their derivatives, both of which are bulky, and since Chile is geographically isolated from its main markets, much of its exports are shipped by sea. Similarly, many imports are heavy goods, such as cars and oil, that are also transported by ship. Hence, seaports play an important role in the Chilean economy.

The management of ports, like many other government activities, was reorganized during the 1980s. Until 1981, Chilean ports were operated inefficiently by the state. In 1981, a new law allowed private firms to enter the business of handling and moving goods at ports. Port ownership is now mixed – ten are state-owned and 22 privately owned – but all are privately operated.

Ocean shipping over the next 15 years is expected to increase sixfold, requiring port infrastructure investments of over U.S.$1 billion.[43] Most of this increase in traffic will come from international trade, since domestic coastal shipments of freight are expected to remain relatively constant.

Transportation Infrastructure

Chile invested relatively little in transportation infrastructure during the 1970s and 1980s. During these two decades, Chile's population increased 40 percent and economic activity 60 percent, yet total investment by the Ministry of Public Works *decreased* by 34 percent. In 1990, the new government addressed the infrastructure deficit through increased public investment and an ambitious franchising program.[44]

Under the franchising program, the private firm that wins the concession contract builds and finances the infrastructure project, and then collects user fees for a specified period of time. In 1991, the Chilean Congress passed a law allowing the state to franchise almost any public work, including roads, ports, and airports.

As a result, all of Chile's main highways are now built, financed, and operated by private firms. Between 1993 and 1998, 14 highway projects were franchised representing an investment of over U.S.$3 billion. Another 135 infrastructure proposals, mostly highway franchises, have been filed by private firms: 100 of these have been rejected and nine approved. It is expected that smaller highways and urban roads will be franchised in the future.

Truckers initially opposed paying tolls on these privatized roads, claiming it would be too costly for them. The conflict was resolved in April 2000, with truckers agreeing to pay tolls in exchange for a 50 percent reduction in diesel fuel taxes.

Private investments in infrastructure increased from zero in 1990 (excluding ports where private investments were already significant) to U.S.$700 million in 1999, and now roughly equal public investments. Total annual public and private investment is about six times greater than in 1990. Chile now has over 16,000 kilometers of paved interurban roads, almost 60 percent more than a decade earlier.

Table 9 summarizes investments in roads, airports, and ports through the 1990s. Most of the investment has been for roads. More than U.S.$2 billion of the U.S.$3 billion private investment in roads is being committed to repave and add lanes to Route 5, the 1,500 kilometer north-south highway. Improvements are also being made to Chile's 15 major airports, in particular Santiago's International Airport, primarily with investments from the private sector. The main seaports have also been improved and a new port was built in Punta Arenas, the country's southernmost seaport.

Table 9

Investment in Roads, Ports, and Airports in the 1990s (Million U.S.$)

Mode	1990	1994	1999
Roads	209.0	446.8*	1,188.7**
Ports***	3.4	30.8	21.2
Airports	5.1	10.4	59.3****
TOTAL	226.0	480.1	1,257.7

*3.7 percent of this was from private sector funds.
**54.6 percent was from private sector funds.
***Data are for state-owned ports only.
****83.2 percent of this was from private sector funds.
Source: "La década de la infraestructura 1990-1999," Ministerio de Obras Públicas.

With more private highway investment, the Ministry of Public Works has been able to invest in other facilities that are not likely to be profitable. Public funds have been used to finance roads along the coast and Andean foothills and to build a number of roads that improve connections with other countries.

Summary

The market is the principal force shaping the expanding interurban transportation system, particularly since the deregulation and privatization of the 1980s. A large share of services and infrastructure has been transferred to private ownership and control. Freight trains, trucks, and interurban buses are now completely private. Those services that could not compete have been discontinued or curtailed. Passenger train service has been curtailed, though the government is financing equipment for use on shorter suburban routes. The deregulated bus system is losing ground to cars but continues to offer a range of services at fares that cover costs. Importantly, Chile has found in the franchising system a powerful mechanism to finance many important infrastructure projects.

III. Policies and Strategies

Serious traffic congestion and air quality problems in Santiago have motivated increasingly aggressive government responses. It can be expected that more measures will be taken. In other large and mid-size cities in Chile, congestion problems are beginning to be tackled. Perhaps the most remarkable aspect of Chile's transportation system is the small role public finance plays. Most interurban roads and most bus services have been privatized and urban rail (Metro) operations are financed out of the fare box. Further privatization of infrastructure and services and the use of fees and other market instruments to deal with transportation challenges are at the forefront of public debate.

A. Santiago

Rapid growth in vehicle usage began to create significant traffic congestion and air quality problems during the 1980s in Santiago. In 1986, the city government responded by restricting the use of some vehicles on polluted days. On each of 22 polluted days, one-fifth of buses, taxis, and cars were banned from traveling in much of the municipal area. Restrictions were based on the last number on the license plate. Though initially planned as an emergency measure, it has become permanent. The area covered by the restriction has increased and it is currently applied nine months every year to cars without catalytic converters[45] (which in 1986 included virtually all vehicles). On especially severe pollution days the restriction is extended to more license plate numbers and more hours. On emergency days, 80 percent of non-catalyst equipped vehicles (approximately 40 percent of the car fleet in 2000) are banned. The restriction has become increasingly controversial because its environmental effect diminished as catalytic converters became more common and because it disproportionately burdened lower-income households that could not afford new catalyst-equipped cars. In 2001, restrictions were applied for the first time to catalyst-equipped cars. There has been no evaluation of the effectiveness of the measure. As indicated above, pollution from buses was also becoming a major concern in the 1980s.

In 1990 the democratic national government directly confronted the air pollution problem. The newly created Special Commission for Decontamination of the Metropolitan Region adopted a master plan that targeted buses and cars. As a result, older buses were scrapped,[46] increasingly stringent emission standards were imposed on new buses, only the cleaner new buses were allowed on the city's main routes, and improved enforcement measures were implemented. New cars from 1992 onwards were also required to meet tight exhaust emissions standards (achievable only with catalytic converters), vehicle emissions inspections were implemented, and street paving and cleaning were increased to reduce dust and particulate matter. The measures were quite extraordinary and were effective at restraining escalating pollution and congestion problems.

Urban Transportation Plans for Santiago

At the end of 1995, SECTRA mounted a large transportation study to develop a 15-year plan for Santiago. Mathematical models were developed to study changes in infrastructure, land use, and a variety of financing and market instruments. The resulting Development Plan for the Urban Transportation System elaborated a base case scenario for 1997-98, which incorporated projects and road improvements programmed as of 1995. An important goal of the plan was to maintain the split between transportation modes at current levels – that is, to restrain car use. The Development Plan included a long list of recommendations, including proposals for more roads, dedicated lanes for buses, and rail transit lines, and the imposition of a number of taxes and fees. These recommended market instruments included a fee of U.S.$4 to enter the city center during peak morning hours for all vehicles except buses; a road-use charge varying between U.S.$0.12 and $4 per kilometer depending on location beginning in 2005; parking fees according to trip purpose (work, study, or other) and length of stay; sale of operating concessions to bus companies on bus lanes to raise funds for the bus lanes; and integrated transit fares for buses and the Metro.

If the Development Plan were implemented, it was estimated that average speeds for private transportation would fall from 25 kilometers per hour in 1991 to 20 kilometers per hour in 2005 and public transportation speeds would rise from 16 to 19 kilometers per hour.

The plan was to be financed by income from road fees, charges to public transportation operators using bus lanes, and contributions from public funds. The cost of the investment plan was U.S.$2.8 billion, well above financing for previous programs for the city of Santiago.

However, none of the proposed market instruments have been adopted and the only significant investment has been the building of Line 5 of the Metro. Road pricing was specifically rejected by politicians, as it was perceived to be highly unpopular, especially among the voting and vocal middle and upper income groups. As environmental conditions worsen and the economy expands, there is reason to believe that many of the recommended investments and market instruments will eventually be adopted. The main initiative during the past few years has been the further development of the route tendering process that will consider environmental as well as transportation factors.

In 2000, SECTRA released a new Urban Transport Development Plan for Santiago. The goals of this plan are to maintain the current share of trips taken on public transportation; reduce the average length of trips; promote non-motorized trips; and ensure that users pay the true costs of transportation. In addition to proposing incentives for increasing the use of public transportation and restraining car use, and strategies to use land more efficiently, the plan calls for a reorganization of the transportation system and more engagement by non-governmental organizations.

Air Pollution Prevention and Decontamination Plan (APPDP)[47]

Santiago is one of the most highly polluted cities in the world.[48] In August 1996, the Greater Santiago region was declared a saturated zone – exceeding ambient standards for particulates, ozone, and carbon monoxide (based on World Health Organization standards).

Santiago's pollution problem is exacerbated in winter by surrounding hills that prevent the circulation of air masses and lead to thermal inversions that trap pollutants near the ground – much like Mexico City and Los Angeles. Santiago's inhabitants suffer from particulate pollution in autumn and winter, and high ozone levels in spring and summer. Short- and long-term health effects have been documented, including mortality and morbidity related to particulates.[49] The transportation system is the primary source of Santiago's air pollution. Mobile sources contribute 92 percent of the city's carbon monoxide emissions (CO), 71 percent of nitrogen oxides (NO_x) and 46 percent of volatile organic compounds (VOCs). The latter two are precursors to photochemical ozone formation. Transportation is directly responsible for only 7 percent of particulate emissions, but vehicles also stir up large amounts of dust, which is the principal source of the smallest and most health-threatening particles (as it is in the United States and elsewhere). Buses are believed to be the principal source of these particles and, because they operate in dense population areas and directly expose many people to pollution, are believed to cause the greatest health hazard. Buses are also a major source of NO_x, while cars are major sources of CO, NO_x, and VOCs.[50]

The government is mounting increasingly effective efforts to reduce pollution. In June 1998, the regional Environmental Commission launched the Greater Santiago Air Pollution Prevention and Decontamination Plan (APPDP). This umbrella plan developed 54 specific measures. The planning process involved many government agencies and more than 300 representatives of non-governmental organizations, business, government, and academia. In transportation, four overall strategies were proposed:

1) Reduce emissions per vehicle;

2) Reduce emissions from activities related to freight and passenger transportation;

3) Incorporate environmental variables in transportation planning; and

4) Avoid new motorized trips.

An implementation schedule was designed for each measure, and compliance and enforcement responsibilities were assigned. The goal was to meet air quality standards by 2011. The overall cost for these measures, for those that could be quantified, was about U.S.$1 billion, but there were many other measures that had not been sufficiently specified to be quantified in monetary terms.[51]

After two years, due to financal limitations and political resistance, less than half of the measures scheduled for implementation had in fact been adopted or advanced.[52] Those that have been implemented are the easiest and least expensive to adopt – primarily low cost technological changes that had relatively little impact. The most important success may have been tightened emission standards for buses (equivalent to the United States' 1994 bus standards). However, fuel changes were delayed due to resistance by the state-owned oil company. Road user fees also were not adopted, and parking fees were only sporadically applied. Most infrastructure initiatives, such as expanding the number of designated bus-only lanes, were ignored during this time.

However, in June 2000, an emergency plan was adopted[53] that reflects the growing willingness and capacity to implement significant new measures. On days with severe pollution, cars are banned from six important arterial lanes, and only buses, colectivos, and taxis are allowed. Those lanes comprise 105 kilometers, and 80 percent of all bus lines circulate on these lanes. The results have been significant. Travel times for bus passengers were reduced between 5 and 45 percent on the main arteries, averaging a 38 percent reduction in travel times on buses. Car travel time did not increase since fewer cars circulated with less congestion. Metro ridership increased by 10 percent and emissions were estimated to fall by 20 percent, and savings due to less travel time and less fuel consumption were estimated to be U.S.$50,000 per day.[54] Based on these successes, the Transport Ministry decided in 2001 to make the dedicated lanes for buses, taxis, and colectivos permanent, and to create additional dedicated bus lanes on Alameda and along two other main arteries.

Another initiative has been the testing of natural gas in buses. The government offered a subsidy to the first 40 buses to convert from diesel to natural gas, since natural gas buses cost considerably more than diesel buses. Operators, skeptical of the economics of natural gas buses, have not embraced the vehicles.

Continued advances in reducing Santiago's air pollution depend strongly on the relationship between environmental policymakers in CONAMA and government agencies that oversee transportation activities, and on support from businesses and voters. Improved air quality – and reduced traffic congestion and GHG emissions – will often require behavioral adaptation and acceptance of extra costs by some travelers and interest groups. Considerable political and educational effort is necessary to effect change.

Major Public Initiatives and Forces of Change in Urban Areas

Santiago and other smaller cities in Chile are expanding rapidly. This growth is occurring along several dimensions that have direct effects on energy use and GHG emissions. Major public initiatives and forces of change in urban areas are:

1. *Car ownership.* A major driver of change for the transportation system is car ownership (and use). Because Chile's economy is expected to grow at close to 6 percent per year, the car population is likely to double every ten years.[55]

2. *Traffic congestion.* Public pressure for traffic solutions is mounting in Santiago and other cities. The Development Plan for the Urban Transportation System was a first – albeit limited – response. The route tendering program has been important. Exclusive bus lanes and road management schemes, including reversible lanes, have also proved effective. Further implementation of the measures recommended in the Development Plan will be required as car use increases. Minicars, half the size of conventional sedans, are one possible additional change. They require less parking and road space, consume less energy, produce fewer GHG emissions, and are less expensive than full-size cars. Overall, improved traffic management and increased support of public transit are needed.

3. *Environmental stress.* Santiago's air pollution is motivating efforts to restrain vehicle use and enhance public transportation. However, if the current political environment and institutional framework remain, change will be slow. The most politically feasible options are based on introducing new technologies, especially to reduce emissions from vehicles. Environmental technology standards introduced in Santiago, such as catalytic converters, may rapidly spread to other cities.

4. *Urban form and governance in Santiago.* The city is not well integrated in terms of infrastructure or governance. There is growing concern, for a variety of economic, environmental, and political reasons, that growth must be better managed. The national Housing Ministry aims to contain growth within the city limits so that the city center remains densely populated. The national government also intends to encourage better transportation connections between suburban centers and Santiago. However, the tools for controlling urban sprawl are limited and the real estate industry and large land owners are powerful.

Initiatives to address these phenomena are not motivated by climate change concerns. But responses to other phenomena, especially traffic congestion, pollution, and urban sprawl, are largely consistent with restraining GHG emissions.

The types of policies and measures that could gain widespread support and could have a significant effect on reducing GHGs are likely to be those premised on market principles, coupled with more traditional government responses. The principal motivations would be to reduce urban air pollution and traffic congestion. These strategies include the following:

- *Introducing new and enhanced technology,* including conversion of urban buses from diesel to hydrogen fuel cell, and use of natural gas and small battery-powered electric cars. This strategy may be promising in Chile, because Argentina and Bolivia, neighbors of Chile, have plentiful natural gas. Natural gas can be used in internal combustion engines, and can be converted into hydrogen for use in fuel cells.

- *Improving public transportation,* including through the use of integrated bus routing and fare structures, exclusive bus lanes, more comfortable buses, significant expansion of suburban trains, and expanded Metro service.

- *Encouraging smaller cars and alternatives to car use,* including through the use of parking restrictions, road fees, and the elimination of tax incentives for larger, inefficient cars and light duty vehicles.

B. Interurban

From a policy perspective, the main problem relating to interurban transportation in Chile has been inadequate road, rail, port, and airport infrastructure. Consequently most of the current efforts in interurban transportation planning are devoted to increasing and improving this infrastructure. As opposed to the urban setting, where air pollution and congestion problems are driving policy responses that are generally consistent with GHG reduction strategies, interurban transportation policy responses, except a general support for rail transportation, will not promote better environmental stewardship.

The franchising system will continue to be used to increase and enhance infrastructure. Since the main interurban roads have already been franchised, less heavily used routes will be next, together with some international routes and major bridges, though lower traffic levels on those facilities suggests that additional franchising will be limited. Urban road franchises are another application being pursued,[56] and the franchising of road maintenance is being studied. Additionally, franchising suburban train and airport services has also been considered.

As indicated earlier, these franchising operations will in principle, and perhaps in practice, allow reallocation of resources to transportation investments that are less commercially viable but of great societal importance – including urban transportation infrastructure, both for cars and buses, and development of the coastal and mountainous routes, parallel to Route 5, Chile's main interurban artery.

A thorny problem recently settled was the charge to trucks for the use of road infrastructure. The strong Confederation of Truck Owners opposed this charge on the grounds that an existing tax on diesel fuel had been justified to finance road infrastructure, and they were therefore being charged twice. In April 2000, an agreement was reached whereby truck owners accepted road tolls in exchange for a reduction of taxes on diesel fuel. Taxes are to be reduced over five years to half their previous level (from 40 percent to 20 percent), as tolls go into operation on the franchised roads.

Large new railroad projects, though periodically debated, do not seem to be commercially viable or to serve important unmet needs, so will most probably not be expanded in the near future. It is expected that the only enhancements will be by the private sector, making only incremental improvements on selected cargo-carrying lines.

The efforts of the State-owned *Empresa de Ferrocarriles del Estado* (EFE) (which supplanted the government's earlier company, Ferrocarriles del Estado, in 1986) are more ambitious for the center and south of Chile. The most probable scenario for the next five years includes the consolidation of the three suburban trains in operation under EFE, development of new suburban trains, and the modernization and improvement of the longer route between Santiago and Temuco (a mid-size city 680 kilometers south of Santiago). The concession law, passed to promote the private operation of publicly owned infrastructure, is expected to be used to finance the suburban train service between Santiago and Melipilla, and to Til-Til. These trains could absorb significant increases in suburban travel between these locations and Santiago. In the longer term, this scenario could evolve into a system where EFE acts as superintendent of rail transportation establishing standards, maintaining, improving and extending rail infrastructure, and administering transportation contracts. Additionally, it might offer some transportation services, but these would be limited, with preference given to private operators and concessionaires.

Market forces are expected to continue to play a dominant role in interurban transportation services. In freight, private truck operations will continue to expand into the future. Trucking services will become more specialized, serving specific sectors. Trucks will become larger and will transport ever-larger volumes of freight. Being more flexible and reliable than rail, they will continue to compete with trains for many goods, even in long distance routes.

The car will clearly strengthen its role as the most important interurban passenger transportation mode. The bus system will most probably maintain its current size, while passenger trains perhaps will be competitive on some of the shorter routes. Passenger travel by airplane will continue to increase in importance.

IV. Scenarios for the Future

Chile has relatively high per capita GHG emissions. Chile's economy and transportation system are expanding and evolving rapidly. As indicated above, this development has been shaped by market forces, and only recently have concerns about associated externalities begun to be translated into specific environmental and sectoral policies. The strongest concerns are related to urban pollution and traffic congestion. The questions addressed here are whether current trends will continue and, if so, the implications for GHG emissions and what can be done about them.

A. Energy Use and Greenhouse Gas Emissions in 2000

Energy consumption by the transportation sector is increasing at a very high rate, tripling from 1985 to 1998. The increases cut across both passenger and freight, and urban and interurban transportation. Passenger travel now consumes about twice as much energy as freight travel, and the energy split between urban and interurban travel is about 42 percent versus 58 percent. The main energy consuming modes are cars (43 percent), trucks (24 percent), ships (13 percent), buses (10 percent), and airplanes (10 percent). Trains consume less than 1 percent.

Almost all the energy consumed in the transportation sector is derived from petroleum. The principal transportation fuels are gasoline and diesel fuel, each accounting for over 40 percent of the total.[57] Gasoline is used by almost all personal cars, and by most light and medium duty commercial vehicles. Most taxis use gasoline, but a few use diesel and, in the far south where there are large natural gas fields, some use natural gas. Buses and large freight trucks burn diesel. The urban rail system uses electricity, interurban trains use both diesel and electricity, and ships use diesel and heavy petroleum fuels. Over 99 percent of energy used for transportation in Chile is derived from petroleum, 95 percent of which is imported.

Reducing oil imports and GHG emissions is neither a priority nor a major public issue in Chile. Chile did, however, ratify the United Nations Framework Convention on Climate Change in 1994. This Convention requires that developing countries report on GHG emissions for a reference year. In response to this requirement, CONAMA prepared an inventory of GHGs for Chile for the year 1994.[58] Transportation was found to be responsible for 35 percent of total energy sector emissions.[59] Subsequent international studies listed in Table 10 report a somewhat lower estimate (28 percent).

Table 10

CO_2 Emissions for Various Countries (1998)

Country	CO_2 Emissions Per Capita from Transportation (kg)	Transportation Sector Percentage of Total Carbon Emissions	Cars per 1,000 People (1996)
Chile	1028	28	110
China	178	8	8
India	120	13	7
South Africa	1740*	20*	121
Japan	1971	22	552
United Kingdom	2238	24	441
United States	6082	30	769

Note: The numbers for Chile in this table are different than reported by CONAMA; the differences could not be reconciled but the cross-country comparisons are presented because they used a standard approach across countries.
Sources: International Energy Agency, 2000. *CO_2 Emissions From Fuel Combustion: 1971-1998*. Metschies, Gerhard P. May 1999. *Fuel Prices and Taxation*. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. Available at: *www.worldbank.org/html/fpd/transport/urbtrans/other/fuel.pdf*.
*The published International Energy Agency numbers for South Africa were adjusted by the authors to account for the large upstream emissions resulting from that country's conversion of coal into transportation fuels.

A more detailed analysis of GHG emissions from the transportation sector only was conducted subsequently and findings are reported in Table 11. It shows that this sector emitted 21,881 gigagrams (Gg) of CO_2 in 2000. (A gigagram is equal to 1,000 tonnes.) The relative share of GHG emissions across modes is roughly the same as for energy use, since almost all fuel is from petroleum, and the analysis considered only "tailpipe" emissions.[60]

As indicated in Table 10, Chile's transportation sector is responsible for a relatively high percentage of GHG emissions, given the country's per capita income level. While Chile produces only about one-sixth the GHGs of the United States per capita, Chile's per capita transportation-related GHG emissions are about half as great as Japan's and the United Kingdom's, which are far more affluent. Chile's relatively high per capita emissions rate (compared to other developing countries) is due largely to extensive use of trucks and the large amount of interurban freight and passenger travel, including considerable airplane travel.

Even so, Chile is a minor contributor to global climate change. Chile only has 15 million people and thus is a small net user of energy and producer of GHGs. Also, plant growth on abandoned lands and

Table 11

Chile's CO_2 Emissions (Gg) by Mode, Direct Emissions Only, 2000[61]

Mode	Urban Passenger	Urban Freight	Interurban Passenger	Interurban Freight	Total
Private cars	3,214 (15%)	-	1,544 (7%)	-	4,758 (22%)
Light duty trucks	2,046 (9%)	-	982 (4%)	-	3,028 (14%)
Taxis	2,098 (10%)	-	-	-	2,098 (10%)
Buses	1,833 (8%)	-	388 (2%)	-	2,221 (10%)
Trucks**	-	556 (3%)*	-	4,256 (19%)	4,812 (22%)
Trains	-	-	8 (0.04%)	40 (0.2%)	48 (0.2%)
Ships	-	-	-	2,867 (13%)	2,867 (13%)
Airplanes	-	-	2,049 (9%)	-	2,049 (9%)
TOTAL	9,191 (42%)	556 (3%)*	4,971 (23%)	7,163 (33%)	21,881 (100%)

*Only Santiago
**Medium and heavy duty trucks
Note: Percentages may not add to 100 due to rounding.
Source: Cifuentes, B. (2000) "Cuantificación y Proyección de Escenarios de Emisiones de Gases de Efecto Invernadero en el Sector Transporte en Chile," memoria para optar al grado de Ingeniero Civil Industrial, Universidad de Chile.

forest plantations is serving as an expanding carbon "sink," absorbing much of the CO_2 emitted from fossil fuel combustion – as much as 92 percent according to a recent estimate.[62]

B. Greenhouse Gas Emission Scenarios

GHG emission scenarios are a commonly employed technique for dealing with the complexity and uncertainty of emissions forecasting. Ideally, a researcher generates relevant information using credible research methods and objectively analyzes the data in the context of alternative scenarios of the future. The scenarios are intended to reflect plausible, but often quite contrary, descriptions of the prospective development pathways. This approach can provide a useful context for the development of "no regrets" public policy and business strategies.

Careful research on policies that are socially, economically, and environmentally desirable and attainable in Chile is needed. Further information is required regarding economic growth, potential technological improvements, and travel and vehicle purchase behavior. To capture and respond to this uncertainty and limited knowledge, two plausible GHG emissions scenarios were developed for Chile.

To generate scenarios, the authors interviewed Chilean transportation experts and political leaders, analyzed historical data, and examined various options and strategies. From this research, the authors developed two visions of the future: a "business as usual" high GHG emissions scenario and a low GHG emissions scenario. The principal difference between the scenarios is the effectiveness of efforts aimed at curbing urban air pollution and congestion by restraining vehicle use, encouraging the use of natural gas fuels and electric-drive vehicles, and improving public transportation. Since air transportation will not be affected by the proposed measures, it is not considered in the scenarios.

Fuel economy and GHG emission factors for each type of vehicle are presented in Table 12. The fuel economy parameters were used as inputs to estimate GHG parameters. The modal split, load factor, and energy use factors were converted into GHG estimates. The appendix describes the calculations of lifecycle CO_2-equivalent measures for each scenario. A detailed model developed earlier for OECD countries and other case study countries (analyzed in this series of reports on transportation in developing countries) was adapted for Chile. These estimates take into account emissions from the production and distribution of fuel as well as direct emissions from fuel combustion in vehicles.

Table 12

Greenhouse Gas Emissions for Passenger Vehicles and Fuels in Chile (life-cycle CO_2-equivalents, grams/vehicle-kilometer or grams/passenger-kilometer, as indicated)

	2000		2020	
	Fuel	GHG	Fuel	GHG
Mode	Liters/100 km	g/vehicle-km	Liters/100 km	g/vehicle-km
Gasoline cars	10.0	366	10.0	323
Diesel cars*	11.1	224	11.1	215
Natural gas cars	-	-	-	233
Electric cars	-	-	-	88
Diesel buses	50	1,603	50	1,596
Fuel Cell buses (hydrogen)	-	-	-	770
Electric minicars	-	-	-	37
Metro	-	[45 g/passenger-km]	-	[34 g/passenger-km]
Interurban train	-	[31 g/passenger-km]	-	[23 g/passenger-km]

*In Chile, diesel vehicles tend to be larger and older than gasoline cars, thus their fuel consumption is greater. In general, diesel engines are more energy efficient than gasoline engines. Energy consumption by vehicles, both diesel and gasoline, tends not to improve over time because as income levels increase, consumers desire larger engines and more accessories which offset engineering efficency improvements.

C. High Greenhouse Gas Emissions Scenario

The high GHG emissions scenario is an extrapolation of observable and emerging trends. No major new policy initiatives or public investments are incorporated. Past economic trends, rates of technological change, and behavioral patterns are assumed to continue into the future. The gradual shift toward personal vehicles and trucks continues.

Government plays a relatively passive role in this “business-as-usual” scenario. Current trends are maintained, with car and truck travel continuing to increase, and bus and most rail transportation losing market share. Traffic congestion continues to worsen. As more families become car owners, including virtually all business and government leaders, political pressure grows for more road infrastructure and fewer restrictions on vehicle purchases and use. The result is more highway development, which further encourages car use, diverts funds from public transit, and promotes pollution and urban sprawl. Even though traffic congestion, road infrastructure, and oil import costs could be deemed unacceptable, it is assumed this would not occur for several decades, beyond the 2020 horizon of this report.

The elements of this business-as-usual scenario closely follow the forecasts developed as background for this report.[63] MEPLAN, a sophisticated integrated land use and transportation model developed by the Ministry of Public Works (MOP), was used to project transportation demand.[64] The model is premised on forecasts of various economic and demographic parameters. The principal parameters used in the model – based on expert judgement of what can be expected over the next two decades – are as follows, expressed as increase per year: GDP, 5.8 percent; consumption, 5.4 percent; investment, 6.9 percent; population, 1.0 percent; and number of households, 2.2 percent. Using other business-as-usual transportation inputs adopted by the government, with additional refinement by the authors, MEPLAN was used to project passenger and freight travel for cars, trucks, and buses between 2000 and 2020, for both urban and interurban travel. The results are presented in Figures 5 and 6 and Table 13.

Passenger-kilometers in this scenario increase 141 percent between 2000 and 2020, and freight transportation increases 59 percent (shown in Figure 5 as 2.41 and 1.59, respectively). As indicated in Table 13, cars increase their share of passenger travel from 31 percent to 39 percent, largely at the expense of buses. However, most travel is still by bus (59 percent), for both urban and interurban travel. For freight, trucking accounts for over 80 percent of freight movements in 2000 and retains that percentage over time.

Figure 5

Evolution of Total Travel
in Chile 2000-2020 (Travel in 2000=1)

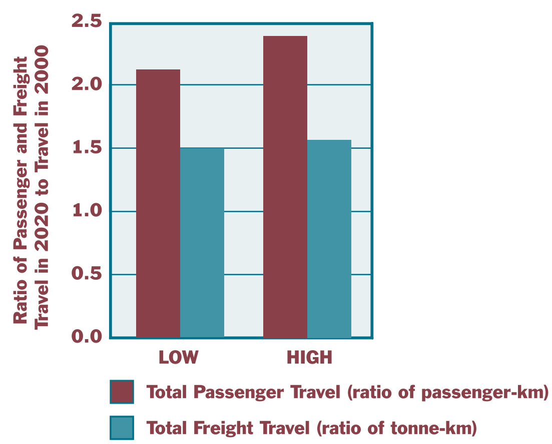
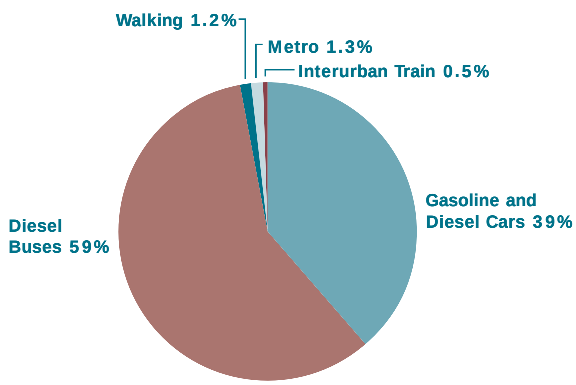


Figure 6

Mode of Travel in Passenger-kilometers, High Emissions Scenario (2020)



Based on the parameters in these two scenarios, the total GHG emissions for this high scenario are presented in Figure 7. In the period 2000-2020, total life-cycle GHG emissions increase 117 percent (shown as 2.17). Total GHG emissions per passenger-kilometer increase faster, by 149 percent (shown as 2.49), while freight emissions per tonne-kilometer increase 42 percent (shown as 1.42).

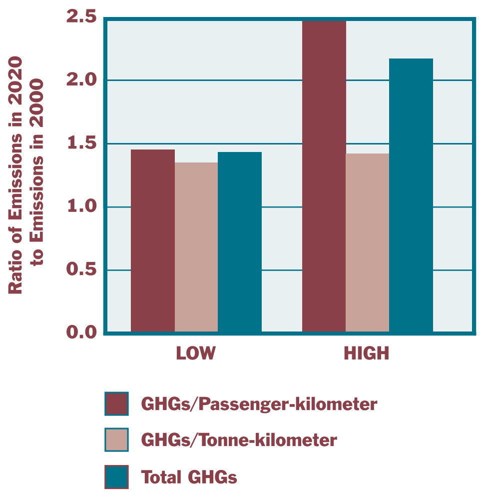
Table 13

Key Parameters for Scenarios

	2000	2020	
Passenger Transportation	**Baseline**	**Low**	**High**
Passenger Per Vehicle			
Pasenger car	1.9	1.9	1.9
Minicar	N/A	1.5	N/A
Bicycle	1.0	1.0	1.0
Bus	34.0	40.0	34.0
Average load factor (percent of seats filled)			
Metro	40	44	40
Interurban train	70	77	70
Modal Split (percent passenger-kilometers)			
Gasoline cars	29	18	35.6
Diesel cars	2	3	3
Natural gas cars	-	5	0
Electric cars	-	3	0
Electric minicars	-	5	-
Diesel buses	65	20.6	58.5
Fuel cell bus (Hydrogen)	-	42	-
Walking	2.2	1.2	1.2
Metro	1.4	1.3	1.2
Interurban train	0.7	0.9	0.5
TOTAL	100	100	100
Freight Transportation			
Modal Split (percent tonne-kilometers)			
Large (heavy duty) truck (diesel)	65	58	63
Medium duty truck (diesel)	20	18	20
Large (heavy duty) truck (CNG)	-	5	-
Medium duty truck (CNG)	-	2	-
Train (diesel)	2	2	2
Cargo ship (fuel oil)	8	9	9
Tanker (fuel oil)	3	3	3
Barge (fuel oil) and other	3	3	3
TOTAL	100	100	100

Figure 7

GHG Emissions from Passenger and Freight Transportation in Chile (2020)



The principal source of the increased GHG emissions is increased use of cars and other light duty vehicles owned by private individuals and businesses, especially in urban areas. Most of the increase in emissions from interurban transportation is due to increased use of diesel trucks.

Emissions could be higher than the estimated 117 percent increase. The transportation growth forecasts were premised on strong economic growth – an average of 5.8 percent per year. This economic growth is slower than the 7.9 percent observed between 1988 and 1998, but higher than in earlier years. With higher economic growth, there would be even higher GHG emissions. Thus, this scenario should not be considered a ceiling or maximum emissions scenario.

In summary, the high emissions scenario is one of rapid expansion in the number of vehicles, energy use, and GHG emissions. The economic cost to build more roads and import more oil, and the environmental and lifestyle costs of more traffic congestion, noise, and pollution, could be large. Whether these costs would be seen as acceptable is unknown.

D. Low Greenhouse Gas Emissions Scenario

This scenario explores a more restrained trajectory of motorization and GHG emissions. It is premised on the observation that GHG emissions are unlikely to become a salient issue in Chile in the near future, but that other related goals would be aggressively pursued. These other goals include reductions in air pollution, traffic congestion, and costly road infrastructure investments.

To construct this low-emission future, the authors have made a series of assumptions and projections. To maintain the focus on transportation and environmental variables, this scenario assumes the same economic growth rates as the high scenario. If a lower growth rate were used, as suggested by the recent economic slowdown in Chile, the motorization rate would increase more slowly and freight shipments would be reduced, resulting in lower GHG emissions.

As discussed previously, transportation trends in Chile are clear and consistent: cars and trucks are becoming more important. This low scenario is premised on restraining the growth of cars and trucks, both of which are large consumers of energy and infrastructure resources, and disproportionate producers of GHG emissions. It is important to emphasize that Chile has undertaken more structural changes in this sector in the past two decades than perhaps any other developing country.

While it is not likely that Chile would engage in another set of radical structural changes in the forseeable future, one can imagine a stronger embrace of market-based policy approaches to accomplish societal goals. The principles are straightforward: ensure that users pay the full cost of the services and facilities they use; convert fixed costs into variable costs as much as possible (so that decisions to use vehicles and roads are more sensitive to actual costs); and create market instruments to internalize the cost of externalities such as pollution and traffic congestion. Chile is already an international model in privatizing roads and transit services, and more open than most to even greater use of market approaches. A next logical step is to use market forces to ensure that transportation users receive accurate market signals about the true cost of owning and operating vehicles.

In this scenario, government is aggressive and assertive in supporting public transportation and managing motorization. Air pollution and traffic congestion, along with economic pressures to restrain road infrastructure investments, are the motivating forces. Measures taken to accomplish these goals in urban areas include parking surcharges and restrictions; road and vehicle fees based on usage and vehicle size; improved bus systems (e.g., integrated routing and fare structures, comfortable buses, exclusive rights-of-way for buses); and expanded Metro service. In response to the demand for private vehicles, the government could discourage purchases of full-size personal vehicles and encourage minicars. Because these vehicles require less parking and road space, minicars could be subject to lenient vehicle usage and parking rules. The result is greater use of buses and Metro trains, restrained growth in vehicle ownership and use, and a shift to smaller vehicles in urban areas.

The net effect of this variety of assertive public initiatives is that over a 20 year period, growth is restricted to only a slight increase in cars' share of passenger travel, from 31 percent in 2000 to 34 percent in 2020 (see Table 13). Significantly, this market share is lower than the 39 percent share in the high scenario. Additionally, operation of the bus system is improved substantially in the low scenario, with better matching of service to demand. Very low off-peak occupancy rates are increased by reducing service where ridership is especially low and offering lower off-peak fares where and when the potential exists to increase ridership. Occupancy increases from an average of 34 to 40 passengers. There is also a 10 percent reduction in total passenger-kilometers travelled, and a 5 percent reduction in freight transportation, the latter primarily due to urban restrictions.

Suburban trains gain substantially more passengers by improving service from Santiago to Temuco and Valparaíso. Consequently, instead of the projected 77 percent increase in rail passenger-kilometers between 2000 and 2020 in the high GHG scenario, rail passenger-kilometers triple (representing a 6 percent growth rate per year, much higher than the 2.9 percent rate assumed in the high scenario). Increased passenger-kilometers indicate greater access to transportation services.

In addition, under the low emission scenario, transportation authorities make a full-fledged commitment to introduce natural gas. Air pollution rules are established to encourage more use of natural gas vehicles, which have the side benefits of lowering GHG emissions and reducing demand for oil imports. Favorable taxes on natural gas are enacted, along with other supportive measures such as consumer credit, subsidies, and prohibitions on entering downtown zones with gasoline and diesel powered vehicles. Other specific measures include the large-scale conversion of urban buses to natural gas. Though this measure does not lead to GHG reductions, it has several other advantages, including reducing air pollution. First, it can create a familiar and favorable public image for natural gas vehicles. Second, it spurs creation of a natural gas distribution network in the main cities, facilitating the introduction of natural gas into other vehicle markets. And third, it provides the fuel infrastructure for making hydrogen at fuel stations. The hydrogen would be used to power fuel cell buses that are gradually introduced after 2010 (initially with international subsidies or through the Clean Development Mechanism of the Kyoto Protocol).

Hydrogen fuel cell buses have zero air pollutant emissions and much reduced energy use and GHG emissions. The United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) have launched a major program to help developing countries prepare for large-scale commercial deployment of fuel cell buses. A total of U.S.$60 million has been committed over five years. As of early

2002, the UNDP/GEF program was supporting commercial demonstrations of multiple fuel cell buses and the associated refueling systems in Beijing, Cairo, Mexico City, Delhi, São Paulo, and Shanghai. Santiago is a candidate for future support. Several manufacturers are expected to offer fuel cell buses beginning in 2003-04, with purchase prices steadily dropping thereafter.

Following the shift to natural gas buses, and concurrent with the shift to fuel cell buses, a massive shift to compressed natural gas (CNG) by taxis and light and medium duty trucks is posited, followed eventually by private cars. The GHG benefits would be large, since almost all these vehicles are converting from gasoline rather than more energy-efficient diesel. In addition, strong public policy support for air pollution reduction leads to the introduction of battery electric vehicles in cities – primarily as minicars for local travel, but also for some light and medium duty vehicles that are used for short trips within cities.

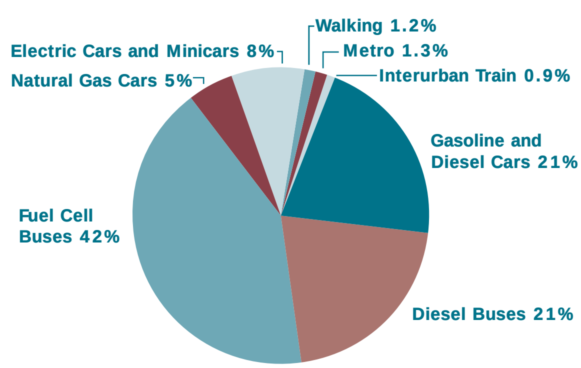
The net result by 2020 is that in urban areas, all taxis and about one-tenth of all other light and medium duty vehicles (cars and trucks) are running on CNG, and all new buses are hydrogen-fueled fuel cell buses. An additional 5 percent of private cars and 10 percent of light and medium duty commercial vehicles are battery-powered electric vehicles – with very low emissions because the electricity comes mostly from zero-emitting hydroelectricity. Also, electric minicars are introduced, reaching 5 percent of total passenger-kilometers traveled (see Figures 5 and 8, and Table 13).

In summary, the low emissions scenario is one that combines rapid diffusion of new vehicle and energy technologies with effective reduction in air pollution and urban policies that result in both lower emissions and fewer passenger-kilometers traveled. Many smaller trucks switch to natural gas and suburban trains gain market share relative to cars (see Figure 8 for mode split by passenger-kilometer).

The GHG impact of the low scenario is presented in Figure 7, expressed relative

Figure 8

Mode of Travel in Passenger-kilometers, Low Emissions Scenario (2020)



to 2000. The net effect is only a 42 percent increase in GHG emissions between 2000 and 2020 (shown as 1.42) – compared to the much greater 117 percent increase in the high scenario.

Most of the difference between the scenarios is due to changes in passenger transportation. The posited changes in the freight sector are far more modest – in part because there appear to be greater opportunities for mode shifts and less energy-intensive technologies in passenger transportation, but also because opportunties for change in the freight sector are not as well understood.

V. Conclusion

In the last twenty years, Chile's economy has transitioned from relatively slow growth to dynamic, market-oriented, rapid growth. Between 1985 and 1998, the economic output increased 2.5 times and the transportation and communications sector by more than 3.5 times. Transportation now accounts for one-third of the nation's energy use. This rapid growth is expected to continue.

The car plays a central role in determining the relationship between transportation and future GHG emissions in Chile. Cars are the key player in transportation growth, in both urban and interurban travel. Cars and other light duty vehicles account for 45 percent of Chile's total transportation-related GHG emissions, followed by trucks at 24 percent.

If current patterns prevail, as in the high emission (business-as-usual) scenario, car and truck use will continue to expand at a rapid rate, and GHG emissions will more than double. Is there another plausible future? Until relatively recently, the environmental consequences of Chile's rapid development received little scrutiny. That changed around 1990, when attention was drawn to Santiago's increasingly severe air pollution and traffic congestion (as well as pollution from copper smelters). Since 1990, the environment has become a salient policy issue, and urban transportation has been central to the debate.

How might change occur? It is important to emphasize that Chile has undertaken more structural changes in this sector in the past two decades than perhaps any other developing country. Whether it has the resources and will to pursue another set of radical changes in the near- and medium-term future remains uncertain. However, one can imagine expanded use of market-based policies to accomplish societal goals. Indeed, Chile has come to rely on market forces to guide public decisions. Most transportation services and infrastructure are now owned or managed by private companies, and market principles are being widely used even in providing traditonal public services.

The low emission scenario constructed for this report is premised on slowing the growth in private car use and shifting to more environmentally beneficial fuels and technologies. This is based on an understanding that climate change is not on Chile's list of priorities, but that many measures aimed at other higher priority environmental and economic concerns will have the ancillary benefit of reducing GHG emissions. The types of policies and measures that could gain widespread support and could have a significant effect are likely to be those premised on market principles, coupled with more traditional government responses. They are basically aimed at improving urban air quality and traffic congestion and include:

- *Introducing new and enhanced technology:* conversion of urban buses from diesel to fuel cell, use of natural gas and battery-powered electric cars, and introduction of minicars, including electric minicars.
- *Improving public transportation:* integration of bus routing and fare structures, establishment of exclusive bus lanes, provision of more comfortable buses, significant expansion of suburban trains, and expansion of Metro service.
- *Encouraging smaller cars and alternatives to car use:* parking restrictions, road fees, elimination of tax incentives for larger and inefficient cars and light duty vehicles.

Based on the results of this report, the low emission scenario yields an emissions increase of only 42 percent between 2000 and 2020, compared to an increase of 117 percent under the high, business-as-usual scenario.

In the end, it is difficult to imagine a near- to medium-term future in which GHG emissions do not increase significantly. Further reductions could be achieved in freight transportation but would require strong political leadership. On a positive note, Chile's heavy reliance on market forces and the virtual absence of government intervention in the energy market creates a good opportunity for foreign companies and governments to invest in GHG reduction projects through the Clean Development Mechanism. The lesson is that now is the time to begin laying the foundation for a more fundamental strategy shift toward the low GHG emission scenario.

Glossary

Bus occupancy: Average number of passengers on buses, taking into account non-revenue travel such as returning to the garage. Also referred to as "load factor," expressed as average ridership or as the average percentage of seats filled (adjusted for standees).

Clean Develoment Mechanism (CDM): One of the market-based flexibility mechanisms of the Kyoto Protocol, CDM encourages investment in greenhouse gas reduction projects in developing countries by allowing industrialized countries to apply the resulting emission reductions toward their Kyoto Protocol targets.

Colectivo: A vehicle, usually a sedan style car, that provides taxi-like jitney or paratransit services. These vehicles collect multiple passengers and operate along fixed routes, but without fixed schedules.

CONAMA: *Comisión Nacional del Medio Ambiente,* the National Environmental Commission, a coordinating body charged with establishing policies to protect the environment.

Decontamination Plan: A suite of actions to be undertaken in order to bring into compliance an area where pollution levels exceed environmental quality and emission standards.

EFE: *Empresa de Ferrocarriles del Estado,* the state-owned railroad system that serves both freight and passenger rail users.

Franchising: A system in which a private firm wins a government concession (generally through a competitive bidding process) to build or operate a facility or service traditionally offered by the public sector. The firm earns a profit by collecting user fees for a specified period of time.

Jitney: A vehicle that transports passengers along a fixed route for a fare.

Kyoto Protocol: An agreement negotiated in Kyoto, Japan, in 1997 to strengthen commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The Protocol sets binding emission targets for industrialized countries averaging 5.2 percent below 1990 levels by 2008-12, and establishes market-based mechanisms that allow parties to meet their targets in part by trading emission allowances or sponsoring emission reduction projects in developing countries. The Protocol will enter into force when ratified by 55 countries, including countries accounting for 55 percent of carbon dioxide (CO_2) emissions from industrialized countries in 1990.

Light duty truck: Includes small and large vans and pick-up trucks, mostly used by businesses for commercial purposes.

MEPLAN: A sophisticated, integrated urban land use and transportation model developed by the Ministry of Public Works of Chile.

Metro: Urban railway or subway; also known as heavy passenger rail.

Metrobus: A feeder bus for the Metro.

Metrotren: A suburban train connecting to the Metro.

Minicar: A car designed for urban use that is about half the size of a conventional sedan. In Japan, where they are common, they are defined as vehicles with engine capacity of 660 cc or less. Also sometimes referred to as a "city car."

Modal split: The share of total passenger or freight travel on different kinds of transportation, usually measured as a percentage or fraction.

Paratransit: Broad term referring to *colectivos*, jitney services, and other public transportation that provides a service intermediate between that of conventional buses and private cars.

Passenger-kilometer: One passenger moving one kilometer.

Reversible lanes: A road management scheme to handle greater vehicle flows by reversing the flow in one or more lanes each day to increase the number of lanes serving traffic in the peak direction (i.e., more lanes serving traffic entering the city center in the morning and more lanes serving outbound traffic in the afternoon).

Route tender: A process whereby authorities grant exclusive service rights to operators (of public transit, for example) for a given period of time. In return, the concessionaires agree to meet operating requirements, technological standards, and management procedures established by the public tender.

Tonne-kilometer: One tonne (of freight) moving one kilometer.

United Nations Framework Convention on Climate Change (UNFCCC): One of three international agreements negotiated at the 1992 UN Conference on Environment and Development, the UNFCCC set a long-term objective of stabilizing atmospheric concentrations of greenhouse gases at a level that would “prevent dangerous anthropogenic interference with the climate system.” The Convention called for industrialized countries to voluntarily return their greenhouse gas emissions to 1990 levels by 2000.

Appendix

A. Research Approach

This report was a collaboration between researchers at the University of California, Davis and the University of Chile. The report is based on an extensive review of the literature, a series of interviews in November 1999 with Chilean experts and leaders in Santiago, further review of reports and other materials identified during interviews, and data analyses conducted by Dr. Raúl O'Ryan and Dr. Mark Delucchi. Dr. O'Ryan generated the first set of travel and energy assumptions and parameters for the scenarios. After extensive consultation among the authors and others, the final set of parameters was specified. Dr. Delucchi converted these numeric measures into quantitative GHG emissions estimates for the two scenarios.

Interviewees

Francisco Martínez, Civil Engineering Department, University of Chile

Rodrigo Fernández, Civil Engineering Department, University of Chile

Sergio González, former Undersecretary of Transport

Sonia Morales, Subdirector for Roads, Ministry of Public Works

Cristián López, Director of Research Unit, Planning Office, Ministry of Public Works

Iván Jana, General Coordinator of Project Franchising, Ministry of Public Works

Sergio González, Regional Director for the Metropolitan Region, Ministry of Housing and Urbanism

Henry Malbrán, consultant to the Regional Director for the Metropolitan Region, Ministry of Transport and Telecommunications

Carlos Gárate, Director, Strategic Planning Office, Ministry of Transport and Telecommunications

Juan Pedro Searle, Director, Climate Change Department, National Environmental Commission (CONAMA)

Patricio Vallespin, Director, Metropolitan Regional CONAMA, National Environmental Commission (CONAMA)

Jorge Cáceres, Decontamination Plan Group, Metropolitan Regional CONAMA, National Environmental Commission (CONAMA)

Marcelo Farah, Senior Engineer, Urban Transport Commission (Sectra)

Nicolás Flaño, President, State Railroad Enterprise (EFE)

Jaime Bravo, Director of the Environment and Renewable Energy Area, National Energy Commission

B. Overview of Lifecycle Energy Use and Emissions Model (LEM)

There are many ways to produce and use energy, and many sources of emissions in an energy-production-and-use pathway. Several kinds of GHGs are also emitted at each source. An evaluation of GHG emissions associated with transportation activities must be broad, detailed, and systematic. It must encompass the full "lifecycle" emissions of a particular technology or policy, and include all of the relevant pollutants and their effects. To this end, Dr. Delucchi has developed a detailed, comprehensive model of lifecycle emissions of urban air pollutants and GHGs from various transportation modes. Many governments and companies use this model. Dr. Delucchi updated and adapted the model for this report.

The Lifecycle Energy Use and Emissions Model (LEM) considers: motorized two-wheelers, cars, buses, and trucks operating on a range of fuels and propulsion technologies; bicycles; heavy-rail and light-rail transit; ships; and freight railroads. The LEM estimates energy use, GHG emissions, and urban air pollutants for the transportation modes listed above. The model includes lifecycles for fuels and electricity (end use, fuel dispensing, fuel distribution, fuel production, feedstock transportation, and feedstock production), vehicles (materials production, vehicle assembly, operation and maintenance, and indirect support infrastructure), and infrastructure (materials for infrastructure, and construction of infrastructure). Greenhouse gas results mentioned in this report include only emissions associated with fuels and electricity since accurate data are unavailable in Chile for materials, manufacturing, and construction.

The LEM characterizes emissions of GHGs and criteria pollutants from several sources: fuel combustion, evaporation and leakage of liquid fuels, venting or flaring of gas mixtures, chemical transformations, and changes in the carbon content of solid or biomass fuel. The model estimates emissions of CO_2, methane, nitrous oxide, carbon monoxide, oxides of nitrogen, nonmethane organic compounds, sulfur dioxide, particular matter, CFC-12, and HFC-134a. The LEM estimates emissions of each pollutant individually, and also converts the GHG emissions into CO_2-equivalent GHG emissions. To calculate total CO_2-equivalent emissions, the model uses CO_2-equivalency factors (CEFs) that convert mass emissions of all non-CO_2 gases into an equivalent mass amount of CO_2. Delucchi derived these CEFs using various sources and methods, including but not limited to research by others on Global Warming Potentials (GWPs) and Economic Damage Indices (EDIs). GWPs relate different gases to CO_2 in terms of their relative effects on global warming. EDIs relate the gases to CO_2 in terms of their relative warming-induced economic damages. As a sensitivity analysis, the LEM model also was run accounting only for those gases for which the Intergovernmental Panel on Climate Change (IPCC) has published global warming potentials relative to CO_2, and using those GWPs instead of the CEFs. This made less than a 10 percent difference in the GHG emission estimate and did not affect the relative difference between the scenarios.

Travel

Data specific to Chile used for this report come from multiple local sources. Most of it is collected and cited in O'Ryan and Turrentine (2000). Co-authors O'Ryan and Turrentine collected unpublished data from various researchers and stakeholders in Chile, as indicated in their 2000 report. Delucchi and the other co-authors of this report used their professional judgment and published and unpublished data solicited from Chilean experts to make small adjustments in these data.

Electricity

The U.S. Energy Information Administration's (EIA's) International Energy Outlook (2001a) and Export Council for Energy Efficiency (2001b) report fuel-use shares for electricity generation in 1998. Information from various sources indicate that coal use for power generation is slated to fall in coming years as natural gas fuels more of Chile's electricity. The U.S. Department of Energy (DOE) Office of Fossil Energy (2001) provides data on efficiencies of Chilean power plants. It is assumed that current and future gas-fired power plants are of relatively modern design and have emissions levels similar to gas-fired turbine plants in the United States. Oil and coal-fired plants are assumed to be older and higher polluting, and that the sulfur content of coal used in Chile is relatively high (EIA, 2001c).

Oil and Gas

In 1998, Chile imported 95 percent of the crude oil it consumed, 12 percent of gasoline consumed and 17 percent of distillate consumed (EIA, 2001a). Chile's main sources of crude oil imports are Argentina (via a 400 kilometer pipeline), Nigeria, Gabon, and Venezuela (EIA, 2001c; Office of Fossil Energy, 2001). Chile imports about 30 percent of its natural gas from Argentina (EIA, 2001a). Because Chile has supported large gas-to-liquids projects – the largest methanol production facility in the world, for example, is in Chile [Office of Fossil Energy, 2001] – Delucchi assumes that all gas used to produce methanol and Fischer-Tropsch diesel is domestic.

Data References for LEM

Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99), U.S. Department of Energy, Washington, D.C., February (2001a). See also the EIA's "Country Energy Data Reports," *www.eia.doe.gov/emeu/world/country/*.

Energy Information Administration, *International Energy Outlook 2001*, DOE/EIA-0484(2001), U.S. Department of Energy, Washington, D.C., March (2001b).

Energy Information Administration, *Chile*, Country Analysis Brief, *www.eia.doe.gov/emeu/cabs/chile.html,* U.S. Department of Energy, Washington, D.C., May (2001c).

Energy Information Administration, *Chile: Environmental Issues*, Country Analysis Brief, *www.eia.doe.gov/emeu/cabs/chilenv.html,* U.S. Department of Energy, Washington, D.C., July (2000).

Export Council for Energy Efficiency, ECEE - *Chile Market Assessment 4*. Electric End-Use and Efficiency Potential, *www.ecee.org/pubs/assess/chile/Chile4.htm,* accessed September 2 (2001a).

Export Council for Energy Efficiency, ECEE - *Chile Market Assessment 3*. Energy and Electricity in Chile, *www.ecee.org/pubs/assess/chile/Chile3.htm,* accessed September 2 (2001b).

Intergovernmental Panel on Climate Change, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: The Greenhouse Gas Inventory Reference Manual,* Intergovernmental Panel on Climate Change, United Nations Environment Programme, Organization for Economic Cooperation and Development, International Energy Agency, Paris, France (1997). Available on-line at *www.iea.org/ipcc/invs6.htm.*

Office of Fossil Energy, *An Energy Overview of Chile, www.fe.doe.gov/international/chilover.html,* U.S. Department of Energy, Washington, D.C., accessed September 2 (2001).

R. O'Ryan and T. Turrentine, *Greenhouse Gas Emissions in the Transport Sector, Case Study for Chile,* UCD-ITS-RR-00-10, Working Paper, Institute of Transportation Studies, University of California, Davis, November (2000).

References for LEM Documentation

The 1997 version of the model is documented in several reports, shown below. Complete, up-to-date working documentation is available from the author. (Please note that Dr. Delucchi changed the spelling of his name from DeLuchi in the mid-1990s.)

DeLuchi, M.A. 1991. *Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity* 1. Center for Transportation Research, Argonne National Laboratory, Argonne, IL. ANL/ESD/TM-22. November.

DeLuchi, M.A. 1993. *Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity* 2. Appendices A-S. Center for Transportation Research, Argonne National Laboratory, Argonne, IL. ANL/ESD/TM-22. November.

DeLuchi, M.A. 1996. *Emissions of Criteria Pollutants, Toxic Air Pollutants, and Greenhouse Gases, from the Use of Alternative Transportation Modes and Fuels.* Institute of Transportation Studies, University of California, Davis. UCD-ITS-RR-96-12. January.

DeLuchi, M.A., and T. E. Lipman. 1997. *Emissions of Non-CO_2 Greenhouse Gases from the Production and Use of Transportation Fuels and Electricity.* Institute of Transportation Studies, University of California, Davis. UCD-ITS-RR-97-5. February.

DeLuchi, M.A. 1997. *A Revised Model of Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity.* Institute of Transportation Studies, University of California, Davis. UCD-ITS-RR-97-22. November.

Endnotes

1. The actual figure is U.S.$4,600, ranking it 72nd in the world between Hungary and Croatia. 2001 World Development Indicators Database, World Bank, July 2001.

2. Malbrán., H, A. Dourthé, Y.M. Wityk, *Santiago, Chile's Experience with the Regulation of the Public Transport Market,* Secretaría Ministerial de Transportes y Telecomunicaciones Región Metropolitana, 1999. Unpublished report.

3. Instituto Nacional de Estadísticas (INE), *Población Total Estimada al 30 de Junio de Cada Año, según Área Urbana y Rural y Regiones, 1999-2005,* 1999.

4. Meller et al., "Growth, Equity and the Environment in Chile, Issues and Evidence," *World Development,* 1996.

5. MIDEPLAN, Inquiry CASEN, "Ingreso Promedio Mensual de los Hogares por Quintil de Ingreso Autónomo Regional, Según Composición, Zona y Población en cada Quintil, 1998," 1999.

6. Meller et al., 1996.

7. Between 1974 and 1981 GDP grew at only 1.8 percent per year (Meller et al. 1996). Between 1980 and 1990, export volumes increased by 5.7 percent per year, whereas from 1990-95, they grew at 10.5 percent per year on average (World Bank, 1997).

8. Chile at a Glance, January 2002, World Bank. See *http: www.worldbank.org/html/estdr/offrep/lac/c12.htm.*

9. CAPP, "Informe País: Estado del Medio Ambiente en Chile-1999," Universidad de Chile, Centro de Análisis de Políticas Públicas, Santiago, Chile, 2000.

10. "Decontamination" here refers to environmental improvement in a general sense rather than specifically to the clean up of a brownfield or other polluted site.

11. Saturated zones may include a whole city or region (as is the case for Santiago, where the whole Metropolitan Region has been declared saturated) or a specific area affected by highly polluting sources (as has been the case with emissions from specific mining sources).

12. See O'Ryan and del Valle, *Managing Air Quality in Santiago: What Needs to be Done?* Estudios de Economía (23), August 1996, Special Issue on Urban Economics.

13. In 2000, the Ministry of Public Works and the Ministry of Transport and Telecommunications were merged.

14. SECTRA is a technical body dedicated to planning transportation systems, both urban and interurban. It depends on four Ministries: Transport, Telecommunications and Public Works (MOPTT); Housing (MINVU); Planning (MIDEPLAN); and the General Secretariat for the Presidency (SEGPRES).

15. Statistics in Chile do not distinguish between rural and urban. However, the more affluent live in cities and as a result most of the increase in car ownership occurs there. Data come from Instituto Nacional de Estadísticas (INE), 1975, 1980, 1985, 1990, 1995, and 1998, "Annuario de Transporte y Comunicaciones," Santiago, Chile.

16. See CONAMA, PNUMA, 2000, "Informe País: Estado del Medio Ambiente en Chile-1999," Chile.

17. INE, 1998, "Anuario de Demografía," Santiago.

18. A *colectivo* is a vehicle, usually a sedan-style car, that provides jitney or pararansit services. Colectivos collect multiple passengers and operate over fixed routes, but without fixed schedules.

19. SECTRA, "Encuesta Origen Destino de Viajes en la Gran Santiago 1991," Comisión de Planificación de Inversiones en Infraestructura de Transporte, Santiago, 1991.

20. O'Ryan, 1986, "Energía y Transporte de Pasajeros en Santiago: Impactos de una Gestión Integrada," Memoria para optar al título de Ingeniero Civil Eléctrico y al grado de Magister en Ingeniería Industrial, Universidad de Chile.

21. Malbrán et al., 1999.

22. Malbrán et al., 1999.

23. Ministry of Transport and Telecomunications (1997), "Estudio de Demanda del Sistema de Transporte de Superficie de Santiago 1997." Prepared by the Secretaría Regional Ministerial de la Región Metropolitana, Santiago. 1997.

24. This is the measured waiting time. Mean waiting time according to users *surveyed* was 8.6 minutes, i.e., people perceive waiting periods as lasting more than twice as long as they really do.

25. Zegras, C. and Litman, T., "An Analysis of the Full Costs and Impacts of Passenger Transport in Santiago de Chile." International Institute for Energy Conservation (IIEC), Latin America, 1997.

26. Malbrán et al., 1999.

27. Escudero, Juan, "A 5 Años del Plan de Descontaminación de la Región Metropolitana," Acción Ciudadana por el Medio Ambiente/Friedrich Ebert Stiftung, 1996.

28. Fernández, D., "The Modernization of Santiago's Public Transport: 1990-1992," *Transport Reviews,* Vol. 14 N° 2, 1994.

29. Information in this paragraph comes from Malbrán et al., 1999.

30. Zegras and Litman, 1996.

31. Information im this paragraph comes from the World Business Council for Sustainable Development, *Mobility 2001,* Switzerland, 2001, pp. 4-9.

32. SECTRA, "Encuesta Origen Destino de Viajes en la Gran Santiago 1991," Comisión de Planificación de Inversiones en Infraestructura de Transporte, 1991. Considering the increase in ridership on the Metro in the last decade, this percentage is certainly somewhat higher now. Unfortunately, a more current number is not available.

33. Hall, S., Zegras, C., and Malbrán, H., "Transportation and Energy in Santiago, Chile," *Transport Policy,* Vol. 1, No. 4, 1994.

34. O'Ryan, 1986.

35. Thomson, I., "Una Evaluación Crítica de Algunos Aspectos del Desarrollo del Sistema de Transporte Urbano de Santiago de Chile," CEPAL, 1995.

36. The numbers in this section come from Thomson, 1995.

37. Data on buses, trains, and airplanes come from "Anuario de Transporte y Comunicaciones 1998," INE.

38. Unfortunately there is no information on the number of interurban passengers transported by car. The number of cars passing through selected tollbooths has been used as a proxy.

39. Information from Planning Division, MOP, used for the MEPLAN model.

40. At the end of the nineteenth century Chile went to war with both Perú and Bolivia, gaining substantial territory and leaving Bolivia landlocked. To improve relations, various initiatives have been undertaken, including the heavily subsidized operation of trains connecting Perú with Chile's seaport at Arica (formerly a Peruvian city) and the Bolivian capital, La Paz, with Arica.

41. Based on Brown, R., "The Political Framework of Regulatory Reform of Transport Enterprises: Bus and Truck Deregulation in Chile," Santiago: CEPAL, 1990. World Bank Seminar on Regulatory Reform in Transport, 7-8 June.

42. These data are calculated from trucks passing through toll booths. Based on data in Instituto Nacional de Estadísticas (INE), "Anuario de Transporte y Comunicaciones," years 1975, 1980, 1985, 1990-1991-1992, 1995, and 1998.

43. Moguillanski G., 1997, "Chile: las reformas estructurales y la inversión privada en área de infraestructura," *Serie Reformas Económicas* N° 2, Santiago: CEPAL, 1997.

44. The following discussion of infrastructure franchising is largely taken from Engel, Fischer and Galetovic, "The Chilean Infrastructure Concessions Program: Evaluation, Lessons and Prospects for the Future," Working Paper #60, Centro de Economía Aplicada, Depto. Ingeniería Industrial, Universidad de Chile, Chile, 1999.

45. Catalytic converters are currently the standard air pollution control devices on most cars throughout the world. They rely on catalysts to chemically convert pollutants into harmless substances.

46. Over 2,600 buses over 18 years of age were scrapped in 1991, followed by another 2,000 more during the following three years. These measures cost the government U.S.$14 million in compensation payments but reduced the number of buses to the current 9,000.

47. The description of the APPDP is based on CONAMA, "Plan de Prevención y Decontaminación Atmosférica de la Región Metropolitana (PPDA)." *Final Report,* Santiago, 1997.

48. O'Ryan, Raul, and L. Larraguibel, "Air Pollution in Santiago: what is it, what has been done, what is needed?" *Perspectivas en Política, Economía y Gestión,* Vol. 4, No. 1, pp. 153-191, 2000.

49. See for example Salinas M., Vega J., "El Efecto de la Contaminación Atmosférica Externa en la Mortalidad: Un Estudio Ecológico Sobre Santiago, Chile." *World Health Stat Q* 48(2):118-25, 1995; Ostro B., Eskeland G.S., Sánchez J.M., Feysioglu T., "Air Pollution and Health Effects: A Study of Medical Visits Among Children in Santiago, Chile." *Environmental Health Perspectives* 107(1):69-73, 1999; Cifuentes, L., V.H. Borja-Aburto, Gouveia, N., Thurston, G., Davis, D. (2001) "Hidden Health Benefits of Greenhouse Gas Mitigation." *Science* 293: 1257-59; Sanhueza, P., Vargas C., Jiménez J., "Mortalidad Diaria en Santiago y su Relación con la Contaminación Atmosférica." *Restiva Médica de Chile* 127(2):235-42, 1999.

50. CONAMA (2000). Auditoría del Plan de Prevención y Descontaminación Atmosférica de la Región Metropolitana. See *http://www.conama.cl/.*

51. CONAMA, 1997.

52. CONAMA, 2000.

53. The plan is called the Emergency Road Network *(Red Vial de Emergencia).*

54. Information provided by SECTRA in various presentations.

55. Unpublished analyses by P. Arellano, based on information from a 1987-88 income survey, suggest that the income elasticity of demand for car purchases in Chile is about 2.3. But even with much lower elasticities, car ownership will likely increase faster than economic growth, as it does in many middle-income countries.

56. In Santiago the first urban concession – the Costanera Norte Project – has recently been initiated.

57. Comisión Nacional de Energía, "Balance Nacional de Energía," 1977-1996 and 1997.

58. CONAMA, "Primera Comunicación Nacional bajo la Convención Marco de las Naciones Unidas sobre Cambio Climático," Santiago, Chile, p. 23, 1999.

59. These are not full lifecycle emissions. Only direct ("tailpipe") emissions of Intergovernmental Panel on Climate Change-designated greenhouse gases were included. Upstream emissions from fuel production and distribution, as calculated in the greenhouse gas models used for the scenarios in this report, were not considered by CONAMA. See the Appendix to this report for further discussion.

60. "Tailpipe" emissions are those from fuel combustion in the vehicle, not from the production or distribution of the fuel or vehicle.

61. Upstream emissions are not included in these calculations; only direct ("tailpipe") emissions are included.

62. CONAMA, "Primera Comunicación Nacional bajo la Convencion Marco de las Nacionas Unidas sobre Cambio Climatico," Chile, 1999, p. 23.

63. O'Ryan R. and T. Turrentine, "Greenhouse Gas Emissions in the Transport Sector 2000-2020: Case Study for Chile," University of California, Davis, Institute for Transportation Studies Working paper UCD-ITS-RR-00-10, November 2000.

64. However, transportation demand is also dependent on accessibility in the model, since improvements in infrastructure can reduce transportation costs, and increase demand for a given product, or influence the location of economic activities. Demand and supply of goods in the economy are equilibrated through prices, and demand and supply of transportation through trip time. This model has been developed and used to predict road infrastructure, port, and airport requirements through 2020.

notes

notes

This report looks at the greenhouse gas emissions from the transportation sector in Chile. It identifies policies and technologies that will simultaneously reduce emissions growth while improving air quality, reducing congestion, improving safety, and enhancing transportation services. The Pew Center on Global Climate Change was established by the Pew Charitable Trusts to bring a new cooperative approach and critical scientific, economic, and technological expertise to the global climate change debate. We intend to inform this debate through wide-ranging analyses that will add new facts and perspectives in four areas: policy (domestic and international), economics, environment, and solutions.

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