TRANSPORTATION IN DEVELOPING COUNTRIES: GREENHOUSE GAS SCENARIOS FOR CHILE

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Executive Summary

Chile is a lightly populated country of 15 million that has undergone large economic transformations. Over the past 25 years, the economy has evolved from a slow-growing state-directed economy into a fast growing, market-oriented economy. Its South American neighbors are imitating this transformation. The changes have been especially great in the transport sector, with the private sector taking over many traditional public sector activities.

This report addresses the implications of Chile's economic growth on transportation, energy use, greenhouse gas emissions, and other environmental impacts.. Both urban and interurban transport are included.

Chile's transport sector is experiencing rapid growth, especially in Santiago. Between 1985 and 1998, the economy increased 2.5 fold (7.4% per year) and the transport sector more than 3.5 fold (over 10% per year). Public transport continues to lose market share. Between 1977 and 1991, cars increased their share of passenger travel by more than 60%, while the bus share fell 27%. These shifts are motivated by the strong urbanization process, with over 85% 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.

Transport consumes almost 40% of energy sector emissions and is responsible for about 28% GHG emissionsin in Chile. Of the total GHG emissions from transport, 45% is from cars and taxis, 24% from trucks, 14% from ships, 10% from planes, 9.5% from buses, and nearly zero from trains. Passenger transport accounts for about 2/3 of transportation's greenhouse gas emissions (GHG), while about 1/3 is from freight; and interurban transport accounts for over half of total GHG emissions.

Chile's policymakers, both at the national and sectoral levels, have largely ignored the environmental consequences of rapid development; a policy of "grow first, clean up later" was pursued until 1990. The lack of interest in GHG emission reductions stems from this growth-oriented thinking, as well as a realization that Chile's impact on greenhouse gases is small compared to major industrial nations. With only 15 million people each using on average less than 1/6 as much energy as each US resident, and with extensive carbon-consuming biotic resources, including vast forests, offsettinjg its anthropocentric production of CO_2, its relative impact on global climate change is small. Thus while sympathetic to global warming issues, Chile is not likely to view its contribution as significant and global warming is not likely to motivate policy action. But worsening pollution and traffic congestion have placed motor vehicles at the center of policy debates over its development path. Thus, even though global warming is not a priority issue for the nation, actions directed at resolving transportation and air pollution problems will have the side effect of slowing greenhouse gas emissions growth.

We develop high ("business-as-usual") and low scenarios for greenhouse gases for the next two decades. The scenarios are based upon interviews with experts and policymakers, and extensive analysis of transport and energy data gathered from a wide range of Chilean sources.

In the next twenty years, in the "business-as-usual scenario," we assume strong continued economic growth (5.8% annual GDP growth) and no strong actions taken to curb environmental problems. The result is a doubling of energy consumption by the transport sector, and more than a doubling of greenhouse gas emissions. Passenger-related energy use and greenhouse gases increase faster than freight-related energy use and emissions, resulting in passenger transport increasing its share of transport greenhouse gas emissions from 70% to 80% over the 20 years

In an alternative "low emissions" scenario, changes include policies to improve and enhance public transport, and to introduce cleaner and more efficient vehicles. The net effect is a 34% increase in greenhouse gas emissions, resulting in 38% fewer emissions than in the high scenario.

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1. Introduction

Chile is a lightly populated country of 15 million that is undergoing a major economic tran sformation. The changes have been especially great in the transport sector, with the private sector taking over many traditional public sector activities. Vehicle use is soaring.

This report addresses transformations in the transportation sector, and the implications for energy use, greenhouse gas emissions and other environmental impacts. Both urban and interurban transport is addressed.

1.1. Economic Development

Chile is a narrow country squeezed between the Andes Mountains and the Pacific Ocean (see Figure 1). It stretches more than 4,200 km from Peru to the southern tip of the continent. The climate ranges from arid desert in the north to sub-arctic in the far south. The main economic activities are mining and fishing in the arid north, agriculture in some northern valleys, and a variety of industries related to natural resources in the narrow southern strip. In the central part of Chile are temperate valleys and coastline – and most of the population and business.

Santiago, located in the central part of the country (Region Metropolitana), dominates the country. It produces 42% of Chile's Gross Domestic Product[1] and is home to almost 5.5 million inhabitants, 37% of the nation's population.[2] No other city exceeds one million. Santiago's population tripled between 1960 and 1990. Only about 2 million people, out of 15 million total, live in rural areas. The rural population is stagnant, while the urban population, in Santiago and elsewhere, continues to increase.

The transition to a more urban and affluent society has resulted in rapid growth in travel and car ownership. In the past quarter century, the population of Chile grew approximately 1.8 percent per year, while travel increased 6.2 percent annually, and car ownership 8.6 percent.[3]

Chile's economy has successfully undergone a radical transformation. It went from an extraordinarily high level of state ownership, under a democratic government, to an extraordinarily high level of private control, under a military and then democratic government. Earlier the economy was premised on import substitution and state control; now it is premised on export promotion and market forces. Since a deep recession in the early 1980s, the economy has been flourishing. Chile is widely recognized as having the most market-based and stable economy in Latin America, with strong exports and an expanding private sector. The economic well-being is matched with strong social well-being, as demonstrated by high life expectancy (75 years), low infant mortality (13 per 1,000 births), and low adult illiteracy (5 percent).[4]

Figure 1: Chile's Thirteen Regions

The modern economic transformation began in 1973 when a democratically elected socialist government was pushed aside by a military dictatorship. The socialist government had nationalized enterprises and controlled most prices. The military replaced it with a highly liberalized free market system in which the private sector played an increasingly dominant role. Between 1973 and 1982, almost all state-owned firms and banks were privatized, market forces were introduced to most productive sectors and services, and tariffs were reduced 90% for almost all products.

Through the mid 1980s, the wide shifts in policy resulted in poor economic performance. Between 1974 and 1981 GDP grew only 1.8% per year.[5] Since 1985, the economy has consolidated, with exports serving as the engine of growth. By the early 1990s, export volumes were increasing over 10% per year on average.[6] Between 1988 and 1998 the Chilean economy expanded at an annual growth rate of 7.9%. Its income per capita is now about $5,000, one of the highest in Latin America, ranking 32nd in the world. The fastest growing economic sectors in recent years have been transport, communications, and fisheries.

Since 1990, democratically elected governments have maintained the economic reforms, while focusing increasingly on reducing social inequity and poverty. Poverty levels have fallen dramatically, from almost 40% of the population in 1990, to just over 20% in 1998.[7] At the other end, though, the richest 10% receive almost 30 times more income than the poorest 10%, unchanged in decades.

1.2. Environmental Strategies

Rapid growth places great stress on the environment. Until recently, policymakers largely overlooked environmental consequences. The prevailing attitude, as in other expanding economies, was to focus on economic growth, and defer environmental protection to later. Environmental issues came to the forefront in the 1990s, motivated by worsening air and water pollution, particularly in Santiago; adverse publicity about ecological dumping; and a desire to join the North American Free Trade Agreement (requiring the country to address US concerns about the environmental implications of increased trade).

The democratic government elected in 1990 initiated a restructuring of institutions to protect the environment. A month after coming into office, the national government established the Special Commission for Metropolitan Region Decontamination, and a few months later, the National Commission for the Environment (CONAMA). In 1994, the General Environmental Law (GEL) was passed. It builds on a decentralized institutional framework, charging CONAMA with overseeing and coordinating with other public institutions.

The GEL requires that large private and public sector projects undergo environmental impact assessments, and mandated improvements in environmental quality. The Santiago metropolitan area was determined to be in non-compliance and required to develop an elaborate Decontamination Plan.

Environmental issues continue to gain increasing attention, but actual progress is impeded by poor integration between environmental, transportation, and economic policies. Economic policies to boost exports and liberalize the industry are not coordinated with air quality policy, and energy policy is not coordinated with environmental or transport policy. An important first step was the adoption in 1990 of the first Santiago Decontamination Plan.[8]

2. Chile's Urban Transport Picture

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

Buses are still the primary mode of transport in cities, but cars are playing an expanding role. As indicated in Table 1, the number of light duty vehicles, mostly in urban areas,[9] increased over 5 fold from 1975 to 1995, an increase of 8.6% per year. More than one of every 10 people in the country now owns a car. In Santiago the rate is about one in eight.

Table 1: Urban Buses and Cars, and Motorization Rate, Chile, 1975-1995

Year	Urban buses	Light duty vehicles*	Motorization rate (Vehicles/person)
1975	16,563	255,717	0.03
1980	20,734	448,492	0.04
1985	21,491	624,884	0.05
1990	28,730	906,626	0.07
1995	33,970	1,330,376	0.10

*Includes private cars (cars, jeeps and station wagons) and commercial vehicles (small and large vans, and pick ups). Source: "Parque de Vehículos en Circulación", años 1975, 1980, 1985, 1990 y 1995, INE; and "Población Estimada al 30 de Junio de cada año", INE. Though rural vehicles are also considered, these are very minor compared to urban cars, see note 10.

Car ownership is not particularly high compared to other regions of similar income. In Table 2, 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, but Delhi is much poorer. Chile's motorization is similar to South Africa, but Chile is somewhat more affluent.

Table 2: Vehicle Ownership and Other Characteristics for Selected Cities and Countries

Region	Year	Population	Income per Capita*	Vehicles per 1,000 Persons**	Passenger Cars per 1,000 Persons***
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
Shanghai	2000	13,000,000	$4,000	69	22
Delhi	1998	13,400,000	$850	200	63
Santiago	1998	5,332,100	$5,200	183	129
Chile	1998	14,821,714	$4,930	137	109
S. 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 Shanghai, Delhi, and South Africa are from other reports in this series on transport being published by the Pew Center for Global Climate Change (2001 and 2002). Chile and Santiago data are referenced elsewhere in this report.

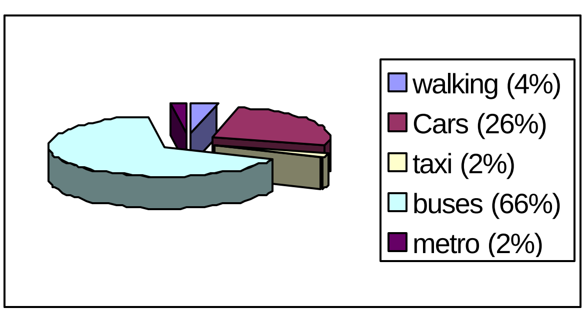
* For cities in this table, gross city product per capita are used as proxies for income, and for nations, gross domestic product per capita.

** Includes motorized two-wheelers in case of Shanghai and Delhi, but excludes mopeds (less than 50 cc).

***Includes light trucks used for private transportation.

Measured in terms of passenger-kilometers traveled, buses account for 66% of all urban travel. As indicated in Figure 1, cars carry 26% of total passenger kilometers, and all other modes 8 percent.

Figure 2: Urban Travel in Chile by Passenger-Kilometers Traveled



Source: Authors from various primary sources.

2.1. Santiago's Transport Context

Greater Santiago includes 34 relatively autonomous "*comunas*" (municipalities) spread over 2000 square kilometers. Each is responsible for maintaining local roads and facilities for public transportation (e.g., bus stops), along with controlling local land-use. Due to lack of local funding, and limited access to other funding resulting from decentralization of authority, about 1000 km of streets remained unpaved as of 1994. [10]

The population density of Greater Santiago is rather low, with about 8,000 residents per square kilometer.[11] Densities range from 17,000 per square kilometer in Lo Prado, a poor community near the center, to 10,250 in the central business district, and less than 5,000 in affluent neighborhoods. These densities are not great compared to other megacities.

Dispersed development results in more and longer trips. Residents of the poor shanty towns on Santiago's periphery (*poblaciones)* have particularly long trips, especially when measured in time, since they rely on walking and buses.

The principal motorized transport modes in Santiago are cars, taxis, "colectivos,"[12] buses, and rail transit ("metro"). As indicated in Table 3, of the 8.4 million trips per workday, 49% are in buses, 16% in cars (including taxis), 5% in the (rail) Metro, and 9% by other means.[13] (Note that these travel percentages are for number of trips, while Figure 1 percentages are for passenger-kilometers.) Motorcycles, scooters, and even bicycles are virtually absent. Another 20% of trips are non-motorized, mostly walking.[14] Table 3 shows that in just 14 years, the cars' share rose by more than 60%, while the bus share fell by 27%. Additionally, the number of trips per person increased from 1.14 trips/person to 2.12 trips/person in the same period, due to the increase in income and expansion of the city. While the use of the Metro and colectivos has increased, the overall trend is toward greater reliance on cars and less on public transport.

Table 3 – Travel by Mode in Greater Santiago, 1977-1991

Mode	% of trips - 1977	% of trips – 1991
Car	9.8	15.9
Bus	66.4	48.7
Metro	3.3	5.0
Walking	16.4	19.8
Collective Taxi	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.

2.2. Mass Transport in Santiago

The provision of transit services is problematic worldwide. As affluence increases, demand for more residential space and personal transport increases. As trip origins and destinations diffuse, mass transit becomes less competitive and the desire for personal vehicles accelerates. To assure affordable access to all segments of society, governments almost everywhere have been faced with the need of infusing transit services with increasing subsidies. Santiago faces those same pressures. Santiago has taken a path different from most. Santiago now relies on private 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 (running 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 trolley buses by 1978.[15] Buses now dominate, supplemented by paratransit services 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.[16]

In 1975, bus markets began to be liberalized – part of the sweeping "free market" transformation of Chile. The result was total freedom of routes by 1988.[17] The number of buses and smaller 21-seat "taxi-buses" rose 50% and 75%, respectively, between 1978 and 1985. Network coverage improved and waiting times dropped. Fully 93% of users are now within walking distance of bus stops,[18] and the mean waiting time is only 3.7 minutes.[19]

Deregulation was not all positive, though. More service did not lead to more passengers. Bus occupancy (percent of seats filled) fell by over 50% between 1978 and 1985.[20] The result was lower income per bus. Bus operators compensated by raising fares almost 200% in real terms between 1979 and 1990.[21]

Not only did deregulation lead to shrinking market share and higher bus fares, it also led to deteriorating safety, increasing air pollution, and worsening traffic congestion. Safety deteriorated because of aging vehicles and deferred maintenance, and operators competing fiercely in the streets for passengers. Air pollution worsened in part because of deferred maintenance and use of older diesel buses. And traffic became more congested as a result of the additional buses and their often erratic jockeying for passengers. Overall, the image of the bus system worsened, and the popularity of cars increased. According to one observer, bus service

> "… had fallen entirely under the control of a entrepreneurial cartel that controlled prices and governed competition. Excess capacity had developed, estimated in the range of 35-40%, 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."[22]

Local authorities responded in 1990 with a new innovation: route tenders.[23] 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 decide the point of origin and destination of tendered routes, but beyond the regulated area, operators can determine the route and frequency they prefer. Outside the restricted area, competition is open: any operator may provide service.

Bus service dropped dramatically on affected routes, as intended. Along Avenida Libertador Bernardo O'Higgins, the number of buses dropped from 1200 per hour in March 1990 to 550 per hour after the tender.[24] 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).[25] 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 US$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 apparant downside to the tender process is reduced service in the targeted areas, and increased congestion resulting from a concentration of buses along some routes just outside the tendered routes.

The principal government investment in buses has been in dedicated bus lanes. In 1995, 5 kilometers of segregated bus lanes were built. Additionally, non segregated bus-only lanes were established along some important transport corridors. This investment in bus lanes is greater than in most cities, though proportionately less (in terms of bus operation) than in cities such as Tokyo and Curitiba.[26] Several projects for additional bus lanes were specified in the 1995 Development Plan for the Greater Santiago Urban Transportation System, but were not begun until 2000.

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 highly dense cities. Indeed, the stretch of rail built in the 1990s cost over US$370 million, and was the largest public infrastructure project carried out in Chile during the decade.[27] The construction of the Metro was paid for by government, but it is now one of the world's few heavy rail passenger systems that does not require government subsidies for operation.

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 Metrobus tickets with a reduced fare 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 other stations along the line. In most corridors, buses continue to operate in competition with the subway system. The rail system serves 5% of total urban trips[28] and the Metrobus another 1%.[29] Normal (non-Metrobus) buses serve almost half of all trips.

2.3. Colectivos and Taxis

Colectivos and taxis serve the gap between 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 Transportation and Telecommunications. In 1978, as part of economic liberalization, limits on the number of taxis were lifted. In 1984, Greater Santiago had over 25,000 taxis, one taxi for every 160 inhabitants.[30] By 1996, it had over 50,000 taxis, one for every 100 inhabitants. In 1997, at the suggestion of CONAMA (the National Environmental Commission), the number of taxis in Greater Santiago was frozen to allow time to review their impact on city pollution problems. The taxi fleet remains frozen at that number.

Colectivos are a taxi-like service along fixed routes, using cars that carry up to five passengers. This paratransit service started as an experiment in 1967, with 380 vehicles covering 19 routes. It has continued to expand, providing a service intermediate between taxis and buses. They offer faster travel than buses at about three times 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 Transportation Ministry banned colectivos from the Avenida Libertador Bernardo O'Higgins (Santiago's main street) in an attempt to reduce traffic congestion along this congested route. An implicit goal of this measure was to demonstrate that the restrictions applied in 1991 were not directed solely at buses.[31]

2.4. Cars in Santiago

The ownership and use of cars in Santiago has increased substantially in the last 30 years.[32] In 1966, less than 50,000 cars were owned by the 2.4 million residents of Greater Santiago – roughly 2 per 100 inhabitants. This rate was relatively low, even when compared to other developing country cities of that time, including Manila (7.7 per hundred) and Teheran (4.4 per hundred).[33] That year, just 7.6% 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 6 per hundred inhabitants, with cars carrying 9.8% of trips.

Those high 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 '70s. When the economy was opened in the late '70s, these nascent companies largely disappeared. No cars are produced today in Chile (though some are assembled from knock-down kits).

Import restrictions on cars were eliminated during the late 1970s and early '80s, resulting in access to cheaper and better cars. From 1977 to 1991, the population rose 30%, while cars increased 94%, resulting in 9 cars per hundred inhabitants. This trend has continued, with Santiago's rate reaching about

13 in 1998. This motorization rate is low compared to cities in developed countries, but the number of vehicles has continued to increase about 10% per year in recent years.

3. Urban Policies and Strategies

The rapid growth in vehicle usage began to create significant traffic congestion and air quality problems during the 1980s. 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 non-catalyst equipped cars (which was virtually all vehicles) were banned from traveling in much of the municipal area. The restrictions were based on the last number in 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 applied nine months every year. On especially severe pollution days the restriction is extended to more license numbers and more hours. On emergency days, 80% of non-catalyst vehicles (approximately 40% of the car fleet in 2000) are not allowed to circulate. The restriction has become increasingly controversial, because its effect diminishes as catalytic converters become more common and because it discriminates against the poor who cannot afford new catalyst-equipped cars.[34] 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. It required bus fleets to eliminate the oldest vehicles,[35] imposed increasingly stringent emission standards on new buses, allowed only the cleaner new buses on the city's main routes,[36] and required more stringent emissions inspections and enforcement. It also required cars from 1992 onwards to meet tight exhaust emissions standards (achievable only with catalytic converters), adopted and implemented a toughening of vehicle inspections, and accelerated street paving and cleaning to reduce dust and particulate matter. The measures were quite extraordinary, but only slowed the escalating pollution and congestion problems.

At the end of 1995, the Transportation Secretariat (SECTRA) mounted a large transport study to develop a 15 year plan for Santiago. Models were developed to study changes in infrastructure, land use, and a variety of financing and market instruments. The base scenario for 1997-1998 incorporated projects and road improvements programmed as of 1995. An important goal of the Plan was to maintain the split between transport 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 the following: an immediate fee of US$4 to enter the city center during peak morning hours for all vehicles except buses; a road-use charge varying between 12 cents and US$4 per km depending on location, beginning in 2005; parking fees according to trip purpose (work, study, 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 km/hr in 1991 to 20 km/hr in 2005, while public transportation speeds would rise from 16 km/hr to 19 km/hr.

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 US$ 2.8 billion, well above financing for previous programs for the city of Santiago.

None of the proposed instruments have been adopted. The only significant investment has been the building of Line 5 of the Metro. Road fees were specifically rejected by politicians.

3.1 Air Pollution Prevention and Decontamination Plan (APPDP)[37]

Santiago is one of the most highly polluted cities in the world.[38] 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 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 ozone in spring and summer. Short and long term health effects have been documented,[39] including mortality and morbidity related to particulates. The transport system is the primary source of Santiago's air pollution. Mobile sources contribute 92% of the city's carbon monoxide emissions (CO), 71% of nitrogen oxides (NO_x) and 46% of volatile organic compounds (VOC). The latter two are precursors to ozone formation. Transportation is directly responsible for only 7% of particulate emissions, but is indirectly responsible for the large amounts of dust stirred up by vehicles on roads and is also the principal source of the smallest and most health-threatening particles (as it is in the US and elsewhere). Buses are believed to be the principal source of these health-threatening fine particles and, because they operate in dense population areas and therefore directly expose many people to the pollution, are believed to cause the greatest health effect. Buses are also a major source of NO_x, while cars are major sources of CO, NO_x, and VOCs.[40]

In June 1998 the regional Environmental Commission launched the Greater Santiago Air Pollution Prevention and Decontamination Plan. This umbrella plan developed 54 specific measures. The planning process involved many government agencies and more than 300 representatives of non-government organizations, business, government, and academia. The proposed measures were intended to 1) improve vehicle emissions with strengthened vehicle emissions standards; 2) improve diesel and gasoline fuel quality and introduce clean-burning alternative fuels, with pilot programs for CNG and LPG; 3) enhance transit, by building more dedicated bus lanes and improving bus terminals and transfer facilities; 4) restrain use of cars, taxis, and trucks, with higher taxi license fees, freezes on number of taxis, reduced parking, higher parking fees, new road user fees, higher registration fees for polluting vehicles, prohibitions on truck operation in designated areas at peak hours, favored access to low-emitting trucks (with emissions certificates), and improved cargo infrastructure and terminals; 5) improve pedestrian and cycling facilities; and 6) utilize new communications technologies to enhance transit and traffic management.

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 those measures, for those that could be monetized, was about US$1 billion, but there were many more measures that had not been sufficiently specified to be be monetized. [41]

After two years, less than half the measures scheduled for that period have in fact been adopted or advanced.[42] Those that have been acted upon are the easiest and cheapest to adopt; they are mostly low cost technological changes, and tend to have little impact. The most important success may have been tightened emission standards for buses (equivalent to the US's 1994 bus standards). However, fuel changes were delayed due to resistance by the state-owned oil company, and traffic operations changes were ignored. Road user fees also were not adopted, and parking fees were only sporadically applied. Infrastructure initiatives, such as segregated bus lanes also did not advance. This lack of action, even for relatively simple measures, signals that broader and more expensive initiatives, such as redesign of the bus system, will progress slowly or not at all. [43]

Finally, natural gas is being tested on some buses and its future use will be decided based on the results. The government offered a subsidy to the first 40 buses to convert, since natural gas buses cost considerably more than diesel buses, but no further subsidies since. Operators, skeptical of the economics of natural gas buses, have not embraced the vehicles.

Advances in reducing Santiago's air pollution depend strongly on the relationship between CONAMA and the government agencies that oversee transportation activities, and support from businesses and voters. Improved air quality – and reduced traffic congestion and greenhouse gases – will often require behavioral adaptation, impose some extra costs, and adversely affect some interests. Considerable political and educational effort is necessary to accomplish change.

3.2 Major Public Initiatives and Forces of Change in Urban Areas

Santiago and other smaller cities are expanding rapidly. This growth is occurring along several dimensions that have direct effects on energy use and greenhouse gas emissions.

1. **Car ownership**. A major driver of change for the transport system is car ownership (and use). With Chile's economy expected to grow at close to 6% per year, the car population is likely to double every ten years.[44]

2. **Traffic congestion.** Public pressure for traffic solutions is mounting. The Development Plan for the Urban Transportation System was a first response. The route tendering program has been important. More changes are being demanded.

3. **Environmental stress**. Santiago's air pollution is motivating efforts to restrain vehicle use and enhance public transport. However, if the current politics and institutional framework remain, it is unlikely that this will occur. The most politically feasible options are technological, especially reduced emissions from vehicles.

4. **Urban form and governance**. Chile and Santiago are rapidly urbanizing. 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 the growth must be better managed. The national Housing Ministry is aiming to contain growth within the city limit so that the city densifies. The national government also intends to encourage better connection of suburban centers to Santiago.

None of these phenomena are motivated by the reduction in greenhouse gas emissions. But responses to traffic congestion, pollution, and urban sprawl are largely consistent with the drive to reduce greenhouse gas emissions

4 Interurban Transport in Chile

The principal modes of interurban passenger transport in Chile are car, bus, train and airplane; and the principal interurban freight modes are truck, rail, and ship. Data are sparse and uneven for interurban transport, but it is clear that major transformations have occurred over the past few decades.

Tables 4 and 5 present overall trends in intercity passenger and freight transport, using available data.[45] As indicated, the importance of buses has been steadily decreasing as the car increases in importance, more so in recent years. Between 1990 and 1998 the number of cars passing through interuran toll booths increased by 88%, while the number of passengers on buses and rail have stagnated (though as indicated later, rail is expected to stage a resurgence). The largest increase was airline travel, with average increases over 11% per year. Around 1995, cars caught up with buses in number of passengers transported,[46] and are now becoming steadily more important.

Table 4: Interurban travel in Chile: 1990-1998

Year	Cars*	Bus (pass/year)	Rail (pass/year)	Airplane (pass/year)	
				Domestic	International**
1975	2,456,799	376,830	20,554,000	301,945	227,035
1985	3,887,856	621,871	8,914,305	563,471	263,440
1987	4,394,366	616,142	7,239,290	645,918	345,058
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,
**Only considers national enterprises,
Sources: "Anuario Estadístico", years 1990, 1994, 1998, INE.

The principal difficulty with freight transport is that the numbers are not readily comparable. Tonnes transported in one mode cannot be directly compared to tonnes transported in another mode (for instance, a shipment of one tonne of coal generates much less revenue and is much less time sensitive than a one tonne shipment of computer chips). Also, good historical data are not available for tonnes and tonne-kilometers transported by trucks, the most important mode. With these caveats, Table 5 presents some trends. Truck transport is the most important mode, followed by ship, rail, and then airplane. However, when only national freight transport is considered, trains and ship transport are similar.

Investment in trains has stagnated for decades, and freight trains have steadily lost market share to trucks and ships. Total ocean shipping has increased sharply over the past few decades, but almost all of it is for international cargo. Coastal shipments within the country have been relatively constant at around 16-20 million tonnes per year. Air cargo shipments are increasing sharply, but the quantity shipped is small.

Table 5: Freight transport by mode, 1960-1998

Year	Railroad (tonnes)	Air (tonne-kilometers)***		Ships (tonnes)
		National	International*	Total
1960	9,868,000	**	**	27,406,000
1970	13,967,000	**	**	**
1980	16,961,000	**	**	43,779,598
1990	19.134,000	**	**	47,751,822
1995	17,401,529	17,043	168,723	59,064,240
1996	18,215,482	23,359	181,766	64,378,591
1997	18,012,214	27,385	213,611	64,769,457
1998	20,634,277	29,709	229,910	64,407,665

*Includes cargo loaded and unloaded.
**Not available.
***Data for tonnes are not available. 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."

4.1 Freight and Passenger Railroads

The first trains in Chile were privately owned and used for mining in the north of Chile. When various mines stopped or slowed production due to low international prices, the State acquired the lines, creating the State-owned system, Ferrocarriles del Estado (FFCC del E). 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% in 1890), by 1975 almost 88% was in State hands.

Along with an extensive domestic rail network, five international rail lines have connected Chile with Perú, Bolivia and Argentina. The line to Peru is maintained for political reasons; one line to Bolivia is highly profitable, carrying minerals; another line to La Paz, Bolivia, built in 1913 as part of Chile's obligations to Bolivia, is a key passenger and cargo link that loses money; and the line to Argentina ended passenger transport in 1979 and freight in 1984.

Even with government subsidies of the railroads, road transport has continued to increase its share of both passenger and freight travel. The State rail company, did not operate like a business. For example, FFCC del E served remote locations in the north, operating passenger trains until the 1970s, well after privately-owned cargo trains had ceased service. It had 25,000 employees, its own hospital, funeral parlor, and a variety of other ancillary services. Even with substantial subsidies, the quality of service steadily declined.

During the 1973-1990 market reforms of the military government, rail maintenance and capital investments were deferred, 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 transport. Their policy was to maintain state ownership of passenger rail systems (understanding that privatization was not possible without large public subsidies estimated at US$140-150 million), and to privatize freight rail lines.

The government spent US$28 million improving tracks close to Santiago and between two other cities, and additional funds for modern suburban ("metrotren") passenger services. On targeted routes, the decay of the passenger train system was reversed, with significant increases in ridership. By 1997, the government had sold off the train network just north of Santiago, used principally for cargo, and in the south had sold the right to use tracks (rather than the tracks themselves). Traffic stabilized in the north and increased in the south. It is widely viewed that the decline in rail service has been halted, and that both passenger and freight service are starting to expand, albeit slowly.

4.2 Interurban passenger buses

In the 1970s, the bus system was transformed from a heavily regulated sector to a competitive, deregulated service.[47] Until the mid-seventies, 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 the rigid control of the importation and distribution of buses. Holders of concessions were free to increase the frequency of their services, and maximum passenger fares were fixed nationally, based on class of service and route length on paved and unpaved roads. In August 1978 it eliminated fare controls, and in November 1979 opened the market to new companies.

Unlike the trucking sector, 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. The industry has remained relatively stable as a result, unlike the less concentrated trucking industry. In the 1980s, intercity bus services consolidated. They offer diverse service with relatively stable fares.

4.3 Trucking

The trucking industry has been less stable. Trucking became increasingly important in the sixties as highways developed. Like buses. it 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% and industry capacity increased 33%.

In 1982 Chile (and the rest of Latin America) went into a severe recession, and the peso was severely devalued. Demand for trucking fell an estimated 70% (for trucks of more than 11 tonne capacity), while fuel and parts prices increased. 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 nineties, strong economic growth has eased the problems of the trucking sector, though many 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 fruit, forestry products, and mining. Larger, better organized and more professional trucking companies have emerged. However, the sector is still atomized. On average, there are less than three trucks per owner, and many own just one truck.

The net result of these changes has been a large increase in trucking activity. The number of large long-haul trucks passing through toll booths tripled between 1985 and 1998 – from 359,000 to 1,077,000, while in the same period smaller trucks doubled their activity.[48]

4.4 Ocean Shipping

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 Chile is geographically isolated from its main markets, a large fraction of its exports are shipped by sea. Similarly, a large fraction of imports are heavy goods, such as cars and oil, which are also shipped. Hence, seaports play an important role in the economy.

The operation of ports, like many other government activities, was reorganized during the eighties. Until 1981, Chilean ports were operated by the state, and operations were inefficient. In 1981, a new law allowed private firms to enter the business of handling and moving goods at ports. Port ownership is now mixed -- 10 are state owned and 22 privately owned – but all are privately operated.

Ocean shipping over the next fifteen years is expected to increase six fold, requiring port infrastructure investments over US$1 billion.[49] Most of this increase in traffic will come from international trade, since domestic coastal shipments of freight are expected to remain relatively constant.

4.5 Trends in Transport Infrastructure

The country invested relatively little in transport infrastructure during the 1970s and '80s. During these two decades, the population increased 40% and economic activity 60%, yet total investment by the Ministry of Public Works (MOP), the institution in charge of infrastructure construction and maintenance in Chile, *decreased* by 34%. In 1990, the new government addressed the infrastructure deficit through increased public investment and an ambitious franchising program.[50]

Under the latter program, a private firm builds and finances the infrastructure project, and then collects user fees for a specified period of time. In 1991 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, fourteen highway projects were franchised for an investment of over US$3 billion. Another 135 infrastructure proposals, mostly highway franchises, have been filed by private firms: 100 have been rejected and 9 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% reduction in diesel fuel taxes.

Private investments in infrastructure increased from zero in 1990 (excluding ports where private investments were significant) to US$ 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 km of paved interurban roads, almost 60% more than a decade earlier.

Table 6 summarizes investments in roads, airports and ports through the 1990s. Most of the investment was for roads. Over $2 billion of the $3 billion private investment in roads, is being committed to repave and add lanes to Route 5, the 1500 km north-south highway. Improvements are also being made to Chile's 15 major airports, in particular Santiago's International Airport, basically with investments from the private sector. The infrastructure of the main seaports have also been improved, and a new port built in Punta Arenas, the country's most southern port.

Table 6: Total Investment in Roads, Ports and Airports in the 1990s (Million US$).

	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% of this was private sector funds.
**54.6% was private sector funds.

***Data are for State owned ports only.
****83.2% was privatge sector funds.
Source: "La década de la infraestructura 1990-1999", Ministerio de Obras Públicas.

With more private investment is diverted to highways, 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.

4.6 Summary

Market forces are the principal force shaping the expanding interurban transport, increasingly so since the deregulation and privatization of the 1980s. A large share of services and infrastructure have been transferred to private ownership and /or control. Freight trains, trucks, interurban buses are now completely private. Those services that could not compete have disappeared or been 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.

In summary, market forces are playing a dominant role in interurban transport. The resulting trends are clear. In freight, truck is by far the most important mode and will continue to expand in the future, though rail is now stabilized. And cars are slowly increasing their market dominance over buses. The lone exception to this reliance on market forces and private competition may be suburban passenger transport, buoyed by substantial state investments.

5. Energy Use and Greenhouse Gas Emissions

Energy consumption by the transport sector continues to increase, tripling from 1977 to 1997. Almost all the energy is based on petroleum. The increases cut across for both passenger and freight, and urban and interurban. Passenger travel now consumes about twice as much energy as freight travel, and urban travel consumes about 42% of national transport energy versus 58% for interurban travel. The main energy consuming modes are cars (43%), trucks (24%), ships (13%), buses (10%) and planes (10%). Trains consume much less than 1% of energy.

The principal transportation fuels are gasoline and diesel fuel (derived from petroleum), each accounting for over 40% of the total.[51] Almost all personal cars and a majority of light and medium duty commercial vehicles (including pickup trucks and vans)[52], used for both business and mass transit, burn gasoline. Approximately 20% of of light and medium duty commercial vehicles burn diesel. Most taxis use gasoline, but a few use diesel and, in the far south, 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% of the transport energy is derived from petroleum, 95 percent of it imported.

Reduction in oil imports and greenhouse gas emissions are not priorities nor major issues in Chile. Chile did, howeer, sign the Rio Summit Framework Convention in 1992, and it became law on April 13, 1995. This Convention requires that developing countries report on greenhouse gas emissions for a reference year. In response to this requirement, CONAMA prepared an inventory of greenhouse gases for Chile for the year 1994.[53] Transportation was found to be responsible for almost 40% of total energy sector emissions,[54] equivalent to about 28% of the nation's CO_2 emissions.

A detailed analysis of the transport sector conducted subsequently for 1997 is provided in Table 7. Only carbon dioxide is analyzed, but since 99 percent of the fuel combusted was derived from petroleum, the relative shares would be accurate even if all greenhouse gases were included.

Table 7: CO_2 Emissions by Mode, 1997 (Gg)

Mode	Urban		Interurban		Total
	Passenger	Freight	Passenger	Freight	
Cars	5,841	-	2,152	-	7,993 (43%)
Private Cars	2,507	-	1,332	-	3,839
Light Duty	1,542	-	820	-	2,362
Taxis	1,792	-	-	-	1,792
Bus	1,457	-	314	-	1,770 (9.5%)
Metro	0	-	-	-	0
Truck	-	507 *	-	3,883	4,390 (23.5%)
Train	-	-	8	36	44 (0.24%)
Ship	-	-	-	2,549	2,549 (13.7%)
Plane	-	-	1,861	-	1,861 (10%)
Total	7,298 (39.2%)	507 (2.7%)	4,335 (23.3%)	6,468 (34.8%)	18,608 (100%)

* Only Santiago

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.

As indicated in Table 8, on a per capita basis, Chile's transportation sector is a relatively high emitter of greenhouse gases, given its income (see Table 2). While it produces only 1/6 as much as the US, Chile's transport-related GHG emissions are about half as great as Japan and the United Kingdom, which are far more affluent. It also produces more CO_2 per capita than South Africa, which has a higher motorization rate, is less affluent, and makes extensive use of CO_2-intensive synthetic fuels. Chile's relatively high per capita rate is due largely to extensive use of trucks and the large amount of intercity freight and passenger travel (including considerable plane travel). On the other hand, Chile is a minor contributor to global climate change. That is because Chile only has 15 million people, and thus is a small net user of energy and producer of GHGs, and also because Chile's extensive vegetation-rich land absorbs through photosynthesis most of the CO_2 produced in the country -- about 92% according to one estimate.[55]

Table 8: CO_2 Emissions for Various Countries (1998)

Country	Carbon Dioxide Emissions Per Capita from Transport (kg)	Transport Sector Percent of Total Carbon Emissions	Cars Per 1000 People (1996)
Chile	**1028***	**28%**	**110**
China	**178**	**8%**	**8**
India	**120**	**13%**	**7**
South Africa	**870**	**10%**	**121**
Japan	1971	22%	552
United Kingdom	2238	24%	441
United States	6082	30%	769

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**.

6. Scenarios

Chile's economy and transportation system are expanding and evolving. Will current trends continue and, if so, what are the implications for GHG emissions? A definitive response is not yet possible. Careful research on policies that are socially, economically and environmentally desirable and attainable is needed. Much more information needs to be gathered on economic growth, technological improvement, and travel and vehicle purchase behavior. Given uncertainty and limited knowledge, two plausible greenhouse gas emissions scenarios are developed for Chile.

Scenarios are a commonly employed technique for dealing with complexity and uncertainty in forecasting. Ideally, one generates relevant information using credible research methods and objectively analyzes it with alternative scenarios of the future. The scenarios reflect believable, 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 strategy.

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 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 enhancing public transport.

6.1 High Emission Scenario: 2000-2020

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. The result is a 117% increase in GHG emissions from the transport sector over the next 20 years.

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

Government plays a passive role in this scenario. Current trends are maintained, with car and truck travel continuing to increase, and bus and most rail transport losing market share. Traffic congestion continues to worsen. As more families become car owners, including virtually all the business and government leaders, political pressure grows for more road infrastructure and less restrictions on vehicle purchase and use. The result is more highways to reduce congestion, encouraging even more car use, pollution and urban sprawl. At some point, traffic congestion would become stifling, and road infrastructure and oil imports costs would be deemed unacceptable. However, this might not occur for several decades, beyond the 2020 horizon.

The elements of this business-as-usual scenario closely follow the forecasts developed by O'Ryan and Turrentine (2000) as background for this report. MEPLAN, a sophisticated integrated land use and transport model developed by the Ministry of Public Works (MOP), was used to project transport demand.[56] The model is premised on forecasts of various economic and demographic parameters. The principal parameters used in the model for the 2000-2020 period are as follows, expressed as percent change per year: GDP 5.8%, consumption 5.4%, investment 6.9%, population 1%, and households 2.2%. Using 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 1997 and 2020, for both urban and interurban travel.The results are presented in Table 9.

As indicated, passenger-kilometers increase 141% during the 2000-2020 time period, and freight by 59%. Cars increases their share of passenger travel from 31% to 39%, largely at the expense of buses. However, most travel is still by bus, for both urban and interurban travel -- somewhat more than half for urban travel and somewhat less than half for interurban. Interurban passenger travel increases most rapidly, more than tripling, while urban travel increases two fold. Air travel has the largest percentage increase, but still only accounts for 7.5% of travel. In freight, truck accounts for about ¾of freight movements in 2000, and retains that percentage over time.

Fuel economy and GHG emission factors for each type of vehicle are presented in Table 10. The fuel economy parameters were used as inputs to estimate GHG parameters. Dr. Mark Delucchi of the University of California, Davis converted the modal split, load factor, and energy use factors into GHG estimates. The appendix describes Delucchi's calculations of fuel cycle CO_2-equivalent measures for each scenario. He adapted for Chile a detailed model developed earlier for OECD countries and other case study countries analyzed in this series of reports on transport in developing countries.

Table 9: Key Parameters for Scenarios

	2000	2020	
		low	high
Total travel			
Total passenger travel (ratio)	1	2.17	2.41
Total freight travel (ratio)	1	1.51	1.59
Passenger per vehicle			
Passenger car	1.9	1.9	1.9
Mini car	N/A	1.5	1.5
Bicycle	1.0	1.0	1.0
Minibus	16.0	16.0	16.0
Bus	34.0	40.0	34.0
Average load factor (% seats filled)			
Metro	0.40	0.44	0.40
Interurban train	0.70	0.77	0.70
Modal shares of total passenger kilometers			
Gasoline cars	0.29	0.18	0.36
Diesel cars	0.02	0.03	0.03
Natural gas cars	-	0.05	0.00
Electric cars	-	0.03	0.00
Electric minicars	-	0.05	-
Diesel buses	0.65	0.21	0.59
Fuel cell bus (Hydrogen	-	0.42	-
Walking	0.02	0.01	0.01
Metro	0.01	0.01	0.01
Interurban train	0.01	0.01	0.01
TOTAL	**1.00**	**1.00**	**1.00**
Modal shares of total tonne kilometers			
Large truck (diesel)	0.65	0.58	0.63
Medium truck (diesel)	0.20	0.18	0.20
Large truck (CNG)	-	0.05	-
Medium truck (CNG)	-	0.02	-
Train (diesel)	0.02	0.02	0.02
Cargo ship (fuel oil)	0.08	0.09	0.09
Tanker (fuel oil)	0.03	0.03	0.03

Barge (fuel oil)	0.02	0.02	0.02
Pipeline (electricity)	0.01	0.01	0.01
TOTAL	**1.00**	**1.00**	**1.00**

Table 10: Greenhouse Gas Emission for Passenger Vehicles and Fuels in Chile, CO_2-equivalent Grams/Vehicle-kilometer

	2000		2020	
Mode	**Fuel**	**GHG**	**Fuel**	**GHG**
	Liters/100km	g/vehicle-km	Liters/100km	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 bus (hydrogen)	-	-	-	234
Electric minicars				37
Metro	-	[45 g/pass-km]	-	[34 g/pass-km]
Inteurban train	-	[31 g/pass-km]	-	[23 g/pass-km]

*Diesel vehicles are larger and older than gasoline cars, thus the fuel economy is lower.

Based on the parameters in these two scenarios, the total GHG emissions for this 2020 high scenario are presented in Figure 3. In the period 2000-2020 total fuel cycle greenhouse gas emissions increase 117%. Total greenhouse gases from passenger transport increase faster, by 149%, while freight increases only 42%. As a result, passenger transport increases its share of transport greenhouse gas emissions from 70% in 2000 to 80% in 2020.

Figure 3: GHG Emissions from passenger and freight transport in Chile (2020)

WE WILL CONVERT THE FOLLOWING NUMBERS INTO A BAR CHART

Ratio of Greenhouse gas emissions 2020/2000	2020	
	LOW	HIGH
Passenger Travel	1.42	2.49
Freight Travel	1.31	1.35
Total	1.32	2.17

The principal source of the increased greenhouse gas emissions are from increased use of cars and other light duty vehicles owned by private indiviuals and businesses, especially in urban areas. Most of the increase in emissions from interurban transport are due to increased use of diesel trucks.

In summary, the high emissions scenario is one of rapid expansion in vehicles, energy use, and GHG emissions. The economic costs 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.

6.2 Low Emissions Scenario for Chile, 2000-2020

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

To construct this low emission future, a series of assumptions and projections have been made. To maintain the focus on transport and environmental variables, this scenario assumes the same economic growth rates as the high scenario. If a lower growth were used, the motorization rate would be slowed, and freight shipments would be less, resulting in reduced greenhouse emissions.

As discussed previously, transport 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 land, and disproportionate producers of greenhouse gas 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. One cannot expect another set of radical changes in the foreeable future.

However, one can imagine using the market-based policy approach embraced in Chile to accomplish societal goals. In this scenario, government is more aggressive and assertive in supporting public transport and managing motorization. Air pollution and traffic congestion, along with economic pressures to restrain road infrastructure investments, are the motivating forces. The net effect of a variety of assertive public initiatives is a slight increase in cars' share of passenger travel, from 31% in 2000 to 34% in 2020. Signficantly, this market share is sharply lower than the 39% share gained in the high scenario. Additionally, the operation of the bus system is improved substantially, controlling off-peak occupancy rates that are extremely low. Reductions in bus frequency in off peak hours are undertaken, ensuring however that these are still attractive so as to not offset the efforts to improve bus share. As a result, these increase from an average of 34 to 40 passengers.

Measures taken to accomplish this goal in urban areas include parking restrictions, road pricing, and vehicle usage restrictions, coupled with improved bus systems (e.g., integrated routing and fare structures, comfortable buses, exclusive right of way for buses), and more and longer Metro lines. The result of increased comfort and improved quality of service is greater utilization of buses and Metro trains.

One of the most important changes in policy is the elimination of tax breaks for larger, less efficient light and medium duty vehicles, which have become attractive to many households. The final result is a 10% reduction in total passenger-km travelled, and 5% of freight travel, this latter basically due to urban restrictions to freight transport.

It is assumed that suburban trains pick up substantialy more passengers than in the high scenario, i.e, efforts to improve medium distance trains from Santiago to Temuco and to Valparaíso prove very succesful. Consequently, it is assumed that instead of the projected 77% increase in passenger km between 2000 and 2020, that implies a yearly growth rate of 2.9% for the train, a yearly average growth rate of 6% is obtained.

Air pollution rules are directed at encouraging more use of light and heavy duty natural gas vehicles, which have the side benefit of lower GHG emissions and oil imports. It is assumed that there is a full-fledged commitment to introduce this fuel. Its use in buses and urban trucks will provide large air quality benefits, but most important here is the use in cars, taxis, and light trucks. The use of natural gas in diesel-powered buses and trucks produces few if any greenhouse gas benefits, but when used as a subsitute for gasoline, typically in cars and light trucks, the benefits are large. It is assumed favorable taxes on this fuel plus other supportive measures, such as consumer credit, subsidies, and prohibitions to enter downtown zones with petroleum fuels, are enacted.

Specific measures include massive conversion of urban buses to natural gas, which by itself does not lead to GHG reductions, but it has several other advantages, in additon to cleaning the air. First, it creates 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 also provides the fuel infrasctructure for making hydrogen at fuel stations. The hydrogen would be used to fuel the fuel cell buses that are gradually introduced after 2005 (initially with international subsidies). A massive shift to CNG by taxis and small and medium duty trucks follows, and eventually by private cars and light and medium duty vehicles, with large GHG benefits (since these vehicles are converting from gasoline rather than more energy efficeint diesel). In addition, strong support for air pollution reduction leads to the introduction of battery electric vehicles in cities – for both private passenger cars and many light and medium duty vehicles used in cities.

The net result by 2020 is that in urban areas, all taxis and about 1/10 of private cars and small (cars and light trucks) light and medium duty vehicles are running on CNG, and all buses are hydrogen-fueled fuel cell buses. An additional 5% of private cars and 10% 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.

In summary, the low emissions scenario is one that combines rapid expansion in vehicles and energy use with effective decontamination and urban policies. Inteurban transport is affected only through the switch of smaller trucks to natural gas and increased use of the train. The results are lower unit emissions and less passenger and ton kilometers travelled.

The impact on GHG emissions are presented in figure 3, relative to 2000. By 2020, the environmental consequences of this scenario would be an increase in GHG emissions of ONLY 32%. Though significant, it is much lower than the 117% increase obtained under the high scenario. In relative terms, total emissions in the low scenario in 2020 would be 39% less than under the business as usual case.

7. Conclusions

In the last twenty years Chile's ecomomy has transitioned from relatively slow growth to dynamic, market oriented, fast growth. Between 1985 and 1998, the economy's output increased 2.5 times and the transport and communications sector by more than 3.5 times. Transport now accounts for 1/3 of the nation's energy use. This fast growth is expected to endure.

The car plays a central role in determing the transport and greenhouse gas future of Chile. Cars are the key player in transport growth, in both urban and interurban travel. Private and light and medium duty vehicles account for 45% of Chile's total greenhouse gas emissions, followed by trucks at 24%.

If current patterns prevail, as in the high business-as-usual scenario, car and truck use will continue to expand at a rapid rate, and greenhouse gas emissions will more than double. Cars will increase their share of transport's greenhouse gas emissions from 45% of the total today to xx% in 2020. Is there another plausible future? Until recently, the environmental consequences of Chile's rapid development received little scrutiny. of the enviromental consequences. That changed around 1990, when attention was drawn to Santiago's increasingly severe air pollution and traffic congestion (as well as pollutoin from some copper smelters). Since 1990, the environment has become a legitimate policy issue, and transport 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. One cannot expect another set of radical changes in the foreeable future. However, one can imagine using the market-based policy approach embraced in Chile to accomplish societal goals. Indeed, Chile has come to rely on market forces to guide public decisions. Most transport 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 scenario constructed for this report is premised on restraint of cars. It is premised on an understanding that climate change is not on CONAMA's list of priority problems, but that many measures aimed at other higher priority environmental concerns will have the side effect of reducing greenhouse gas 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 include road tolls, elimination of tax breaks for larger cars and light trucks, parking and vehicle usage restrictions, coupled with improved bus systems (e.g., integrated routing and fare structures, comfortable buses, exclusive right of way for buses) and more and longer Metro lines. Additional incentives to improve fuel economy and use natural gas fuels would have additional multiple benefits. The result is only a 34% increase in emissions between 2000 and 2020.

In the end, it is difficult to imagine a near to medium term future in which greenhouse gases do not increase significantly. The lesson is that now is the time to begin laying the foundation for more fundamental long term changes.

APPENDIX:

Research Approach

This report was a collaboration between researchers at University of California, Davis and Univeristy 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. Raul O'Ryan and Dr. Mark Deluchi. Dr. O'Ryan generated the first set of travel and energy assumptions and parameters for the scenarios. After extensive consultation among authors, and with others, the final set of parameters was specified. These numeric measures were converted by Dr. Delucchi into quantitative greenhouse gas emissions estimates for the two scenarios.

INTERVIEWEES

Francisco Martínez, Civil Engineering Department, Universidad de Chile.
Rodrigo Fernández, Civil Engineering Department, Universidad de Chile
Sergio González, ex Transport under secretary
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 Malbran, consultant for 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

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 greenhouse gases are also emitted at each source. An evaluation of greenhouse gas 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. Mark Delucchi of the Institute of Transportation Studies at the University of California, Davis has developed a detailed, comprehensive model of lifecycle emissions of urban air pollutants and greenhouse gases 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 fuel types 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 South Africa for materials, manufacturing, and construction.

The LEM characterizes emissions of greenhouse gases 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. 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 was also 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 greenhouse gas 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 ECEE (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. DOE Office of Fossil Energy (2001) provide data on efficiencies of Chilean powerplants. It is assumed that current and future gas-fired powerplants are of relatively modern design, and have emissions levels similar to gas-fired turbine plants in the U. S., but that oil and coal-fired plants are older and relatively dirty, and that the sulfur content of coal used in Chile is relatively high (EIA, 2001c).

Oil and Gas

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

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[32] The numbers in this section come mostly from Thomson, 1995, ibid.
[33] See Thomson, 1995, ibid.
[34] In 2001 restrictions were applied for the first time to catalyst equipped cars.
[35] Over 2600 buses over 18 years of age were scrapped in 1991, followed by another 2000 more during the following three years. These measures cost the State US$14 million in compensation payments, but reduced the number of buses to the current 9,000.
[36] The opportunity was taken to include a clause to this effect in the route-auctioning process.
[37] The description of the APPDP is based on Conama's Final Report, 1997, "Plan de Prevención y Descontaminación Atmosférica de la Región Metropolitana (PPDA)".
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[43] However, in June 2000, an emergency plan was applied that included destinating six important arteries for buses, i.e. excluding car circulation. The plan worked, congestion problems were minor and initial estimations suggest that emission were reduced.
[44] Analyses by P. Arellano, based on information from income survey 1987-88, suggest that the income elasticity of demand for car purchases in Chile are about 2.3. But even with much lower elasticities, car ownership will increase faster than economic growth, as it does almost everywhere in the developing world.
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[55] CONAMA, 1999, Primera Comunicación Nacional, bajo la Convencion Marco de las Nacionas Unidas sobre Cambio Climatico, Chile.
[56] However, this demand is also dependent on accessibility in the model, since improvements in infrastructure can reduce transport costs, and increase demand for a given product, or location of economic activities. Demand and supply of goods in the economy are equilibrated through prices, and demand and supply of transport through trip time. This model has been developed and used to predict road infrastructure, port and airport requirements up to 2020.