

# Cost Estimates of Transport Air Pollution in Santiago, Chile

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Findings from a study that attempts to monetize the costs of transport air pollution in Santiago, Chile, are presented. The costs per pollutant used in the study come from a 1994 World Bank study estimating morbidity and mortality costs of air pollution in Santiago, based on productivity losses and treatment costs. Using MOBILE-derived vehicle emissions factors and estimated vehicle distances traveled by various vehicle types, the total estimated transport pollution costs incurred in 1994 are presented. Also presented are estimated average air pollution costs per passenger kilometer traveled for pre- and post-EPA87 standard autos and taxis and pre- and post-EPA91 standard buses, as well as for Santiago's Metro (urban heavy rail). Future air pollution trends in Santiago are discussed, and a theoretical discussion of the potential application of these cost estimates for transportation policy making in the city is provided.

Santiago, Chile's capital, is the nation's largest city, comprising nearly 35 percent of the national population and serving as the economic, administrative, cultural, and academic hub of the country. Santiago has served as a primary driver of the sustained economic growth that Chile has experienced since the second half of the 1980s and as a result, has undergone significant urbanization. Today, the city has 5.5 million residents across an urbanized area of more than 500 km<sup>2</sup>.

The city's passenger transport system consists of walking, bicycling, private automobiles, taxis, shared fixed-route taxis (*colectivos*), buses, an underground metro, and suburban rail. Of the 8.4 million trips per day in Santiago in 1991, more than 50 percent were public transport trips (48 percent bus, 4 percent Metro); 20 percent were walking trips; and 16 percent were automobile trips (1). As of 1994, there were approximately 460,000 private motor vehicles in the city, 10,000 motorcycles, 29,000 taxis, 11,000 buses, and 8,000 *colectivos*. There are approximately 315 concessioned bus lines and 150 shared taxi routes, all privately owned and operated without subsidy. The number of buses running on a particular line are fixed, as part of the concession contract. Virtually all buses are diesel powered and most taxis are gasoline powered. The Metro, an urban heavy rail system running primarily underground, is operated by a state-owned company, Metro, S. A., and is currently composed of two lines. The present system totals 27 km, with 37 stops, 50 trains, and 250 cars. A third line, Line 5, running 10 km from the city center to a middle-class neighborhood southeast of downtown Santiago will begin operation in April 1997.

In recent years, automobile use has increased rapidly, Metro use has increased somewhat and bus use has declined. Suburban rail plays a relatively minor role in urban passenger transport. The major factor leading to increased auto use in the city has been rapid income

growth (average household income growth in the first half of this decade was nearly 5 percent per year) and the subsequent growth in private motor vehicle ownership (which has recently been growing at nearly 12 percent per year). One of the major negative effects of Santiago's current transportation system is severe levels of air pollution throughout much of the year.

## AIR POLLUTION IN SANTIAGO

Much of Santiago's pollution problem stems from the city's climate and topography. A thermal inversion acts as a cap over the city during the fall and winter, inhibiting the dispersion and diffusion of pollutants. Pollutant dispersion is further obstructed by the city's location in a valley almost completely surrounded by mountain ranges or foothills. Pollution concentrations are exacerbated by wind speeds that tend to be lowest during the morning and afternoon, coinciding with peak traffic periods (2).

In 1978, Chile established air quality norms, based on U.S. Environmental Protection Agency (EPA) recommendations, for most criteria pollutants, including total suspended particulates, sulfur dioxide (SO<sub>2</sub>), carbon monoxide (CO), ozone, and nitrogen dioxide (NO<sub>2</sub>). In 1991, official norms were adopted for respirable particulates (PM-10) (3). The air quality norms are presented in Table 1. The government declares preemergency or emergency days when ambient levels of particulates reach unhealthy levels. During these declared emergency days, the government imposes measures, such as restrictions on vehicular movements and industrial activity.

Recent trends indicate relative improvements in ambient concentration levels for PM-10 in the city. The number of days where PM-10 levels were twice as high as established norms (considered preemergency conditions) declined from more than 30 in 1989 to 10 in 1995; the number of days when PM-10 levels were three times as high as established norms (considered emergency conditions) declined from 10 in 1989 to 0 in 1995 (3). Carbon monoxide levels have also been declining in recent years, with the number of days in violation declining from 109 in 1992 to 56 in 1995. Ozone levels, on the other hand, generally have been increasing—norms were exceeded 136 days in 1992, 148 days in 1993, and 154 days in 1994. In 1995, the number of days in exceedance declined slightly, to 142 (3). Measured concentration levels for pollutants in violation typically are two to three times as high as the accepted standard (3). Although levels of NO<sub>2</sub> typically do not exceed established norms, trends in recent years have indicated sharp increases in this pollutant, with peak concentration levels in 1995 nearly twice as high as those recorded in 1992 (3). These NO<sub>2</sub> increases indicate that the challenges in addressing future ozone levels likely will be great.

Pollution concentrations vary depending on location and time of day and/or year. Levels of SO<sub>x</sub> are typically highest in industrial

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