ERJ Express. Published on January 26, 2012 as doi: 10.1183/09031936.00157811

COSTS OF CHILDHOOD ASTHMA DUE TO TRAFFIC-RELATED POLLUTION IN TWO CALIFORNIA COMMUNITIES

Running head: Costs of traffic-related childhood asthma burden

Sylvia J. Brandt, Laura Perez, Nino Künzli, Fred Lurmann, Rob McConnell

Affiliations:
Brandt. PhD. Resource Economics and Center for Public Policy and Administration. University of Massachusetts Amherst. Amherst, USA. Brandt@isenberg.umass.edu.

Perez. PhD. Swiss Tropical and Public Health Institute and University of Basel. Basel, Switzerland. l.perez@unibas.ch.

Künzli. MD, PhD. Swiss Tropical and Public Health Institute and University of Basel. Basel, Switzerland. Nino.Kuenzli@unibas.ch

Lurmann. MS. Sonoma Technology, Inc. Petaluma, California. fred@sonomatech.com

McConnell. MD. Keck School of Medicine, University of Southern California. Los Angeles, USA. rmcconne@usc.edu.

Corresponding author:
Sylvia Brandt
Associate Professor
Resource Economics and Center for Public Policy and Administration
205 Stockbridge Hall
University of Massachusetts Amherst
Telephone: 413-545-5722 Fax: 413-545-5853 Email: Brandt@isenberg.umass.edu

Keywords: asthma burden, vehicle emissions, air pollution, children, burden of disease, economic costs

COSTS OF CHILDHOOD ASTHMA DUE TO TRAFFIC-RELATED POLLUTION IN TWO CALIFORNIA COMMUNITIES

Abstract

Recent research suggests the burden of childhood asthma attributable to air pollution has been underestimated in traditional risk assessments, and there are no estimates of these associated costs. We estimated the yearly childhood asthma-related costs attributable to air pollution for Riverside and Long Beach, California, including: 1) the indirect and direct costs of health care utilization due to asthma exacerbations linked to traffic-related pollution (TRP); and 2) the costs of health care for asthma cases attributable to local TRP exposure.

We estimated these costs using estimates from peer-reviewed literature and the authors' analysis of surveys (Medical Expenditure Panel Survey, California Health Interview Survey, National Household Travel Survey, and Health Care Utilization Project).

A lower-bound estimate of the asthma burden attributable to air pollution was $18 million yearly. Asthma cases attributable to TRP exposure accounted for almost half of this cost. The cost of bronchitic episodes was a major proportion of both the annual cost of asthma cases attributable to TRP and of pollution-linked exacerbations.

Traditional risk assessment methods underestimate both the burden of disease and cost of asthma associated with air pollution, and these costs are borne disproportionately by communities with higher than average TRP.

I INTRODUCTION

Ambient regional air pollution levels are known to exacerbate asthma.[1] In addition, emerging evidence indicates that traffic-related pollution (hereafter referred to as *TRP*) also causes asthma in children living in close proximity to major roadways.[2-4] Traditional risk assessments have not estimated either the burden or economic cost of asthma caused by TRP.[5] In addition, most regional air pollution risk assessments have estimated the burden of disease over large populations with a wide range of air pollution exposure, and these results are not very useful for the development of local policy. Previously we used new methods[5] to examine the burden of asthma outcomes due to regional air pollution and TRP in two communities in Southern California, Riverside and Long Beach.[6] In these communities, vehicular traffic is the primary source for high levels of regional air pollution, and there are heavy traffic corridors in close proximity to residential neighborhoods.

For this study we estimated the economic impact of the air pollution-related burden of asthma in Long Beach and Riverside that was reported in Perez et al. (2009).[6] We used a novel approach to estimate costs of two important outcomes associated with TRP, bronchitic symptoms and the annual cost of care for a child with asthma. First, we characterized the annual frequency of asthma outcomes (including bronchitic symptoms) associated with an asthma case. We then estimated the direct cost of each of these outcomes, and we estimated the indirect cost of a parent's/caretaker's time due to these outcomes. Second, we multiplied this cost of a typical case of asthma by the number of asthma cases that were attributable to TRP. Third, we estimated the cost of asthma exacerbations due to representative regional pollutants (NO_2 and O_3) for children with asthma not caused by TRP. Fourth, to get the total asthma-related cost of pollution we summed the cost of TRP-attributable asthma cases and the cost of regional air pollution-related exacerbations among children with asthma not caused by TRP. Thus, we estimated the cost of the burden of TRP-attributable asthma cases not included in previous estimates of the economic impact of air pollution, yet we avoided double counting of asthma exacerbations among the two groups of asthmatics. This new approach to air pollution risk assessment and cost estimation, accounting for the full impact of TRP exposure, is likely to be widely applicable to urban areas with regional air pollution and residential developments near busy roadways.

II METHODS

Overview

In the analysis in Perez et al. (2009)[6], the baseline concentrations for Long Beach and Riverside were the observed 8-year mean concentrations (1996-2004) for NO_2 (33 ppb and 26 ppb, respectively) and O_3 (29 ppb and 57 ppb, respectively) measured at continuously operating Children's Health Study monitoring stations in each community. This baseline was then contrasted to the levels observed in comparison communities --- corresponding to a decrease in NO_2 of 18 ppb and 11 ppb in Long Beach and Riverside and a decrease in O_3 of 27 ppb in Riverside. Our scenarios cover a concentration range for which there is no evidence for non-linear effects. We considered five outcomes associated with regional air pollution-attributable asthma exacerbations: bronchitic episodes, emergency room visits, hospitalizations, asthma-specific office visits and school day absences.[6] Then we considered the number of TRP-attributable asthma cases. [6]

The total cost of an air pollution-attributable asthma outcome equals the cost (direct cost plus indirect cost) for a single asthma-related outcome (eg. an emergency room (ER) visit) multiplied by the quantity of that outcome that is attributable to air pollution. Using secondary datasets we estimated the direct and indirect cost of a single health care utilization as the charge for that service and the opportunity cost (foregone income) of a parent's/caretaker's time. In all cases we used charges that were for the pediatric population, and when possible we used estimates for our geographic area and specific diagnostic code.

A sensitive indicator of air pollution related asthma exacerbation in children is bronchitic symptoms, measured as daily cough, congestion or phlegm, or bronchitis for 3 months in a row.[16] There is no peer-reviewed literature on the aggregate cost of a bronchitic episode, because unlike the other outcomes a bronchitic episode is not itself a final endpoint. Instead a bronchitic episode is a composite of several types of health care utilizations. Our approach was to describe a bronchitic episode using the frequency of each outcome that the peer-reviewed literature suggests is associated with a bronchitic episode. The cost of a bronchitic episode was the sum over each bronchitic-related outcome of the cost (direct and indirect cost) of that outcome multiplied by the frequency of that outcome during an episode.

Like a bronchitic episode, an asthma case has many associated outcomes. Furthermore, there is no published estimate of the annual cost of an asthma case that was appropriate for our population. Nor was there a single database or study that described all outcomes of interest for an asthma case. Consequently, we estimated the frequency of these outcomes for a typical asthma case as the means reported in peer-reviewed literature and the California Health Interview Survey.[7] We selected the peer-reviewed literature with samples that best represented our population, prioritizing the following attributes: outcomes measured, mean age of children studied, urban setting, date of study (preference given to most recent), and consistency of estimates with other published studies.

Advantages of our approach are that is transparent and highlights for policy makers and clinicians the drivers of costs --- the quantity of and cost for each outcome. We believe that these advantages outweigh the disadvantage that our estimates rely on multiple sources. Table 1 specifies the sources (peer-reviewed literature or secondary database) for the quantity and cost of each outcome.

Asthma exacerbations attributable to regional pollution

The number of regional air pollution-attributable outcomes (bronchitic episodes, emergency room visits, hospitalizations, asthma-specific office visits and school day absences) among children with asthma due to other causes were based on our previous estimates.[6] Five outcomes are associated with bronchitic episodes: school absences, antibiotics prescriptions, office visit to a medical doctor, ER visit, and inpatient hospital stay. The bronchitis-related frequency of school absences was reported by Oeffinger et al. (1997).[17] Although antibiotics are not effective for the majority of cases of childhood bronchitis, they are frequently used. We estimated the rate of antibiotic prescriptions as the mean rate of antibiotic prescriptions across four published studies.[18-21] We estimated the number of medical office visits, emergency room visits and inpatient hospitalizations for children as the mean frequency for each outcome for children under 18 with current asthma and an ICD-9 diagnosis code of 490 or 491 in the 2007 Medical Expenditure Panel Survey Condition files.[22] These rates were then adjusted to reflect the sampling used in MEPS.[23] These frequencies for an episode of bronchitis are summarized in Table 2.

Outcomes for asthma cases attributable to traffic proximity

We used our previous estimates of TRP-attributable asthma cases.[6] Seven outcomes are associated with an asthma case: office visits, emergency room visits, hospitalizations, school absences, comorbidities (ear/sinus infections), bronchitic episodes, and medication use (rescue inhalers and control inhalers). In this analysis we quantified the outcomes associated with an asthma case by estimating how frequently each outcome occurred in the pediatric asthma population (first column of Table 3). Frequencies of inpatient hospitalizations and emergency room visits among children (ages 0-17) were calculated using the California Health Interview Survey.[7] We used published estimates of the annual mean number of asthma-specific visits to medical doctors and albuterol inhalers purchased.[8] Since all children with asthma should have an albuterol inhaler, we multiplied the mean number of inhalers per person by the number of asthma cases. In contrast, not all children with asthma have control inhalers. Therefore, we took the mean number of control inhalers (cromolyn inhalers and corticosteroid inhalers) used each year[8] and weighted this by the proportion of children with asthma who use controller medication. This proportion was approximated by the proportion of California children with current asthma who were either 1) taking a controller medication or 2) should have been taking a controller medication based on symptom frequency.[7] We estimated the number of school absences per year due to asthma as the mean of the numbers of school absences due to asthma as reported in six studies.[9-14]

We included the health care utilization of children with asthma for sinusitis, allergic rhinitis and otitis media.[15] Given that not all children with asthma experience these comorbidities, we weighted the additional health care utilization by the prevalence of the comorbidities in children with asthma in excess over the prevalence in children without asthma.[15]

Similarly not every asthma case has a bronchitic episode annually. Therefore, we multiplied by the mean annual prevalence of bronchitic episodes among children with asthma in the study communities (reported as 0.387[6]) by the mean number of each outcome associated with a bronchitic episode. (See the last five rows of the first column of Table 3).

Cost per outcome

All costs were converted to 2010 dollars. Costs of inpatient hospitalization and ER visits for children were based on data from the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality.[24] We approximated the typical cost of an ER visit as the difference between the national mean charge for an inpatient stay and the national mean total charge for the ER visit and hospital stay for those admitted through the ER.[24] The total direct cost of an ER visit and hospitalization was the sum of the facilities charges and physician charges.[25] We used the charge code for moderate complexity (Current Procedural Terminology code [CPT] 99283 for an ER visit and CPT codes 99222, 99232, and 99238 for hospitalization). We used the national mean charge for an office-based physician visit derived from the 2004 Medical Expenditure Panel Survey.[26] We approximated the cost of an urgent care visit for a comorbidity as the cost of a typical office visit.

We calculated the mean price for each drug category from an online database of prices.[32] The cost of an antibiotic treatment was the weighted mean of the average cost of the name brand and generic prescription of amoxicillin clavulanate and the cost of a treatment pack of azithromycin, where the weights were the relative frequency of use when a broad-spectrum antibiotic was used to treat pediatric non-specific respiratory infections.[33] The costs of asthma inhalers (rescue and controller medications) were the average of the prices for each inhaler category and were weighted by the typical utilization of each drug category.[8]

An indirect cost associated with each of these utilizations is the value of the time of the parent/caregiver. The mean round-trip travel time for a medical purpose in an urban area in California in 2009 was 46.6 minutes.[27] The mean time spent waiting for an office visit for asthma was approximately 23 minutes.[28] We used 24 minutes for the time in the examining room.[29] Thus the total time for a physician office visit was 1.56 hours. We calculated the typical length of time for an ER visit using the sum of the median wait time and time receiving care.[30] The total of the mean travel time and median time at the ER was 3.89 hours. We used the mean length of hospital stay (2.2 days for an asthma admission and 3.3 days for a bronchitis admission) as a measure of the time costs of a hospital admission. We used one standard workday (8 hours) as the time associated with a school absence. School absences are an important economic consequence, because they often lead to parents or caregivers missing work. We based the value of an hour on the median household income for Riverside and Long Beach and the typical number of hours worked per year ($28.75 and $25.63, respectively).[31]

The project was exempt from IRB review.

III RESULTS

We estimated that a single episode of bronchitic symptoms costs on average $972 in Riverside and $915 in Long Beach (Table 2). The total annual cost for a typical asthma case was $4,063 in Riverside and $3,819 in Long Beach (Table 3). The largest share of the cost of an asthma case was the indirect cost of asthma-related school absences (34% for Riverside and 32% for Long Beach). The costs that a child with asthma incurred due to related conditions (sinus and ear infections and bronchitic symptoms) totaled $1,010 in Riverside and $926 in Long Beach and accounted for approximately 25% of the typical annual costs in both communities.

The average annual costs of the TRP-attributable cases were $2,808,300 (95% CI of 2,564,100 to 3,052,500) in Riverside and $6,120,000 (95% CI of 5,737,500 to 6,885,000) in Long Beach (Table 4). The total annual cost in these two communities of asthma-related outcomes due to TRP (Table 4), compared to communities with background regional air pollution concentrations and with no homes within 75m of a major roadway, was over $18 million (95% CI of 11,293,719 to 22,446,144).

If we were to consider the exacerbations regardless of cause of asthma onset, as is customary in usual approaches to risk assessment, then the total costs were approximately $9.8 million a year, or only 54% of the true asthma costs from air pollution exposure (Table 5).

IV DISCUSSION

The scale of the total annual economic impact of asthma cases and asthma exacerbations attributable to air pollution was remarkable (approximately $18 million a year), almost half of which was due to TRP-attributable cases of asthma. The cost of these cases is not included in traditional risk assessments. The results are relevant to clinical practice, as much of these costs are borne by the families of children with asthma. The total annual cost associated with a case of asthma ($3,800 to $4,000) was 7% of the median household income in Riverside and 8% in Long Beach.[31] These results are troublesome because the sustainable health care expenditure of an entire family is considered to be 5% of income.

At least some of these costs could be prevented if the ambient air quality in Riverside and Long Beach were improved to resemble those of comparison cleaner air, Southern California communities. Land use policies to discourage building homes near major roads, vehicular fleet conversion to very low or zero-emission vehicles, and increased use of public transportation and reductions in vehicle miles traveled would decrease the rates of asthma associated with traffic pollution. To put the potential benefits of reducing these costs in context, the pollution-attributable direct and indirect asthma-related costs in Riverside correspond to 6% of the county's total 2010 budget for health and welfare ($131 million).[34] The costs in Long Beach are 21% of the city's direct 2010 expenditures of the Department of Health and Human Services ($46.5 million).[35]

There are assumptions and limitations inherent in any study of health care costs. Our approach was to start with identifiable pollution-attributable outcomes then calculate the associated costs using data that best represented our population of interest. At each step we selected the option that would produce the most conservative estimate of the cost of the encounter. We identified three areas in which additional research on the economics of asthma is needed: 1) describing the distribution of the health care utilization over the population of children with asthma; 2) valuing the impact of asthma on the quality of life; and 3) calculating the indirect cost of caregiving.

We relied on a variety of sources to describe a single "typical" asthma case and "typical" bronchitic episode in terms of health care utilization and school absences. Ideally we would like to describe the entire distribution of these costs over the population using a single comprehensive database; however, these data are not available. We assumed that a TRP-attributable asthma case and bronchitic episode had rates of outcomes equal to those due to other causes. We estimated the cost of an asthma case by assuming that without exposure to TRP, the child would not have developed asthma. While the evidence for a causal role of air pollution in the development of asthma is increasingly strong,[1-4] it does not necessarily follow that none of these children would develop asthma in the absence of TRP exposure.

The estimates of the cost of an asthma case and the cost of each pollution-attributable outcome are lower bound estimates as they included the direct and some indirect costs of each outcome, but did not include the value of the impacts on the quality of life, which can be substantial.

We assigned a value to the time investment required of family members due to a child's asthma, at the current labor value in each community. Previous studies have generally "discounted" the value of the time by the proportion of households in which all adult caregivers are employed, implicitly assuming that the value of the caregiver's time who is not employed outside the home is zero. There are three methodological problems with this standard approach. First, caregivers' time has value to the family and society even if they are not employed in the external labor market. Second, weighting the value of time by the employment rate produces biased estimates because it ignores the cost of self-selection out of the labor market, as caregivers that have a child with recurring asthma symptoms are more likely to leave the labor force to provide care. Third, it could be argued that because there is disutility associated with time spent procuring health care (who enjoys waiting in the ER with a sick child?), the market wage we have assigned may actually be an underestimation of the true cost of that time.

V CONCLUSIONS

There is growing epidemiological and toxicological evidence that exposure to air pollution is both a cause of asthma and a trigger for exacerbations. We estimated that the annual cost of a case of asthma is roughly $3,800 to $4,000. The total additional asthma-specific cost in Riverside and Long Beach each year that is due to TRP is approximately $18 million, of which almost 50% is due to the cost of asthma cases attributable to residential traffic proximity and 50% is due to regional air pollution- attributable exacerbations among children with asthma due to other causes. The fact that together these two communities account for only 7% of the population of California[31] suggests that the state-wide costs are truly substantial. While these estimates are specific to Southern California, the approach is applicable and relevant to urban and transportation planning beyond this setting. Indeed, over 50% of the population is estimated to live within 150 meters of major roads in ten European cities studies recently studied (Barcelona, Valencia, Brussels, Vienna, Bilbao, Ljubljana, Rome, Seville, Stockholm and Granada).[36]

ACKNOWLEDGEMENTS
This study was supported with funds from an air quality violations settlement agreement between the South Coast Air Quality Management District, a California state regulatory agency, and BP, from NIEHS grants # 5R01 ES016535, 5P01ES011627, 5P30ES007048, 5P01ES009581, 5R01ES014447, Environmental Protection Agency grants R826708, RD831861 and R831845, and the Hastings Foundation.

REFERENCES

1. HEI Panel on the Health Effects of Traffic-Related Air Pollution. Traffic-related air pollution: A critical review of the literature on emissions, exposure, and health effects. HEI Special Report 17. Boston, MA: Health Effects Institute; 2010. Available at www.healtheffects.org. Last accessed May 3, 2011.
2. Clark N, Demers P, Karr C, Koehoorn M, Lencar C, Tamburic L, Brauer M. Effect of early life exposure to air pollution on development of childhood asthma. *Environ Health Perspect* 2010;118:284-290.
3. Ryan PH, Holguin F. Traffic pollution as a risk factor for developing asthma: Are the issues resolved? *Am J Respir Crit Care Med* 2010;181:530-531.
4. Anderson HR, Favarato G, Atkinson RW. 2011. Long-term exposure to air pollution and the incidence of asthma: meta-analysis of cohort studies. *Air Qual Atmos Health* 2011; 4:1-10.
5. Künzli N, Perez L, Lurmann F, Hricko A, Penfold B, McConnell R. An attributable risk model for exposures assumed to cause both chronic disease and its exacerbations. *Epidemiology* 2008;19:179-185.
6. Perez L, Künzli N, Avol E, Hricko A, Lurmann F, Nicholas E, Gilliland F, Peters J, McConnell R. Global goods movement and the local burden of childhood asthma in Southern California. *Am J Public Health* 2009;99:S622-S628.
7. CHIS. California Health Interview Survey. CHIS 2009Adolescent and Child Public Use File. Los Angeles, CA: UCLA Center for Health Policy Research. Available at http://www.chis.ucla.edu/get-data.html. Last Accessed on December 1, 2010.

8. Kattan M, Stearns S, Crain E, Stout J, Gergen P, Evans R, et al. Cost-effectiveness of a home-based environmental intervention for inner-city children with asthma. *J Allergy Clin Immunol* 2005;116(5):1058–1063.

9. Tinkelman D, Khandker R, Calimlim B, Dean B, Yan S, Ciuryla V, McDermott, L. Absenteeism from school or work among uncontrolled asthma patients. *Pediatric Asthma* 2007:132(4);484a.

10. Dean B, Calimlim B, Kinderman S, Khandker R, & Tinkelman D. The impact of uncontrolled asthma on absenteeism and health related quality of life. *J Asthma* 2009; 46:861-866.

11. Flores G, Bridon C, Torres S, Perez R, Walter T, Brotanek J, Lin H, Tomany-Korman S. Improving asthma outcomes in minority children: A randomized, controlled trial of parent mentors. *Pediatrics* 2009;124:1522-1532.

12. Wolstein J, Meng YY, Babey S. Income disparities in asthma burden and care in California. Los Angeles, CA: UCLA Center for Health Policy Research; 2010. Available at http://www.healthpolicy.ucla.edu/pubs/files/asthma-burden-report-1210.pdf. Last Accessed on December 2, 2010.

13. Magzamen S, Patel B, Davis A, Edelstein J, Tager IB. Kickin' Asthma: School-based asthma education in urban communities. *J Sch Health* 2008;78(12):655-665.

14. Moore C, Uyeda K, Cuevas Y, Villanueva R. Los Angeles Unified School District's comprehensive asthma program: Results show decreased asthma symptoms and missed school days among students with asthma. *NASN Sch Nurse* 2010;25:210-212.

15. Grupp-Phelan J, Lozano P, Fishman P. Health care utilization and cost in children with asthma and selected comorbidities. *J Asthma* 2001;38(4):363-373.

16. McConnell R, Berhane K, Gilliland F, Molitor J, Thomas D, Lurmann F, Avol E, Gauderman J, Peters J. Prospective study of air pollution and bronchitic symptoms in children with asthma. *Am J Respir Crit Care Med* 2003;168:790-797.

17. Oeffinger KC, Snell LM, Foster BM, Panico KG, Archer RK. Diagnosis of acute bronchitis in adults: a national survey of family physicians. *J Fam Pract* 1997;45:402–409.

18. Coco A, Mainou AG. Relation of time spent in an encounter with the use of antibiotics in pediatric office visits for viral respiratory infections. *Arch Pediatr Adolesc Med* 2005;159:1145-1149.

19. Evertsen J, Baumgardner DJ, Regnery A, Banerjee I. Diagnosis and management of pneumonia and bronchitis in outpatient primary care practices. *Prim Care Respir J* 2010;19:237-41.

20. Gonzales R, Sande M. Uncomplicated acute bronchitis. *Ann Intern Med* 2000;133:981-991.

21. Nyquist AC, Gonzales R, Steiner JF, Sande MA. Antibiotic prescribing for children with colds, upper respiratory tract infections, and bronchitis. *JAMA* 1998;279:875-877.

22. MEPS HC-112. 2007 Medical Condition Files. Agency for Healthcare Research and Quality. Available at

http://www.meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp . Accessed on June 29, 2010.

23. Machlin S, Yu W, Zodet M. Computing Standard Errors for MEPS Estimates. Rockville, Md: Agency for Healthcare Research and Quality; 2005. Available at http://www.meps.ahrq.gov/survey_comp/standard_errors.jsp. Last accessed May 3, 2011.

24. HCUPnet, Healthcare Cost and Utilization Project. Agency for Healthcare Research and Quality, Rockville, MD. http://hcupnet.ahrq.gov/ Last Accessed January 15, 2011

25. American Academy of Pediatricians Medicaid Reimbursement Survey 2007/2008. American Academy of Pediatricians. Elk Grove Village, Illinois. Available at http://www.aap.org/research/medreimpdf0708/49state_DC.pdf. Last accessed December 2, 2010.

26. MEPS HC-089. 2004. Full year consolidated data file. Agency for Healthcare Research and Quality. Available at http://www.meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp. Accessed on January 15, 2011. Last Accessed December 15, 2010

27. NHTS. National Household Travel Survey. U.S. Department of Transportation/Federal Highway Administration, Bureau of Transportation Statistics, and National Highway Traffic Safety Administration; 2009. Available at http://nhts.ornl.gov/introduction.shtml. Last Accessed June 30, 2010.

28. Greek AA, Kieckhefer GM, Kim H, Joesch JM, Baydar N. Family perceptions of the usual source of care among children with asthma by race/ethnicity, language, and family income. *J Asthma* 2006;43(1):61–69.

29. Cabana M, Slish K, Evans D, Mellins R, Brown X, Kaciroti N, Clark N. Impact of physician asthma care education on patient outcomes. *Pediatrics* 2006;117:2149-2157.

30. Pitts SR, Niska RW, Xu J, Burt CW. National Hospital Ambulatory Medical Care Survey: 2006 emergency department summary. National health statistics reports; no 7. Hyattsville, MD: National Center for Health Statistics; 2008.

31. US Census Bureau. "State & County Quickfacts" Riverside County, California." Available at http://quickfacts.census.gov/qfd/states/06/06065.html and http://quickfacts.census.gov/qfd/states/06/0643000.html. Last Accessed December 5, 2010.

32. Epocrates. Available at https://online.epocrates.com/ Last Accessed December 15, 2010.

33. Steinman M, Gonzales R, Linder J, Landefeld S. Changing use of antibiotics in community-based outpatient practice, 1991–1999. *Ann Intern Med* 2003;138:525-533.

34. County of Riverside. "Riverside health and welfare budget 2010." Available at http://www.countyofriverside.us/government/budgetandfinancial.html. Last Accessed May 5, 2011.

35. Long Beach. "Department of Health and Human Services." Available at

http://www.longbeach.gov/civica/filebank/blobdload.asp?BlobID=23275. Last Accessed May 5, 2011.

36. Aphekom. Summary report of the Aphekom Project. Available at http://www.endseurope.com/docs/110302b.pdf.Last Accessed November 14, 2011.

TABLE 1: Source for Frequency and Costs of Outcomes

A. Outcomes of asthma exacerbations attributable to regional pollution

	Source for Frequency of Outcome	Source for Cost Estimates
<u>Outcome</u>		
Emergency room visits	Perez et al. (2009)[6]	HCUP (2009)[24] for ICD-9 493 & APA (2007/2008)[25]
Hospitalizations	Perez et al. (2009)[6]	HCUP (2009)[24] for ICD-9 493 & APA (2007/2008)[25]
Asthma office visits	Perez et al. (2009)[6]	MEPS (2007)[26]
School days absent	Perez et al. (2009)[6]	US Census Bureau (2010)[31]
<u>Bronchitis episodes</u>	Perez et al. (2009)[6] for bronchitic episodes attributable to regional pollution. Frequency of outcomes per bronchitis episode as noted below.	
Office visits	MEPS (2007)[26] for ICD-9 490/491	MEPS (2007)[26]
Emergency room visits	MEPS (2007)[26] for ICD-9 490/491	HCUP (2009)[24] for ICD-9 490/491 & APA (2007/2008)[25]
Hospitalizations	MEPS (2007)[26] for ICD-9 490/491	HCUP (2009)[24] for ICD-9 490/491 & APA (2007/2008)[25]
School absences	Oeffiger et al. (1997)[17]	US Census Bureau (2010)[31]
Antibiotics	Mean of frequency of antibiotic prescription for bronchitis reported in: Coco & Mainou (2005)[18], Evertsen et al. (2010)[19], Gonzales & Sande (2000)[20], Nyquist et al. (1998)[21]. Frequency of use of each antibiotic types for respiratory infection: Steinman et al. (2003)[33]	Epocrates (2010)[32]

B. Outcomes of asthma cases attributable to traffic proximity

	Source for Frequency of Outcome	Source for Cost Estimates
<u>Asthma cases attributable to TRP</u>	Perez et al. (2009)[6]	Complied based on frequency and costs of outcomes for representative case as described below.
<u>Outcome per case/year</u>		
Office visit	Kattan et al. (2005)[8]	MEPS (2007)[26]
Emergency room visits	CHIS (2009)[7]	HCUP (2009)[24] for ICD-9 493 & APA (2007/2008)[25]
Hospitalizations	CHIS (2009)[7]	HCUP (2009)[24] for ICD-9 493 & APA (2007/2008)[25]
School days missed	Mean of days in: Tinkelman et al. (2007)[9], Dean et al. (2009)[10], Flores et al. (2009)[11], Wolstein et al. (2010)[12], Magzamen et al. (2008) [13], Moore et al. (2010)[14].	US Census Bureau (2010)[31]

Asthma medication per case/year		
Controller inhalers	Mean number of controller inhaler used: CHIS (2009).[7] Frequency of types of controllers: Kattan et al. (2005).[8]	Epocrates (2010)[32]
Rescue inhalers	Mean number of inhalers used Kattan et al. (2005).[8]	Epocrates (2010)[32]
Co-morbidities per case/year		
Non-urgent office visits	Frequency of comorbidities among asthmatics from Grupp-Phelan et al. (2001).[15].\ Frequency of outcomes due to comorbidity from Grupp-Phelan et al (2001).[15]	MEPS (2007)[26]
Antibiotics		Epocrates (2010)[32]
Urgent care visits		MEPS (2007)[26]
Inpatient days		HCUP (2009)[24] & APA (2007/2008)[25]
Bronchitic episodes per case/year	Frequency of bronchitic episodes per asthma case from Perez et al. (2009).[6] Frequency of outcomes due to bronchitis as described below.	
Office visits	MEPS (2007)[26] for ICD-9 490/491	MEPS (2007)[26]
Emergency room visits	MEPS (2007)[26] for ICD-9 490/491	HCUP (2009)[24] for ICD-9 490/491 & APA (2007/2008)[25]
Hospitalizations	MEPS (2007)[26] for ICD-9 490/491	HCUP (2009)[24] for ICD-9 490/491 & APA (2007/2008)[25]
School absences	Oeffiger et al. (1997)[17]	US Census Bureau (2010)[31]
Antibiotics	Mean of frequency of antibiotic prescription for bronchitis reported in: Coco & Mainou (2005),[18] Evertsen et al. (2010),[19] Gonzales & Sande (2000),[20] Nyquist et al. (1998),[21] Frequency of use of each antibiotic types for respiratory infection: Steinman et al. (2003).[33]	Epocrates (2010)[32]

C. Time associated with outcomes

Time category	Source for travel time	Time on site (wait plus service time)
Office visit --- all cause	NHTS (2009)[29]	Greek et al. (2006)[27] and Cabana et al. (2006)[28]
Emergency room --- all cause	NHTS (2009)[29]	Pitts et al. (2008)[30]
Hospital --- asthma specific	NHTS (2009)[29]	HCUP (2007/2008)[24] for ICD-9 493
Hospital --- bronchitis specific	NHTS (2009)[29]	HCUP (2007/2008)[24] for ICD-9 490/491

Note: For asthma cases the number of outcomes is the mean annual outcomes per asthma case (case/year).

TABLE 2: MEAN ANNUAL FREQUENCY AND RELATED DIRECT AND INDIRECT COSTS OF A TYPICAL BRONCHITIC EPISODE

			Indirect cost per encounter		Annual cost	
Outcome	**Mean encounter frequency**	**Direct cost per encounter**	**Riverside**	**Long Beach**	**Riverside**	**Long Beach**
Office visits	1.15	$113	$45	$40	$182	$176
Emergency room visits	0.06	844	112	100	57	57
Inpatient hospitalizations	0.01	16,625	759	677	174	173
School absences	2	NA	230	205	460	410
Antibiotics	1.16	85	NA	NA	99	99
			TOTAL COST PER CASE		**$972**	**$915**

All costs are rounded to the nearest dollar and are in 2010 USD.

TABLE 3: MEAN ANNUAL FREQUENCY AND DIRECT AND INDIRECT COSTS OF CARE FOR A TYPICAL ASTHMA CASE

	Mean* †	Direct cost per outcome*	Indirect costs per outcome*		Total annual cost	
Outcome			**Riverside**	**Long Beach**	**Riverside**	**Long Beach**
Asthma-specific office visit	1.5	$113	$45	$40	$239	$231
Emergency room visits	0.2	844	112	100	172	170
Inpatient hospitalizations	0.04	12,776	506	451	531	529
School days missed	5.9	NA	230	205	1,362	1,214
Medication						
Inhaled corticosteroid	2.2	125	NA	NA	273	273
Cromolyn	1.1	95	NA	NA	102	102
Albuterol	6.8	55	NA	NA	374	374
Co-morbidities						
Non-urgent office visits	0.9	113	45	40	134	130
Mean cost of antibiotics	2.2	85	NA	NA	243	189
Urgent care visits	0.2	113	112	100	50	47
Inpatient days	0.03	6,646	230	205	206	206
Bronchitic episodes						
Office visits	0.5	113	45	40	71	69
Emergency room visits	0.02	844	112	100	22	22
Inpatient hospitalizations	0.004	16,625	759	677	67	67
School absences	0.8	NA	230	205	178	159
Antibiotics	0.5	85	NA	NA	38	38
	ANNUAL TOTAL COST PER ASTHMA CASE				**$4,063**	**$3,819**

All costs are rounded to the nearest dollar and are in 2010 USD.
*Per Year
†Outcome Frequency

TABLE 4: COST OF OUTCOMES ATTRIBUTABLE TO POLLUTION EXPOSURE FOR CHILDREN IN RIVERSIDE AND LONG BEACH (95% CI)

	Riverside		**Long Beach**		
	Count	**Cost per outcome**	**Count**	**Cost per outcome**	**Total Cost per Year**
Attributable asthma cases	690 (630, 750)	$4,070	1,600 (1500, 1800)	$3,825	$8,928,300
NO_2 Attributable exacerbations of other-cause asthma					
Emergency room visits	40 (5, 70)	956	150 (19, 280)	944	179,840
Inpatient hospitalizations	8 (6, 10)	13,282	27 (22, 32)	13,227	463,385
~~Clinic~~ Office visits	190 (38, 340)	158	440 (80, 780)	153	97,340
Bronchitic episodes	1,500 (440, 2,300)	975	3,100 (1000, 4,400)	918	4,308,300
O_3 Attributable exacerbations of other-cause asthma					
Emergency room visits	230 (150, 310)	956			219,880
Inpatient hospitalizations	12 (9, 15)	13,282			159,384
~~Clinic~~ Office-visits	190 (25, 360)	161			30,590
Bronchitic episodes	2,900 (160, 3,900)	975			2,827,500
School days absent	2,966 (2223, 4,685)	230	626 (43, 1,114)	205	810,510
				TOTAL ANNUAL COST	**$18,025,029**

All costs are rounded to the nearest dollar and are in 2010 USD.
The 95% confidence intervals are reported in parentheses.

TABLE 5: AIR POLLUTION RELATED EXACERBATIONS AND COSTS OF ALL ASTHMATICS

	Riverside		Long Beach		
	Count	**Cost per outcome**	**Count**	**Cost per outcome**	**Total Cost per Year**
NO_2 Attributable exacerbations					
Emergency room visits	42	$956	160	$944	$191,192
Inpatient hospitalizations	8	13,282	30	13,227	503,066
~~Clinic~~ Office visits	200	158	500	153	108,100
Bronchitic episodes	1,600	975	3,400	918	4,681,200
O_3 Attributable exacerbations					
Emergency room visits	250	956			239,000
Inpatient hospitalizations	12	13,282			159,384
~~Clinic~~ Office visits	220	161			35,420
Bronchitic episodes	3,100	975			3,022,500
School days absent	2,966	230	626	205	810,510
		TOTAL ANNUAL COST			**$9,750,372**

All costs are rounded to the nearest dollar and are in 2010 USD.