The Public Health Costs of Traffic Congestion

A Health Risk Assessment

By: Jonathan I. Levy, Jonathan J. Buonocore, & Katherine von Stackelberg

Traffic congestion is a significant issue in virtually every urban area in the United States and around the world. Anyone who spends any time commuting knows that the time and fuel wasted while sitting in traffic can not only be annoying, but can lead to real economic costs. An examination of the peer-reviewed literature shows that there are many previous analyses that estimate the economic costs of congestion based on fuel and time wasted, but that these studies don't include the costs of the potential public health impacts. Sitting in traffic leads to higher tailpipe emissions which everyone is exposed to, and the economic costs of those exposures have not been explored.

Motor vehicle emissions contain pollutants that contribute to outdoor air pollution. One in particular, fine particulate matter (referred to as $PM_{2.5}$) is strongly influenced by motor vehicle emissions. Studies that evaluate the sources of $PM_{2.5}$ in our environment find that vehicles contribute up to one-third of observed $PM_{2.5}$ in urban areas. $PM_{2.5}$ has been associated with premature deaths in many studies, and health impact assessments have shown $PM_{2.5}$-related damages on the order of hundreds of billions of dollars per year. Recently, an expert committee convened by the Health Effects Institute in Boston, Massachusetts, summarized the available evidence on exposure to traffic-generated air pollution and negative health effects. They find strong evidence for a causative role for traffic related air pollution and premature death, particularly from heart attacks and strokes. $PM_{2.5}$ is emitted directly, and it is also produced by secondary formation, as sulfur dioxide (SO_2) and nitrogen oxide (NOx) emissions contribute to the formation of sulfate and nitrate particles. Exposure to $PM_{2.5}$ also causes other health effects such as asthma attacks, and other respiratory illnesses.

In this study, we evaluate the premature deaths resulting from people breathing primary $PM_{2.5}$ and secondarily-formed particles during periods of traffic congestion and compare that to the economic costs from time and fuel wasted. We do this analysis for 83 individual urban areas. We predict how much congestion to expect in each of the 83 urban areas over the period 2000 to 2030. We use several inter-linked models to predict how much of what people are breathing in each urban area is attributable to emissions from traffic congestion. The models predict how many people will die prematurely as a result of being exposed to these traffic conditions over the long term. We assign a dollar value to the predicted deaths using a "value of a statistical life" approach as is done for most regulatory impact analyses. The analysis explores the significance of public health impacts in assessments of predicted traffic congestion to identify information gaps to be addressed to better determine the ongoing public health burden of congestion in the United States, and to set the stage for evaluating potential strategies for relieving traffic congestion. Evaluating such strategies will require models and assumptions that take advantage of conditions and the context unique to each area.

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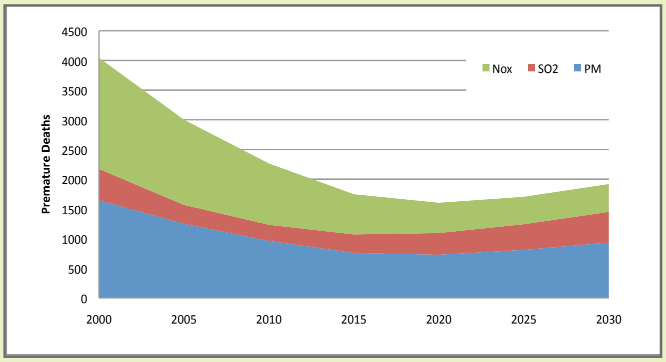
Figure 1

Projected Nationwide Premature Deaths Attributable to Congested Traffic, 2000 - 2030



This graph represents the nationwide estimates for premature deaths attributable to congested traffic for 2000-2030. The colored sections indicate the portion of these premature deaths attributable to NOx, primary $PM_{2.5}$ and SO_2.

to primary $PM_{2.5}$ and 11% attributable to SO_2. However, the relative proportion of the impact attributable to different pollutants varies significantly across urban areas. For example, the proportion due to NOx ranges from 6% in multiple Northeast cities (Hartford, CT; Boston, MA; New Haven, CT; Springfield, MA) to over 70% in less densely populated areas of Texas (Brownsville, Austin) and Washington State (Spokane).

Similarly, the proportion of impact due to primary $PM_{2.5}$ is highest in densely-populated urban areas of the Northeast (approximately 80%) and below 20% in Brownsville. The proportion attributable to SO_2 emissions is highest in California, with four urban areas in California constituting the only places with more than 20% of the mortality risk from SO_2 emissions. These relative proportions are attributable in part to high ambient sulfate in the eastern United States, which tends to reduce particulate nitrate formation, and to conditions in California favoring the secondary formation of particulate sulfate.

Figure 2

The Monetized Health Impacts Attributable to Congestion for Selected Urban Areas, 2000 - 2030

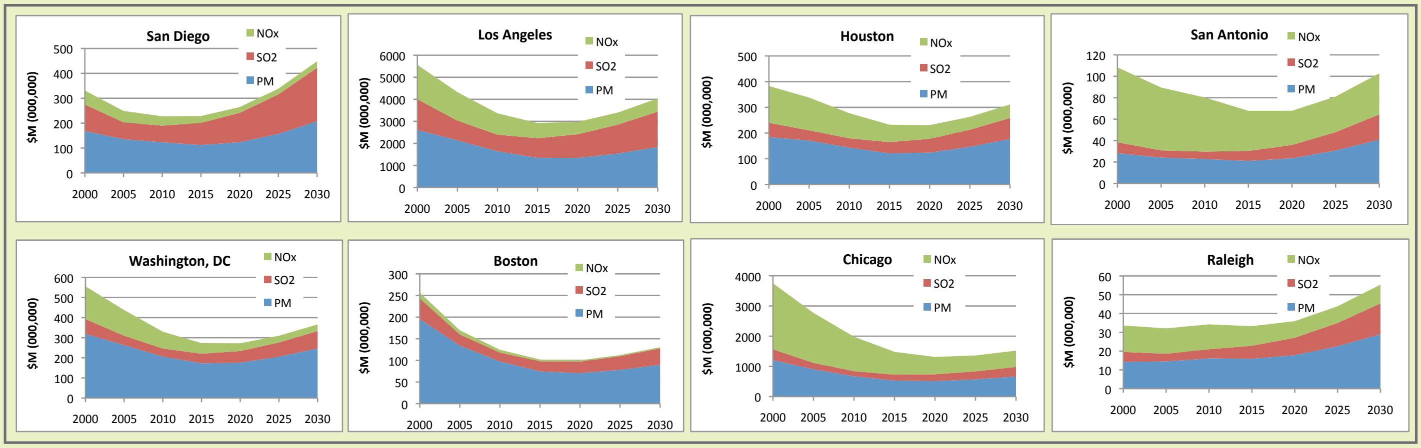
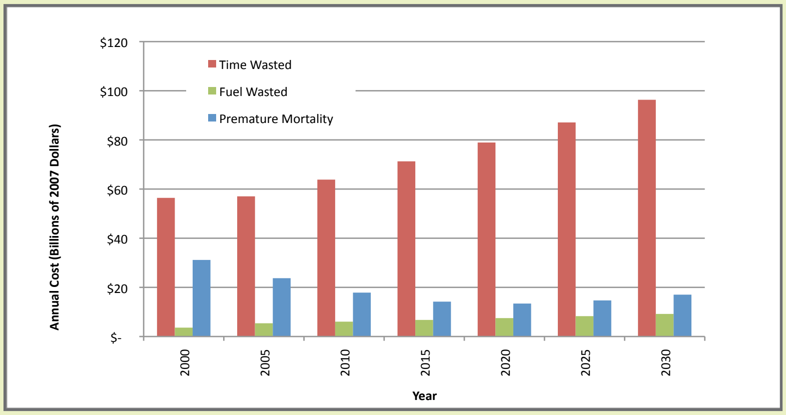


Figure 2 presents the monetized health impacts over time for selected urban areas. These trajectories differ as a function of differential population growth, congestion, population density and atmospheric chemistry. For example, monetized health impacts increase steadily over time in cities such as Raleigh NC and San Diego CA, in which VMT and population growth are significant and primary $PM_{2.5}$ makes a substantial contribution to health risk. In contrast, Chicago and other cities in the Midwest are projected to have small VMT growth and have more substantial contributions to public health damages from NOx emissions, and therefore show a steady decline in health risks over time given the larger decline in NOx emissions per vehicle-mile.

Figure 3 presents the economic costs from time and fuel wasted and monetized estimates of premature mortality attributable to traffic congestion across the 83 urban areas. Overall, time wasted accounts for the bulk of the economic cost associated with traffic congestion, and the cost of delay continues to increase between 2000 and 2030, as this is directly proportional to the extent of congestion. In contrast, reductions in per-vehicle emissions contribute to declines in economic costs associated with premature mortality between 2000 and 2025, with modest increases after that point.

Figure 3

Monetized Premature Mortality as Compared to Projected Time & Fuel Dollars Wasted Attributable to Congested Traffic



As a result, whereas the public health impacts contributed approximately 34% of the total cost of congestion in 2000, this decreases to 14% by 2030. However, the proportion of health impacts attributable to premature mortality varies substantially across urban areas. For example, in 2000, 17 urban areas had health impacts contributing less than 20% of the total cost of congestion, whereas 19 urban areas had contributions in excess of 50%. Those urban areas with relatively small contributions from public health had very high levels of congestion (near or at the 50% threshold) but did not have correspondingly high population density, including Laredo TX, Eugene OR, and Las Vegas NV. In contrast, those urban areas where public health impacts dominated had smaller percentage of time spent in congestion but greater public health benefits per ton of emissions.

Frequently Asked Questions

How was the analysis conducted?

The key components of the analysis include predicting emissions corresponding with traffic congestion for 83 individual urban areas based on travel demand models, which predict how many vehicle-miles people will be traveling in each area. We develop estimates of changes in air pollution (based on $PM_{2.5}$ concentration) associated with these emissions, and apply a concentration-response function that predicts how many people will be impacted by breathing this air pollution. Finally, we assign a dollar value to the predicted number of premature deaths.

Where did we get our data?

We develop estimates of vehicle miles traveled (VMT) based on data and methods from the Center for Urban Transportation Research (CUTR) at the University of Central Florida. We use a model developed by the US EPA called MOBILE6 to estimate city-specific emissions per VMT based on year, temperature profile, and average vehicle speed. We focus on emissions from the baseline year (2000) until 2030. The analysis is conducted for 83 individual urban areas that were previously evaluated by the Texas Transportation Institute (in order to directly compare our results with their estimates of economic costs of congestion) and are in the lower 48 states.

To estimate the changes in air pollution associated with congestion-related emissions from each urban area, we applied a source-receptor (S-R) matrix. S-R matrix is a reduced-form model containing county-to-county transfer factors across the United States, considering both primary $PM_{2.5}$ and secondary formation of sulfate and nitrate particles. To determine the health effects, we use the same studies that the US EPA uses based on a combination of published epidemiological studies and an expert elicitation study addressing the concentration-response function for $PM_{2.5}$-related mortality. To monetize the resulting estimates of mortality attributable to congestion, we applied a value of a statistical life (VSL) of approximately $7.7M in 2007 dollars (for 2000 GDP), the central estimate used in recent EPA regulatory impact analyses.

What does it mean?

Our modeling illustrates that the public health impacts of traffic during periods of congestion, associated with premature mortality from primary and secondary $PM_{2.5}$ concentrations, are appreciable, with thousands of deaths per year and a monetized value of tens of billions of dollars per year. While the monetized public health damages are smaller than the economic value of time wasted, with the differential anticipated to grow over time, there are some geographic areas where public health damages represent a significant proportion of the total damages, even in future years when per-vehicle emissions are expected to be substantially less. Prior analyses of population exposure per unit emissions from motor vehicles demonstrated that these values were highest in dense urban areas for primary $PM_{2.5}$ and secondary sulfate, especially in California, the mid-Atlantic states, and the industrial Midwest, and were highest in the Southeast and Midwest for secondary nitrate. The urban areas with the greatest proportion of damages from public health were often found in parts of California and the Midwest, where the damages per ton of emissions were greater and the projected future population growth was lower. These findings provide an indication that considering only the direct economic costs of congestion will underestimate societal benefits of mitigating congestion, significantly so in certain urban areas.

What did we leave out?

There are clearly numerous other health endpoints or pollutants that may contribute to the public health burden of congestion, including morbidity endpoints associated with $PM_{2.5}$, mortality and morbidity from ozone, and effects of multiple air toxics. This analysis assumed no change to road infrastructure from 2005 levels, and the models, out of necessity, do not use individualized models of traffic congestion in each urban area (that is, although population and traffic demand are specific to each area, the analysis does not consider road closures, construction, or other area-specific factors that might contribute to increases or decreases in congestion over particular time periods). It is important to note that these are not traffic planning models specific to each area. These are models that predict emissions of pollutants associated with congested conditions on broader scales. Therefore, the results are approximations and represent order-of-magnitude predictions. In addition, the relative proportions across pollutants and urban areas are more robust than the specific numeric estimates.

Where do we go from here?

These results indicate that public health impacts of traffic congestion exist and should be considered when evaluating long-term policy alternatives for addressing congestion such as traffic management through congestion pricing, traffic light synchronization and more efficient response to traffic incidents, and adding new highway and public transit capacity. This analysis represents a first step, and future analyses could incorporate more sophisticated approaches for predicting expected emissions under location-specific conditions as opposed to the generalized case presented here. This exploratory study was designed to evaluate the scope of the issue; more refined estimates are possible that would address urban-area specific alternatives and impacts.

Urban Area	Percent VMT Increase					
	2000-2005	2000-2010	2000-2015	2005-2020	2000-2025	2000-2030
Laredo, TX	8%	16%	22%	28%	33%	38%
Las Vegas, NV	15%	25%	32%	37%	42%	46%
Little Rock, AR	-8%	-5%	-3%	0%	3%	6%
Los Angeles--Long Beach--Santa Ana, CA	2%	4%	5%	7%	8%	10%
Louisville, KY--IN	0%	2%	4%	6%	8%	10%
Memphis, TN--MS--AR	-3%	-1%	1%	3%	5%	8%
Miami, FL	4%	8%	13%	18%	22%	26%
Milwaukee, WI	-5%	-4%	-3%	-1%	0%	2%
Minneapolis--St. Paul, MN	0%	5%	9%	14%	17%	20%
Nashville-Davidson, TN	-12%	-3%	4%	11%	17%	24%
New Haven, CT	-2%	1%	4%	7%	9%	12%
New Orleans, LA	-3%	-36%	-25%	-15%	-8%	-2%
New York--Newark, NY--NJ--CT	1%	2%	3%	5%	6%	8%
Oklahoma City, OK	3%	9%	13%	16%	19%	23%
Omaha, NE--IA	5%	10%	14%	19%	23%	27%
Orlando, FL	6%	18%	27%	32%	37%	41%
Oxnard, CA	5%	15%	25%	34%	42%	47%
Pensacola, FL--AL	-7%	4%	12%	19%	26%	31%
Philadelphia, PA--NJ--DE--MD	0%	2%	3%	4%	5%	7%
Phoenix--Mesa, AZ	8%	15%	20%	24%	29%	33%
Pittsburgh, PA	-6%	-6%	-4%	-2%	0%	3%
Portland, OR--WA	4%	7%	10%	13%	16%	19%
Providence, RI--MA	-1%	1%	4%	7%	10%	13%
Raleigh, NC	11%	28%	37%	43%	49%	54%
Richmond, VA	-4%	5%	14%	22%	31%	36%
Riverside--San Bernardino, CA	9%	15%	19%	24%	28%	31%
Rochester, NY	0%	0%	0%	0%	1%	3%
Sacramento, CA	6%	10%	14%	18%	22%	25%
St. Louis, MO--IL	1%	1%	1%	2%	2%	3%
Salem, OR	5%	11%	15%	20%	25%	29%
Salt Lake City, UT	6%	17%	27%	35%	40%	45%
San Antonio, TX	5%	15%	22%	28%	35%	42%
San Diego, CA	1%	10%	15%	20%	26%	31%
San Francisco--Oakland, CA	0%	1%	2%	3%	5%	6%
San Jose, CA	1%	2%	3%	4%	5%	6%
Sarasota--Bradenton, FL	8%	17%	25%	33%	39%	45%
Seattle, WA	2%	6%	8%	11%	14%	17%
Spokane, WA--ID	2%	8%	14%	20%	25%	30%
Springfield, MA--CT	-6%	-5%	-5%	-4%	-2%	-1%
Tampa--St. Petersburg, FL	4%	7%	10%	13%	15%	18%
Toledo, OH--MI	-5%	-6%	-5%	-5%	-4%	-2%
Tucson, AZ	5%	12%	19%	23%	26%	29%
Tulsa, OK	-8%	-2%	4%	10%	16%	22%
Virginia Beach, VA	-1%	3%	7%	10%	14%	17%
Washington, DC--VA--MD	3%	5%	7%	9%	11%	13%

Table B provides estimates of premature mortality and associated social costs across selected years to 2030 for each of the 83 urban areas. While estimates in all individual urban areas were not reported in the published paper, they are included below to provide perspective on the relative proportion of expected impacts across the 83 modeled areas. Given the underlying uncertainties and simplifications in the modeling approach, although the values are listed below with multiple significant figures for ease of comparison, the values in this table should be interpreted as order of magnitude estimates of the potential public health impacts.

Table B: Estimated Selective Public Health Impacts of Traffic Congestion With Status Quo Infrastructure & Mobility Options in 83 U.S. Urban Areas: 2000 - 2030

	2000		2005		2010		2015		2020		2025		2030	
	EPD	$M	EPD	$M	EPD	$M	EPD	$M	EPD	$M	EPD	$M	EPD	$M
Akron, OH	8	63	6	47	4	34	3	27	3	26	3	28	4	32
Albany, NY	<2	9	<2	7	<2	5	<2	4	<1	4	<2	4	<2	5
Albuquerque, NM	4	32	3	25	3	21	2	17	2	17	2	19	3	23
Allentown--Bethlehem, PA--NJ	6	44	4	31	3	25	3	21	3	21	3	24	3	29
Atlanta, GA	93	717	80	633	70	549	56	454	52	431	55	476	62	549
Austin, TX	17	129	14	110	12	92	9	73	8	67	8	73	10	85
Bakersfield, CA	2	17	2	15	2	13	<2	11	<2	11	2	13	2	16
Baltimore, MD	65	499	45	354	32	252	24	195	22	183	23	200	26	228
Beaumont, TX	<1	2	<1	2	<1	<2	<1	<2	<1	<2	<1	<2	<1	<2
Birmingham, AL	9	66	6	48	5	36	4	29	3	27	3	29	4	33
Boston, MA--NH--RI	33	257	21	169	16	125	13	102	12	100	13	112	15	130
Boulder, CO	<2	8	<2	6	<2	5	<2	4	<2	4	<2	4	<2	5
Bridgeport--Stamford, CT--NY	11	83	8	62	6	47	5	38	4	37	5	40	5	46
Brownsville, TX	4	28	3	25	3	20	2	15	2	13	2	14	2	16
Buffalo, NY	4	34	3	23	2	16	2	13	<2	12	2	14	2	16
Cape Coral, FL	10	78	9	75	10	76	8	65	8	64	8	73	10	91
Charleston--North Charleston, SC	2	18	2	14	2	13	2	12	2	14	2	17	2	21
Charlotte, NC--SC	16	120	13	102	12	92	10	78	9	78	10	89	12	105
Chicago, IL--IN	487	3,751	350	2,770	251	1,982	182	1,481	157	1,313	158	1,361	171	1,520
Cincinnati, OH--KY--IN	60	460	41	321	28	220	19	154	15	129	15	129	16	139
Cleveland, OH	34	262	21	165	14	111	10	84	9	77	9	79	10	86
Colorado Springs, CO	4	29	3	21	2	18	2	15	2	14	2	15	2	18
Columbia, SC	2	17	2	12	<2	11	<2	10	<2	11	2	14	2	18
Columbus, OH	19	150	14	109	11	83	8	69	8	68	9	76	10	89
Corpus Christi, TX	2	18	2	13	<2	11	<2	9	<2	9	<2	10	<2	12
Dallas--Fort Worth--Arlington, TX	122	941	103	816	85	671	62	507	54	455	56	483	62	547
Dayton, OH	21	161	13	103	9	70	6	48	5	40	5	39	5	42
Denver--Aurora, CO	41	319	31	245	24	192	18	144	15	126	15	132	17	148
Detroit, MI	173	1,333	116	918	76	603	52	421	43	357	41	355	43	381
El Paso, TX--NM	9	69	7	56	6	47	5	40	5	40	5	47	7	58
Eugene, OR	<2	5	<2	4	<1	4	<1	3	<1	3	<1	4	<2	5
Fresno, CA	9	70	7	58	6	49	5	42	5	42	5	47	6	56
Grand Rapids, MI	8	62	5	36	4	28	3	22	2	21	3	23	3	27
Hartford, CT	7	54	5	38	4	29	3	24	3	23	3	26	3	30
Houston, TX	50	383	43	338	35	277	29	232	28	231	30	263	35	311
Indianapolis, IN	34	264	27	210	19	153	14	113	12	100	12	103	13	112
Jacksonville, FL	5	39	4	32	4	29	3	25	3	26	3	30	4	36
Kansas City, MO--KS	18	142	14	108	11	88	8	67	7	62	8	69	9	84
Laredo, TX	<2	4	<1	4	<1	3	<1	3	<1	3	<1	4	<2	5
Las Vegas, NV	4	34	5	36	4	34	4	33	4	37	5	46	7	61
Little Rock, AR	3	22	2	14	<2	10	<2	8	<2	7	<2	7	<2	7
Los Angeles--Long Beach--Santa Ana, CA	722	5,564	547	4,324	426	3,362	360	2,924	355	2,974	394	3,396	454	4,038

EPD = Estimated Premature Deaths

$M = Estimated Cost in Millions of U.S. Dollars (2007 $)

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Table B Continued:
Estimated Selective Public Health Impacts of Traffic Congestion With Status Quo Infrastructure & Mobility Options in 83 U.S. Urban Areas: 2000 - 2030

	2000		2005		2010		2015		2020		2025		2030	
	EPD	$M	EPD	$M	EPD	$M	EPD	$M	EPD	$M	EPD	$M	EPD	$M
Louisville, KY--IN	34	265	24	192	17	138	12	101	11	89	11	91	11	99
Memphis, TN--MS--AR	16	123	11	84	8	62	6	48	5	44	5	47	6	52
Miami, FL	62	474	47	370	40	316	36	293	38	316	44	379	53	473
Milwaukee, WI	40	308	26	205	18	142	13	102	11	88	10	90	11	99
Minneapolis--St. Paul, MN	66	505	48	380	37	295	29	236	27	225	28	245	32	282
Nashville-Davidson, TN	11	84	6	50	5	42	4	34	4	32	4	36	5	43
New Haven, CT	5	35	3	25	2	19	2	17	2	17	2	19	3	22
New Orleans, LA	10	76	6	51	2	17	2	16	2	19	3	23	3	29
New York--Newark, NY--NJ--CT	644	4,962	477	3,768	337	2,658	244	1,981	212	1,772	215	1,859	234	2,079
Oklahoma City, OK	16	120	12	94	9	73	6	52	5	44	5	44	5	48
Omaha, NE--IA	7	53	6	45	4	34	3	26	3	23	3	25	3	28
Orlando, FL	25	196	21	169	21	166	19	157	19	161	22	191	27	236
Oxnard, CA	4	29	3	24	3	22	3	24	3	29	5	39	6	51
Pensacola, FL--AL	3	23	2	15	2	14	2	12	<2	12	2	14	2	17
Philadelphia, PA--NJ--DE--MD	149	1,145	102	806	71	561	51	416	45	374	46	395	50	441
Phoenix--Mesa, AZ	19	148	17	134	15	116	13	102	12	104	14	123	17	152
Pittsburgh, PA	18	137	11	87	8	63	6	51	6	51	7	57	8	69
Portland, OR--WA	20	154	16	129	13	101	10	81	9	75	9	81	11	94
Providence, RI--MA	11	81	7	59	6	44	5	38	5	39	5	45	6	55
Raleigh, NC	4	34	4	32	4	34	4	33	4	36	5	44	6	55
Richmond, VA	6	45	4	30	3	27	3	25	3	29	4	38	5	49
Riverside--San Bernardino, CA	13	98	11	90	10	80	10	79	11	89	13	111	16	144
Rochester, NY	3	24	2	17	<2	13	<2	10	<2	9	<2	10	<2	12
Sacramento, CA	69	533	60	471	48	378	39	316	36	305	40	343	46	412
St. Louis, MO--IL	103	797	74	589	51	399	34	273	27	224	25	218	26	227
Salem, OR	<1	3	<1	2	<1	2	<1	2	<1	2	<1	2	<1	2
Salt Lake City, UT	5	42	5	37	4	34	4	31	4	34	5	39	6	49
San Antonio, TX	14	108	11	89	10	80	8	68	8	68	9	81	12	103
San Diego, CA	43	331	31	249	29	227	28	229	32	265	39	339	50	449
San Francisco--Oakland, CA	235	1,813	170	1,345	124	981	90	733	77	649	78	675	85	751
San Jose, CA	42	323	31	248	24	191	19	156	18	149	19	163	21	188
Sarasota--Bradenton, FL	2	12	<2	11	<2	9	<2	8	<2	8	<2	9	<2	12
Seattle, WA	32	246	26	203	21	162	16	128	14	119	15	128	17	149
Spokane, WA--ID	<2	7	<2	5	<2	5	<1	4	<1	4	<1	4	<2	5
Springfield, MA--CT	<2	5	<1	3	<1	2	<1	2	<1	2	<1	2	<1	2
Tampa--St. Petersburg, FL	80	619	61	482	45	357	33	265	28	233	28	238	29	260
Toledo, OH--MI	12	91	8	60	5	40	3	28	3	24	3	24	3	26
Tucson, AZ	4	31	3	26	3	23	3	21	2	21	3	24	3	29
Tulsa, OK	9	68	5	43	4	35	3	26	3	24	3	25	3	29
Virginia Beach, VA	13	102	9	74	7	59	6	53	7	56	8	67	9	82
Washington, DC--VA--MD	72	556	55	438	42	330	34	273	33	272	36	310	41	366
Total	4,045	31,161	3,001	23,736	2,264	17,861	1,746	14,192	1,602	13,412	1,703	14,690	1,917	17,034

EPD = Estimated Premature Deaths
$M = Estimated Cost in Millions of U.S. Dollars (2007 $)

The Harvard Center for Risk Analysis (HCRA), founded in 1989, is recognized as a world-leader in applying decision theory, environmental and health science, and economics to a broad range of important environmental and public health issues. HCRA is a research institute within the Harvard School of Public Health, which has the objective of using a variety of analytic methods to inform public policy decisions relevant to public health. Our researchers enjoy successful collaborations across disciplines, and a hallmark of our work is synthesizing and integrating basic environmental sciences with social sciences to better inform decision making. We regularly host interdisciplinary seminars. Since 1993, HCRA has been publishing *Risk in Perspective*, a periodic publication available from our website (www.hcra.harvard.edu). Currently, HCRA hosts the Research Translation Core for a Superfund Basic Research program grant focused on gene-environment interactions (www.srphsph.harvard.edu) and is responsible for developing and communicating policy-relevant research based on the results of studies from partners across the University and MIT.

Authors

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Acknowledgments:

Funding was provided by the American Road and Transportation Builders Association (ARTBA) on behalf of the Transportation Construction Coalition (TCC). ARTBA and TCC were involved in suggesting the topic for research, but neither ARTBA nor TCC played any role in data collection, data analysis, or manuscript writing, and were not involved in manuscript submission.

The full article can be found in Environmental Health 2010, 9:65.
Access it online at: http://www.ehjournal.net/content/9/1/65