Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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Take the Long Way Home

Curriculum Unit 11.04.04
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Introduction

I am writing this unit for a high school statistics classroom. We will use the tools of mathematics to quantify children's exposure to pollution from diesel exhaust, and to model the risks associated with the unique transportation needs of the city of New Haven.

I currently teach AP Statistics as well as Workshop Statistics for Health and Business.

Learning Goals of this Curriculum Unit

This unit will be designed to address the need for project based learning by providing a framework for deep and ongoing research. The College Board, that supervises the curriculum for AP Statistics, requires " projects and laboratories, cooperative group problem-solving, and writing, as a part of concept-oriented instruction and assessment." [1]

The goal of the unit would be to produce collaborative work that addresses a specific issue of concern to the life of our city: How harmful are the current conditions for students' transportation to school? A follow up question may be investigated: What changes could be implemented to improve the current conditions? Student-driven projects need careful planning, support and evaluation in order to make it effective for all learners. The idea of this unit is to provide background and access to the study of a topic that is rich in quantitative questions and relevant to students' lives.

New Haven Public Schools Transportation Matrix

New Haven is a small city, an area that one can easily walk across. Yet nearly everyone is bused to school. In a town with such dense population, schools can be easily located within a reasonable walking distance for all students, yet nearly every student rides a bus. Instead of a single bus picking up a group of students on one corner and bringing them to a nearby building to be educated, the transportation department coordinates transportation to nearly 18,000 students with nearly 2000 who are bused in from surrounding towns. Bus routes crisscross and make three complete morning, and three more complete afternoon circuits to accommodate the intricate magnet school placements of the students of the city.

In order to alleviate the de-facto segregation created by longstanding residential patterns, the New Haven Public School district encourages school choice, through inter-district magnet schools. Unfortunately, the school choice has increased the number of students who need to take a bus to school rather than get there on foot. One of the goals of our investigation will be to examine student transportation and to explore and to quantify the difference in busing required if students were assigned to schools by neighborhood or by magnet choice.

The intent of our work is not to diminish the issues of school segregation, negate the benefits of school choice, but to address the reality of the unintended consequences of such a program. The question is how to achieve the least harm, with competing interests at play. Initiatives such as Michelle Obama's "Let's Move" campaign and the federal and state "Safe Routes to School" program are focusing public attention and funding on our children's needs for physical activity coupled with our environment's needs for less pollution. These programs are not possible or useful, when school choice policies supersede the planning of bicycle and footpaths to centrally located schools. In a perfect world, our urban centers could be dedicated to human powered transport. Unlike suburban sprawl-plans, urban centers can be walk-able, and bike-friendly; certainly, New Haven's small size makes that a possibility.

Currently, our urban centers present its youngest members with the greatest burdens of pollution. Histories of residential use and decay have left the legacy of leaded buildings and soils. Parks are often (ad-hoc or by design) reclaimed dumping grounds. Many studies have demonstrated that densely populated, lower-income neighborhoods have diminished access to and fewer resources for physical activity. A study of physical activity resources, such as parks in Kansas and Missouri concluded that, "incivilities were consistently present and conspicuously bad and offensive at physical activity resources in lower-income, higher ethnic concentration neighborhoods." [2]

No Child Left Behind has caused cities like New Haven to mandate out recess in order to accommodate increased academic instruction time. A kindergarten teacher at my local school explained how 5 year olds at the school had free-play: "the kids get lots of exercise moving from the carpet to their tables."

There are unsafe places to play when you get home and longer mandated school days. During the winter this often means arriving home with dusk. An extensive bus ride in place of a possible walk to school removes the possibility of built in exercise as a way to get to school. The Safe Routes to School program promotes the "walking school bus". [3] Children are picked up along a route, like a traditional school bus, with an adult to monitor the group. This addresses the safety concerns of urban school children, and offers active commuting, but can only be implemented in a neighborhood school setting.

Health effects from Air pollution Exposure

Particle pollution, PM 2.5, is harmful to human health. PM is usually categorized as coarse (PM10 > 10 ug) and Fine (PM 2.5 < 2.5 ug), with the fine being most risky to human health. Fine particles can penetrate more deeply into the lungs. In particular, students on school buses are at highest risk, with their prolonged exposure to the bus cabin, faster respiration rates and smaller airway passages, into which ultra-fine particles may be respired. Current EPA regulation restricts PM 2.5 levels to 15 micrograms per cubic meter of air (Mg / m^3) as an annual average. New Haven achieved an annual average of about 10 Mg / m^3 , in 2009 but within the annual average were some very elevated days. Here we can contrast an annual value of 5.36 Mg / m^3 in Litchfield, nearly half the value of New Haven. [4]

So, what are the risks with particulates? Recent prospective studies have shown a modest increase in risk of developing asthma, associated with elevated levels of PM 2.5. [5] It is very possible that the increased levels of asthma in New Haven are in some part due to the higher levels of PM and other air pollutants. Children in New Haven have a 15% chance of having asthma, contrasted with about an 8-9% chance nationwide. [6]

The 2002 study entitled, The *Concentration-Response Relation between PM 2.5 and Daily Deaths* focused on correlating daily death rates and ambient levels of $PM_{2.5}$

" found an essentially linear relationship down to 2 Mg / m^3 " There appears to be no lower threshold in the effect of particulates. Their conclusion," The magnitude of the association suggests that controlling fine particle pollution would result in thousands fewer early deaths per year. [7]

In January, New Haven recorded daily averages of 36, 43 and 55 Mg / m^3 $PM_{2.5}$ [8.] However, when these peak days are averaged in with the rest of 2011, it is possible that New Haven may achieve overall annual compliance for the year. Yet the EPA recognizes that temporary peaks do present a risk. The federal EPA guideline limits PM 2.5 to 35 Mg / m^3 within a 24 hour mean, making the three dates in January out of compliance.

In a brochure simply entitled, Air Pollution" The EPA says this of short term exposures to particulate matter:

"Short-term exposures can aggravate heart or lung diseases leading to symptoms, increased medication use, hospital admissions, ED visits, and premature mortality; long-term exposures can lead to the development of heart or lung disease and premature mortality."

Some studies have focused on the short-term exposures and associated risks, and it is these to which our work will pay particular attention. The problem our class will quantify is what are the health impacts on children's asthma symptoms, when exposed to higher levels of particulates.

Many observations of the effects of PM 2.5, have tried to quantify the air concentrations that harm human health. A study of children in Seattle, released in 2005 showed associations between short-term increases in PM 2.5 levels and the increase in asthma symptoms. The researchers examined hourly and daily cumulative averages, rather than annual levels of PM 2.5. The study aligned the peaks of particle concentrations with peak symptoms. Their work noted delays is reactions of 1 to 12 hours, with statistically significant associations between short-term increases in particle pollution and airway inflammation. The study notes specific and measureable responses in airway inflammation in rises of as little as 10 Mg / m^3[9].

A later (2008) study in Mexico City looked at several markers of lung distress. The lung inflammation was associated with a 17.5 Mg / m^3 rise in PM 2.5 and measures of lung force were significantly lowered after 4-5 days of cumulative exposure. This effect occurred in asthmatic and non-asthmatic subjects. "The effect appears on the same day as the exposure and can cumulate over several days, resulting in lung function decrement after 4 or 5 days of cumulative exposure.[10]" These previous works were corroborated in a 2010 study linked with the Children's Health Study in southern California. With a sample of 2440 children, this much larger study showed a 17% rise in the level of inflammation markers to be significantly associated with a modest 7.5 Mg / m^3 rise in PM 2.5.[11]

Based on these studies, we can see that normal concentrations of PM 2.5 in New Haven are already presenting a measureable threat to health, as they clearly exceed the 7.5 Mg / m^3 level and often reach the highest estimate of 17.5 Mg / m^3. In addition, students who embark on a bus ride will face an additional exposure, or dose that will cause an additional level of response. The 2002 study that correlated PM 2.5 levels and daily deaths argues that no elevation in particulates is safe, our question is: when is the risk too great?

Pollution from Buses

School buses emit pollution from their diesel engines. Diesel emissions are one of the worst contributors to air pollution. Diesel contains a complex mix of volatile gases and particulate matter. The gases, such as nitrogen oxides, contribute to the formation of ozone, which is harmful to human health and contributes to climate change. The particulate matter or soot that the buses exhaust, contains toxic compounds, which also harm human health and black carbon, and which also contribute to climate change. Other than natural forces such as forest fires, diesel engines are one of the largest producers of particulate pollution. (EPA 2003)[12]

The problem of the air quality of school buses has seen some major attention in the last ten years. A study by Environment & Human Health: Children's Exposure to Diesel Exhaust on School Buses led to changes in the oversight of school bus emissions as well as new legislation regarding the idling of school buses. Researchers had students carry personal and portable monitors to see what pollutants they were exposed to during a school day. They found dramatic variability in levels of particulate exposure, with very high peaks during their school bus commute.

Following the study, New Haven's city and Board of Education joined with partners at the EPA, CT Department of Environmental Protection and the Yale Forestry School to retrofit their school buses with either particle filters or catalytic converters to reduce particle emissions. This work was completed in 2006. As the retrofitted fleet phases out (estimated 2007-2009)[13], the newest buses must comply with the EPA's 2007 regulation that mandates low-sulfur fuel and high efficiency emissions controls.

The EPA projects a 90% reduction in PM by 2030 with the newer technology, and a 95% reduction in Nitrogen dioxide, however, it is unclear what assumptions these projections are based on.[14] These documents forecast a reduction in pollutants emitted by diesel engines while perhaps not addressing the quality of the air that students are breathing during their time ON the school bus. Another problem with current EPA projections is the Agency's focus on particulate matter generally, rather than focusing on the smaller and more dangerous particles. The EPA is projecting a reduction in overall PM without forecasting reductions in the smaller sized particles.

In order to quantify the current exposure associated with school bus travel, we will examine studies of buses using newer technologies. A 2005 study by the "Clean Air Task Force" found that the combination of low-sulfur fuel and a "Spiracle" filter that trapped crankcase emissions virtually eliminated the fine particles within the cabin of the bus. [15] Subsequent studies in 2008 looked at school bus cabin air pollution in Central Texas and in Washington State. In both cases, buses were running low-sulfur diesel fuel. The technologies varied, but both studies examined the impact of retrofits that included filters and catalysts. The Texas study showed an in-cabin reduction in fine PM between 7-43% when using the Spiracle filter. Their conclusion: "retrofit installation could not always be conclusively linked to the decrease of pollutant concentrations in the bus cabin." [16] The Washington State study concluded that the PM 2.5 levels aboard the school buses were double to four times the ambient (outdoor) air levels. [17]

Another issue of particular importance to New Haven students regards the ambient air outside buses, at schools and at bus stops. The Clean Air Task force study [18] and a later (2008) study of the air quality surrounding schools found an increase of PM 2.5 of between 1.8 to 5.7 times the level at a control site. [19] This would indicate that the ambient air in the vicinity of schools is still significantly polluted despite the advent of vehicular pollution control technology and low-sulfur fuel. This finding is particularly troublesome for New Haven Students who not only breath elevated rates of PM in the schoolyard, but at their bus stops which host a multitude of buses to accommodate the diverse destinations within the same neighborhood. This would differ sharply from the exposure of a student at a suburban or rural stop, where a bus may only travel to that location once in the morning and once in the afternoon.

One of the questions we will try to quantify is, how much does the pollution exposure during bus transport increase symptoms, decrease lung function, and put students at risk for medication and hospital visits. Given that students in New Haven are already much more likely to have asthma, by the time they enter school, our concern here is what type of additional pollution burden the bus ride adds to their underlying condition

Lessons

Rather than discrete lessons, this unit will be integrated throughout the curriculum, with much of it providing an opportunity for students to do independent work. During each phase, students will divide into working groups in order to research and brainstorm models that will inform the entire class. At the close of each phase, conference style presentations will enable students to share work with their student colleagues.

Students will need to grapple with these quantitative representations holistically as well as specifically. In turn, this will provide the deep analytical practice needed to succeed in statistics.

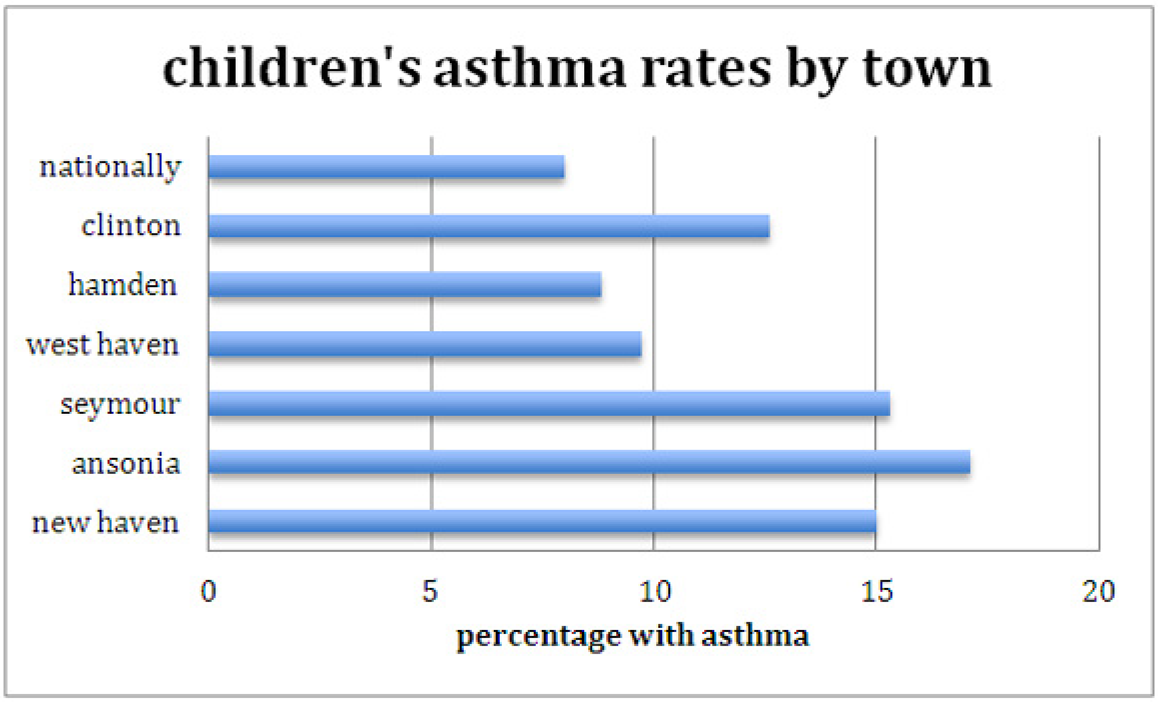
Phase 1 – How are data collected and interpreted?

Asthma distributions

In the beginning of the course, as students develop the skills to interpret graphs and describe distributions, we will look at the most recent state fact sheet on asthma. These graphs will allow students to practice interpretive skills. We can read the introduction to the state air pollution surveillance document and discuss the method of data collection. Students will begin to notice the disparity in the level of disease in their city, when compared with the rest of the state. Together we will begin to ask, "Why?"

An initial task for students is to graph comparisons between their town and another town to compare asthma rates. Using the state surveillance data, students can select their own town and one or more others to compare. Students can present their comparative graphs and the class will discuss how the displays illustrate the information.

Attention will be given to appropriate type of graph, identification of population, sample, variables, and method of data collection. Graph must have appropriate intervals and labels.



Diseases of the lung are naturally connected to the quality of air we breathe. We can then seek out and find statistics on pollution, including particle pollution. From the initial indications of the statistics, students will begin to develop an awareness of the pollution problem within the city. Students may want to believe that the associations they see indicate causation, and we can discuss the appropriate cautions there. Again, this is the place to look at various data displays and to again ask questions about data collection.

Pollution distributions

At this point, an interesting assignment would be to task students with describing a distribution of PM 2.5. Using the same distribution, one group of students should experiment with summary statistics that appear to maximize the PM. Another group can attempt to minimize the PM 2.5 in their summary. Statistics to use could include hourly, daily weekly, monthly and annual means, or mean versus median, or distributions with and without extreme points included. Student groups should display their statistics and discuss the potential parties who would have an interest in one set of statistics versus another set.

Why is the mean higher than the median? Is this a skewed or symmetrical distribution? Would someone with asthma want to know the mean or median to be assured of greater protection? Would a nearby polluter want to report the mean or median? Which values in the distribution are out of compliance with federal guidelines?

Which values have the greatest influence on the mean?

Daily recordings of PM 2.5, New Haven, January 2009 in Mg / m^3

23.9	6.6	11	11.6
3.3	4.8	6.5	13.6
11.6	15	8.8	12
8	29.3	16	12.7
10.6	36.5	13.4	5.2
5.9	44.3	10.7	12.3
10.5	38.7	25.5	12.6
14.8	5.3		10.4

We can look at simple measures of center for this distribution and analyze:

mean 14.56

median 11.6

These types of investigative questions and the ability that students have to manipulate the representations of the data with graphics and statistics, make these simple tasks much deeper. In statistics we need to refocus students away from looking for the "right answer." The math here is about modeling a problem, not providing a solution.

Quantifying the rate of exposure

Once students have examined more than one statistic from a distribution, they may be more confident to describe the distribution of pollution in New Haven. In order to quantify their own exposure to particulates, students quantify the weight of particles inhaled annually.

EX. (PM weight/m3 of air)(volume inhaled of air per respiration) (number of respirations/min)(min/yr)=weight/yr

NEW HAVEN:

(10 Mg / m^3 (.005 m^3 per respiration)(15 respirations/min)(525,600 min/yr)= 394.200 *Mg/yr* about .4 g of

particulates a year

LITCHFIELD:

(5.4 Mg / m^3)(.005 m^3 per respiration)(15 respirations/min)(525600 min/yr)= 394200 *Mg/yr* or about .2 g of particulates a year

Students can see that a twofold increase in pollution translates in to twice as much actual weight of inhaled particulates a year. This notion of calculating the actual weight helps students to make tangible this notion of such a finely dispersed pollution.

Phase 2 - Models for evaluating risk

Students will use probability models to predict a random student's potential exposure to pollutants. These would be combinations of probabilities that have been defined by the students based in their prior research. These will be used to predict the length of bus rides for students, to calculate their exposure to pollutants based on the detected levels of PM on the bus, the duration of rides and their likelihood to be at special risk for health loss.

For example we know that a student has about a 90% chance of being a bus rider and a 15% chance of having asthma. If we think that these events are independent, then the probability of being on the bus and at risk for health affects of high PM is multiplied: (.9)(.15)=.135. Thirteen to fourteen percent of school children in New Haven are at risk for health complications due to PM exposure. That translates to about 2700 children in New Haven.

Our effort will be to build a probability model of exposure, not to prove causation. The question about causation, linking specific pollutants with human health effects, is outside of the scope of our investigation and it is already extremely well researched and documented. We can be sure that the level of pollutants in the air that New Haven residents breathe is elevated. That is true when compared not only to her neighboring communities, but also in comparison to federal health standards.

If we think that 2700 students are at risk, then how big is that risk? The amount of additional exposure to particulates during the school bus commute depends on how long that commute is. Based on the random nature of school assignment and records of applications, students could create a simulation to build a probability distribution that reflects the likelihood of hours spent commuting per week. The expected value of this commute could allow students to quantify the average annual additional burden of inhaled particulates based on the bus rides.

Simulation

An example of simulation might be this:

Students can look at two maps of the city

School district Map

Census Tract Map

Using this information we see there are 29 census tracts in New Haven.

We will use simulation to model 25% randomization and 100% randomization.

Number 145 cards, 5 cards with each value between 1 and 29

The cards represent 5 children from each of the 29 census tracts

100% randomization

New Haven has about 28 elementary schools. We will simulate 100% randomized assignments by shuffling and dealing the cards onto a list of schools.

Collecting Data

Compiling the data using the school district maps. Students can physically measure the distances on the map or use an interactive online tool like Google maps.

Students will choose an endpoint in the center of the census tract. We will mark the centers of each tract. With each card we will use the endpoint of the census tract and measure the distance to the assigned school.

Analyzing the data

Students will have written the distance for bus rides for each student on each card. An average distance can be computed.

A 25% simulation would be similar, every 4th card is assigned to a magnet school and the rest are dealt into a neighborhood school pile. The magnet school children will have their commute measured just like the first simulation. The neighborhood children will be placed in the closest school to the center of their census tract. If the distance in 1 mile mark the card WALK. We can collect average bus ride length and percentage of bus riders. This should model the current situation of bus ridership in New Haven, as about one quarter attend magnet schools, however the transportation department reports a 76-86% statistic of bus ridership.

The additional burdens of the school bus rides will likely be significant. Studies of current technology buses show significant elevation. Particulate averages of 20 Mg / m^3 were found on the Washington State bus runs. Other studies showed particulate levels as low as 21 in Ann Arbor and as high as 163 in Chicago. [20] The study of short-term exposure showed a mounting airway response per 10 Mg / m^3 A short ride on a bus with 160 Mg / m^3 could be very risky.

Phase 3 – Alternatives

After looking at the simulation for totally randomizing school attendance (with no regard for geography), we can simulate school assignments by neighborhood and calculate the percentage who can walk to school. We can rework our calculations for exposure and miles traveled based on these lower bus riding rates. For example, if only 10% ride a bus, the probability of increased risk drops to (0.1)(0.15)=(0.015) This multiplied by 20100 students = 302 students, a reduction of 2,400 students at highest risk.

Students can add value to their calculations by contrasting health care costs, fuel costs and the difference in over all emissions from school buses between the neighborhood model and the randomized model. For example, the school system currently runs 268 buses fairly continuously from 6:30-9:30 each morning and 1:30-4:30 each afternoon. Using the quantitative tools at the United States Department of Transportation, students can quantify diesel output, and cost of fuels. Using state and federal websites, students can quantify healthcare cost, and lost school days per student at high risk.

Student readings and resources

Children's Exposure to Diesel Exhaust on School Buses

This groundbreaking study has led to major changes in policy and the creation of agency agendas within the EPA and state departments of public health.

EPA's Six Common Air Pollutants

Students will be introduced to Ozone, particulate matter, and become familiar with the pollutants that the EPA monitors is determining the quality of air.

Air quality:

EPA :

http://www.airnow.gov/index.cfm?action=airnow.local_state&stateid=7

http://www.epa.gov/airnow/workshop_teachers/air_quality_resources_2011.pdf

The American Lung Association

http://www.stateoftheair.org/

CT Department of Environmental protection

http://www.ct.gov/dep/cwp/view.asp?a=2684&q=321790&depNav_GID=1744&depNav=|

In addition to readings, we will take advantage of some presentations on the subject that have been well produced and are publicly available. This includes the curriculum written for New Haven Public Schools by the Stevens Institute for Technology. Clean School bus curriculum. http://www.ciese.org/curriculum/bus. It has some introductory information about the subject, as well as some exercises in calculating the impact of pollutants.

There are plenty of data and statistics available. The EPA maintains an air quality data mart http://www.epa.gov/ttn/airs/aqsdatamart/ which would allow for students to run different summaries of the statistics than those that that are calculated by the Federal standards. This will help students make comparisons between different summaries of distributions, and decide how best to quantify the level of air pollution in New Haven.

Asthma data sources:

CT Department of Public Health:

Asthma Data Fact Sheets for the Five Largest Cities in Connecticut 2009

Connecticut 2010 School Base Asthma Surveillance Report 2010

http://www.ct.gov/dph/cwp/view.asp?a=3137&q=398480

http://www.epa.gov/asthma/

Mapping

Natural Resources Defense Council

http://www.nrdc.org/air/transportation/qbus.asp

http://maps.google.com/

Appendix: District Standards

The curriculum standards addressed in the unit are contained in the fourth strand of the Connecticut Department of Education's Mathematics Curriculum Framework:

Working with Data: Probability and Statistics

Data can be analyzed to make informed decisions using a variety of strategies, tools and technologies.

In addition, this unit addresses the following standards recommended by the National Council on the Teaching of Mathematics (NCTM)

…understand the differences among various kinds of studies and which types of inferences can legitimately be drawn from each. (We will look at surveys, experiments and observational studies and examine cases where we can draw inferences about causation, and where we can draw inferences about population proportions and means.)

…know the characteristics of well-designed studies, including the role of randomization in surveys and experiments

…use simulations to explore the variability of sample statistics from a known population

…construct sampling distributions to understand how sample statistics reflect the values of population parameters

…use sampling distributions as the basis for informal inference

…evaluate published reports that are based on data by examining the design of the study, the appropriateness of the data analysis, and the validity of conclusions

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Notes

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1 (College Board)
2 (Lee 2005)
3 (Safe Routes to School)
4 (Environmental Protection Agency 2010)
5 (Gilmour 2006)
6 (State of Connecticut 2010)
7 (Schwartz 2002)
8 (Environmental Protection Agency 2011)
9 (Therese F. Mar 2005)
10 (Barraza-Villareal 2008)
11 (K. Berhane* 2011)
12 (EPA 2003)
13 (Northeast States for Coordinated Air Use Management 2006)
14 Office of TransportationEPA420-F-06-064 and Air QualityOctober 2006 Program Update (EPA n.d.)
15 (Hill 2005)
16 (Rim 2008)
17 (Adar 2008)
18 (Hill 2005)
19 (Chunlei Li 2009)
20 (Rim 2008) p 6459