Technical Documentation, Methods, and Data Sources for ValueofLeadPrevention.org and Altarum's Estimates of State-Specific Lead Exposure Costs and Lead Prevention Intervention Costs and Benefits

Overview and Scope of the Analyses

ValueofLeadPrevention.org and the Altarum state and city-level assessments of the economic impacts of childhood lead exposure expands on prior work completed at the national level that analyzed the costs and benefits for the population of children born in the year 2018. These new analyses, for each of the fifty US states and ten select cities, look at impacts for kids born in the year 2019. This work estimates the lifetime economic costs of combined lead exposure for children from paint, water, dust, soil, air, and other sources by using the best available data on current child blood lead levels. Subsequently, this work models the economic benefits of reducing the exposure to environmental lead (and the benefits of resulting lower child blood lead levels) via specific home interventions shown to decrease lead risks: lead hazard control for lead-based paint hazards, lead service line replacement, and enforcement of lead safe renovation, repair, and painting standards.

The economic models and underlying literature used to support the computations of the health and economic impacts of lead exposure for these state and city-level analyses are based on the models built for the prior national work. These approaches and assumptions were made in consult with and vetted by an advisory committee and team of experts (see pages vi-vii of the prior work); hence we continue to use those data and models whenever possible. Details of the specific data collected and analyzed, the Altarum modeling assumptions applied, and sensitivity analyses of those findings are also available in the appendices of the prior work, particularly on pages 102-108.

This Technical Appendix to the *valueofleadprevention.org* data provides details on the additional data collected and methods applied to generate state and local-level estimates. In some cases, additional modeling was required; for example, to estimate the population blood lead distributions for the children born in each state and city, due to the fact that the National Health and Nutrition Examination Survey (NHANES) could not be used to generate blood lead estimates for smaller geographies. Also included in this appendix are the underlying formulas and coefficients used to empower the website's capability of customization, with the literature and prior work used to support these models.

The scope of the modeled interventions (covering a single-year birth cohort) in this tool are defined to allow for precise, repeatable, and understandable magnitudes of benefits, albeit not in a way that policies are likely to be implemented in the real world. For example, the lead hazard control intervention is modeled solely for the hypothetical intervention provided in the homes of the 2019 birth cohort. The approach for this modeled intervention looks first at all the children born into a state or city in 2019, estimates their eventual underlying blood levels based on the prior data and local predictive characteristics of lead exposure, then estimates number of children born into a home built prior to 1978 (the last year lead-based paint was sold in the United States). For each of the children in the 2019 birth cohort born into an older home, we assume a lead test is performed prior to their entrance and that for all homes where lead-based paint is identified, they would receive a lead hazard control intervention to permanently remediate the lead paint hazards. The benefits and costs of this policy are contrasted against a case where the 2019 birth cohort would not receive any lead hazard control interventions and remain at risk for exposure to paint and leaded dust in their homes.

The calculation of the costs and benefits then assumes this policy ends in 2019; therefore, only impacting a single-year cohort. If repeated in future year, the costs and benefits would increase.

When computing the benefits of reduced lead exposure for the 2019 cohort, included are impacts for any future siblings or new children born into that home over the next ten years. Not included in these benefits are the benefits to older siblings already living in the home (who may have unfortunately already been exposed to the environmental lead), benefits to adults in the home, benefits to visitors into the home, or benefits for new children born more than 10 years after the intervention. As a result, these benefit calculations are conservative and likely undercount the true economic impacts of the lead remediation activities.

This modeling approach—assuming testing all older homes of the 2019 cohort and remediating the number of homes where lead is found—is taken for lead service line replacement and the use of lead safe work practices for renovations and repairs.

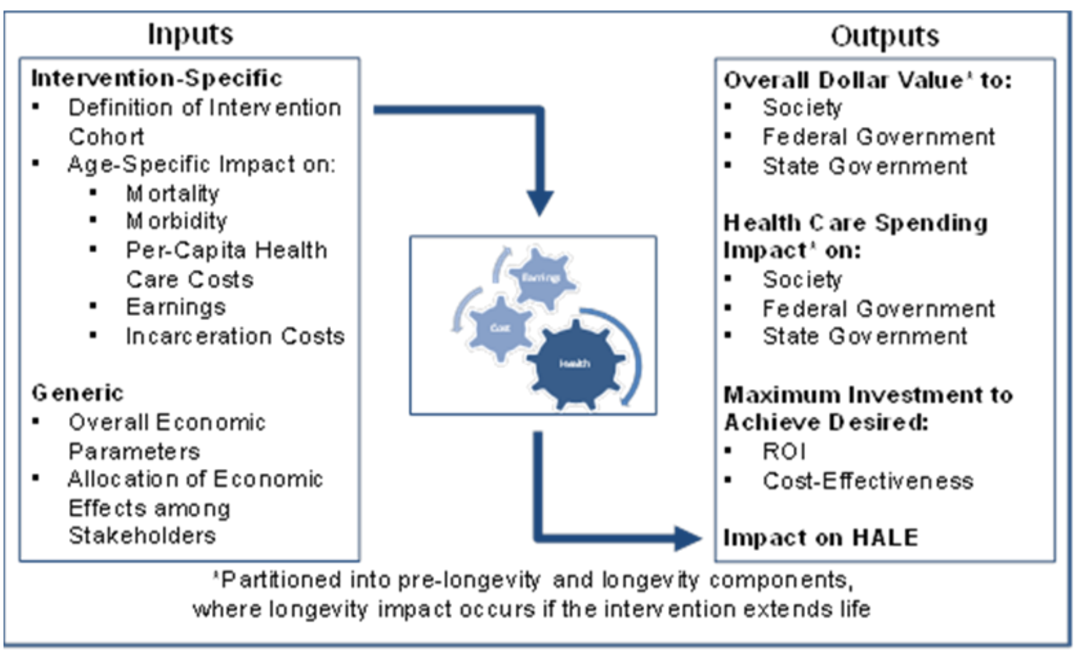
For additional details on the data and models, please see the prior work or contact press@altarum.org.

The Value of Health Tool

The Value of Health Tool is an iteration of an economic model that was funded by the Robert Wood Johnson Foundation. It is used to characterize results describing the financial and health impacts of an investment in prevention from the perspectives of many stakeholders. In this context, prevention is defined very broadly to include investments in the social determinants of health, such as education and the physical environment. The tool uses inputs, such as estimates of an intervention’s impacts on lifetime health, longevity, earnings, health insurance status, and educational spending, alongside assumptions about government and economic conditions (like tax rates, income trends, and economic growth) to show the benefits and costs of an investment that accrue to people and organizations that can influence the investment.

Figure 1 highlights the overarching framework for the tool’s inputs and outputs. In this state and city-level work, the tool was used to estimate the benefits of lead prevention for single-year birth cohort (2019), apportioned between the major stakeholders considered, for the entire lifetimes of children potentially exposed to lead.

Figure 1



In this work we use the Value of Health Tool to:

1. Estimate the costs of current childhood lead exposure by modeling the difference in lifetime health and economic outcomes for a cohort of children exposed to known levels of environmental lead resulting in current blood lead levels vs. a hypothetical cohort exposed to no lead at all (while unrealistic in the short-run, this approach bounds the potential total benefits of lead remediation).

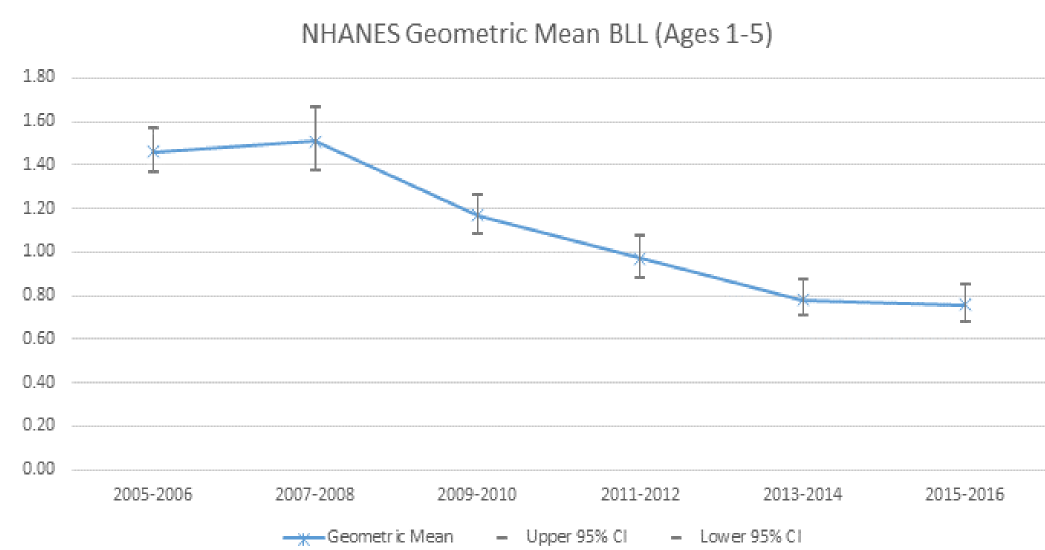
2. Estimate the benefits of specific lead prevention and remediation activities by modeling the difference in health and economic outcomes for a cohort of children exposed to current lead levels vs. the expected cohort that would benefit from a partial reduction lead levels thanks to remediation.

<u>Altarum Estimates of State Child Lead Exposure Levels from Risk Factors and Demographic Data</u>

This section summarizes the data, techniques, and results of the Altarum process for estimating state and local level blood lead levels from publicly-available demographic and local housing characteristic data. This approach is an expansion of the model built by Bradley Schultz et al. (Predicting Blood Lead Levels Among U.S. Children at the Census Tract Level), which was published in *Environmental Justice* in 2017. Altarum adds to the published work using data from recent NHANES to produce estimates of BLL distributions, which are then used to estimate a mean and percentage above specific action levels (2µg/dL, 5µg/dL, and 10µg/dL) of blood lead levels for all ages 1-5 in a particular geographic region for the year 2018. These results serve as inputs to the Altarum cost estimates of the childhood lead exposure and estimates of the potential benefits of lead remediation and prevention policies such as lead service line replacement, lead paint hazard control, and improved renovation and repair standards.

A modeling and estimation approach based on demographic and local data for blood lead levels is required due to existing gaps in blood lead level surveillance. The National Health and Nutrition Examination Survey (NHANES) is a nationally-representative survey which reports results over two-year periods and includes a blood lead test for all participants less than the age of 12. The NHANES data were used in the previous Altarum economic modeling, which focused on harms and potential policies implemented at a national scale. The NHANES data have shown nationally that child blood lead levels have fallen over recent years (see Figure 2). However, the sample of this survey is too small to make representative state-based estimates needed for the current work.

Figure 2



Alternatively, the Centers for Disease Control and Prevention (CDC) curates test results from state lead surveillance programs, which test children under the age of 72 months and then report their results to the CDC. While also important data, these results cannot be used to support representative child blood lead level risks for the entire state, because "the data were collected for program management purposes" and "cannot [be] compare[d] across states or counties because data collection methods vary across grantees." Even though some states test upwards of 25% of all children under the age of 6, these results cannot be broadly applied to the entire state population because testing of children is not randomly assigned. In fact, many states specifically target tests towards areas and children with the highest expected risks for lead exposure.

As a result of these data gaps, the Altarum team considered multiple potential estimation techniques. A variety of authors have developed and published models over the past few years, including Kaplowitz et al. (Public Health Reports), Roberts and English (Statistics in Medicine), Potash et al., and the Washington State Department of Health. The current Altarum model has been built on work from Bradley Schultz and was selected due to the fact their model predicts the geometric mean of blood lead levels for children (rather than the percentage above risk cut-offs), has been applied to data from multiple states and been validated by the findings, and considered an extensive list of predictive factors in the model. The key coefficients used in the modeling include blood sample test type, year of sampling, child age, month of sampling, percentage of the population below the poverty line, percentage of pre-1960 housing, and percentage of the population that is non-Hispanic black. All of these factors were shown to be strong predictors of child blood lead levels at the census tract level.

We modify/extrapolate from the published model in the following ways. First, we remove the coefficients of month of testing and assume a blood lead level tested using a venous sampling (which is the method used by the NHANES examination). We apply the model not to specific census tracts within each state, but instead to state-level averages of the variables described above. This choice may downplay some of the variation in blood lead levels, leading to a slightly conservative, but easier to compute estimate of total blood lead levels. We extrapolate the findings beyond the years tested in the model (ending in 2009) to approximate blood lead levels in the year 2018. We also adjust the final model output by a ratio of age 1-2 blood lead levels compared to age 1-5 blood lead levels to match the previous Altarum work in the NHANES data. Finally, we use previous NHANES data to estimate a full distribution of blood lead levels, beyond just the model result of a geometric mean.

The following are the coefficients of the log-linear regression that will be applied to the state-level data:

Intercept	0.3514
Average Child Age - Months	0.0113
Year of Sampling	-0.049
Percentage Below Poverty Line	0.6765
Percentage of Pre-1960 Housing	0.3999
Percentage of Pop that is Non-Hispanic Black	0.2277

These result can be used to estimate the geometric mean blood lead level for a geographic area for children between the ages of 1-2. We adjust this result by multiplying by 0.885, the average ratio of geometric means of children ages 1-5/ages 1-2 in NHANES from 2006-2016. We then model a log-normal distribution with the geometric mean from the model and a standard deviation approximated from fits of lognormal distributions to NHANES results from 2006-2016. This means we assume a constant coefficient of variation of the predicted state-level distributions, based on the national NHANES data. This approach was tested in NHANES data, comparing the “modeled” results from the combination of above coefficients and national-level estimates and years with the known distributions of nationally-representative child blood lead levels. See figures 3 and 4 for the results comparing the histogram of blood lead levels of 2-year NHANES samples, a fit lognormal distribution and the result of the model.

We expect that when we take this approach to the state and local level it may be slightly conservative, underestimating the right tail of blood lead levels in states with higher risk, leading to a conservative estimate of lead costs and the potential benefits of policies to prevent and remediate lead risks.

Figure 3

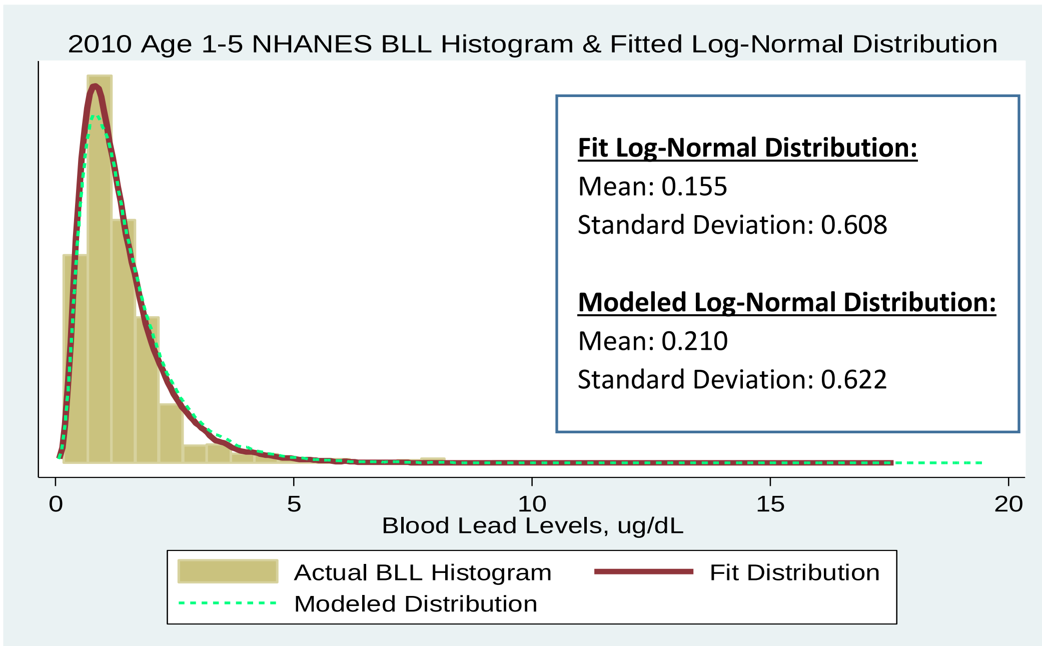
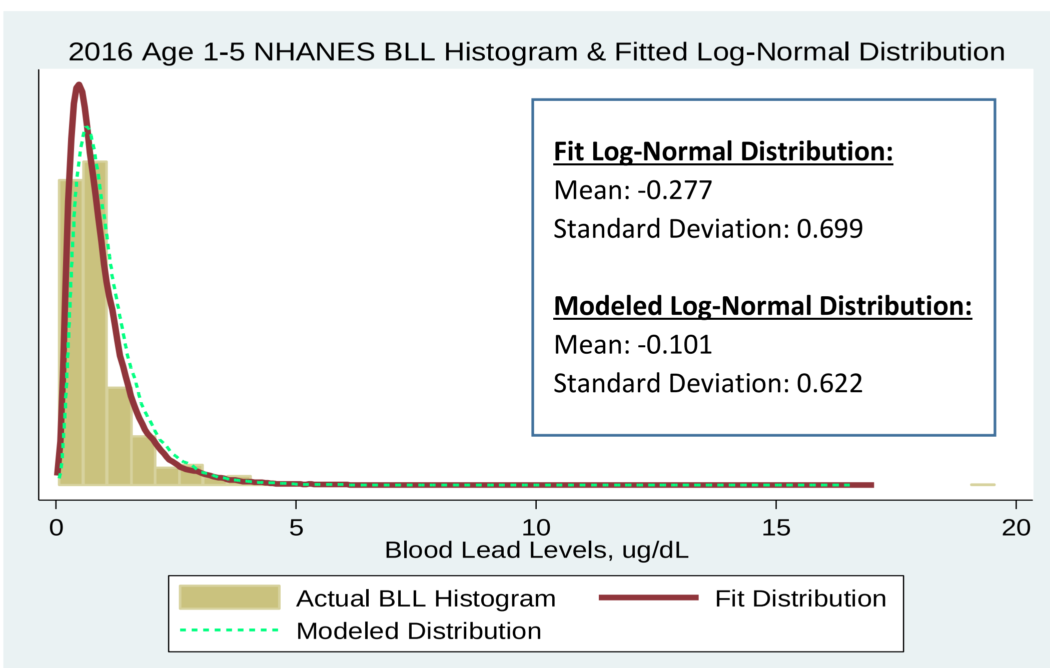


Figure 4



For the city-level inputs of blood lead levels, data from local sources was incorporated into these state-level imputations of blood lead levels, replacing or augmenting the distributions and average blood lead levels with real local data when possible.

Estimates of Economic Impacts of Childhood Lead Exposure

The economic impacts of lead exposure, used to generate the findings on the "Estimate Exposure Burden" sections of the *valueofleadprevention.org* follows a similar approach to the prior work, computing the difference in lifetime health and economic outcomes for a cohort exposed to blood lead levels estimated via the above approach. State and city-specific data on economic parameters were applied, as were state and city-specific lifetime health, education, and earnings trends.

Estimates of Economic Impacts of Lead Hazard Control Interventions

The economic benefits of lead hazard control interventions, resulting from reductions in expected blood lead levels, are calculated by employing the same approaches as was used in the national-level models. Details on the underlying literature and prior work used to estimate the magnitude of the impacts of lead hazard control interventions on child blood lead levels are available in the prior work on pages 43-44 and 107-108. Where possible, state and city baseline data are incorporated into these modeling assumptions to improve the accuracy of the estimates of the economic costs and benefits.

In order to estimate the varying costs and benefits of alternative assumptions or policy designs, Altarum developed the following cost and benefit relationships with the same literature. For example, to establish the relationship between starting dust lead levels and expected improvements in overall blood lead levels, the team used the same 2009 study on the relationship between dust lead levels and blood lead levels as in the prior work. The resulting cost and benefit formulas used on the website are as follows:

Cost Formula:

$\mathbf{Costs}_{\text{Displayed}} = [\mathbf{Homes}_{\text{User}} * \mathbf{TestCost}_{\text{User}} * (\mathbf{Pre78Homes/LBPHHomes})] + (\mathbf{Homes}_{\text{User}} * \mathbf{LHCCost}_{\text{User}})$

Benefits Formula:

$\mathbf{Benefits}_{\text{Displayed}} = \mathbf{Benefits}_{\text{Baseline}} * (\mathbf{Homes}_{\text{User}} / \mathbf{Homes}_{\text{Baseline}}) * \{[0.400 - ((20 - \mathbf{Dust}_{\text{User}}) * .00795)] / 0.400\}$

Estimates of Economic Impacts of Lead Service Line Replacement Interventions

The economic benefits of lead service line replacements, resulting from reductions in expected blood lead levels, are calculated by employing the same approaches as was used in the national-level models. Details on the underlying literature and prior work used to estimate the magnitude of the impacts of lead service line replacement interventions on child blood lead levels are available in the prior work on pages 32-33 and 106-107. Where possible, state and city baseline data are incorporated into these modeling assumptions to improve the accuracy of the estimates of the economic costs and benefits.

In order to estimate the varying costs and benefits of alternative assumptions or policy designs, Altarum developed the following cost and benefit relationships with the same literature. For example, to establish the relationship between starting water lead levels and expected improvements in overall blood lead levels, the team used the same EPA work on the relationship between water lead levels and blood lead levels as in the prior work. The cost and benefit formulas used on the website are as follows:

Cost Formula:
$\mathbf{Costs}_{\text{Displayed}}$ = [$\mathbf{LSL}_{\text{User}}$ * $\mathbf{TestCost}_{\text{User}}$ * (**Pre86Homes/LSLHomes**)] + ($\mathbf{LSL}_{\text{User}}$ * $\mathbf{LSLCost}_{\text{User}}$)

Benefits Formula:
$\mathbf{Benefits}_{\text{Displayed}}$ = $\mathbf{Benefits}_{\text{Baseline}}$ * ($\mathbf{LSL}_{\text{User}}$ / $\mathbf{LSL}_{\text{Baseline}}$) * {[0.395 – ((11.4 – $\mathbf{PPB}_{\text{User}}$) * 0.0423)] / 0.395}

Estimates of Economic Impacts of Renovation, Repair, and Painting Standards Enforcement

The economic benefits of enforcement of renovation, repair, and painting standards, resulting in an increase in the use of lead-safe work practices and reductions in expected blood lead levels, are calculated by employing the same approaches as was used in the national-level models. Details on the underlying literature and prior work used to estimate the magnitude of the impacts of lead hazard control interventions on child blood lead levels are available in the prior work on pages 54 and 108. Where possible, state and city baseline data are incorporated into these modeling assumptions to improve the accuracy of the estimates of the economic costs and benefits.

In order to estimate the varying costs and benefits of alternative assumptions or policy designs, Altarum developed the following cost and benefit relationships with the same literature. For example, to estimate the expected prevented reduction in blood lead levels resulting from lead safe work practices, the team used the same 2008 EPA study as in the prior work. The cost and benefit formulas used on the website are as follows:

Cost Formula:
$\mathbf{Costs}_{\text{Displayed}}$ = ($\mathbf{TestCost}_{\text{User}}$ * $\mathbf{Renos}_{\text{User}}$ * 2.59) + ($\mathbf{LSWPCost}_{\text{User}}$ * $\mathbf{Renos}_{\text{User}}$)

Benefits Formula:
$\mathbf{Benefits}_{\text{Displayed}}$ = $\mathbf{Benefits}_{\text{Baseline}}$ * ($\mathbf{BLL}_{User}$ / $\mathbf{BLL}_{Baseline}$) * ($\mathbf{Renos}_{User}$ / $\mathbf{Renos}_{Baseline}$)