Data Requirements for Valuation of Children's Health Effects and Alternatives to Valuation

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Abstract: Appropriate characterization and valuation of the health risks specific to children is important for effective environmental health risk management. This paper highlights the typical information provided by risk analysts about risks to children and the information needs of economic analysts. Particular emphasis is given to transparency in risk characterization (Browner, 1995) and the required assumptions to bridge the data and knowledge gaps. This paper also provides strategies intended to promote discussion and cooperation between risk and economic analysts, including a list of questions to ensure that key issues are discussed in advance of and during the risk assessment process. Finally, the paper provides an example of coordinated risk and economic analyses that characterized and valued risks and benefits for children.

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Keywords: risk assessment, children, valuation

Introduction

The impact of a health risk to children may differ significantly from the risk to adults for many behavioral, biological, chemical, physical, and other reasons. Perhaps the most striking evidence of differences can be seen in Table 1, which lists the top ten causes of death for all Americans, for children between ages 1 and 14, and for ages less than 1. Clearly the profile of fatality risks strongly depends on age, and regulatory agencies, like the EPA, should explicitly consider this variability in assessments and valuation of health risks.

Recognizing the potential for distinct health risks to children and evaluating those risks in the regulatory process can help identify risk inequities and target policy options that may lead to improved health outcomes for children. For example, tens of children have been killed in minor automobile accidents by the force of deploying passenger-side airbags that were designed to protect unbelted adult men. The magnitude of the trade-off was explored in a recent cost-effectiveness analysis which found that airbags kill one child on net for every 5 to 10 adults they save (Graham et al., 1997). Retrospective analysis suggests that early assessments of the risks and benefits of airbags failed to adequately consider the uncertainty about the effectiveness of airbags and variability in risk for different age groups (Thompson et al., 1999). Incorporation of child-specific risk assessment results into the airbag cost-benefit analysis may have motivated a way to mitigate the dangers of airbags to children while still maintaining the benefits of airbags for adults. At the very least, it would have fully informed the decision makers of some of the risk tradeoffs (Graham and Wiener, 1995) associated with air bags.

Appropriate characterization and valuation of the health risks specific to children is also important for effective environmental health risk management. However, data gaps and other data issues can make the link between risk assessment and economic valuation

difficult. Assessing risks and valuing risk reductions of mortality and morbidity effects for individual children, and children as a population, requires extensive communication and cooperation between risk assessors and economists. The objectives of this issue paper are to:

(1) highlight the informational needs of risk and economic analysts focusing on characterization and valuation of children's health risks;

(2) identify data gaps that limit the ability of analysts to quantitatively estimate and value risks to children; and

(3) provide risk and economic analysts with a common ground to promote coordinated actions that will ultimately improve the health and safety of American children.

The next section highlights the typical information provided by risk analysts about risks to children and the information needs of economic analysts. Particular emphasis is given to transparency in risk characterization (Browner, 1995) and the required assumptions to bridge the data and knowledge gaps. The following section provides strategies intended to promote discussion and cooperation between risk and economic analysts, including a list of questions to ensure that key issues are discussed in advance of and during the risk assessment process. Finally, the paper provides an example of coordinated risk and economic analyses that characterized and valued risks and benefits for children.

Types of information provided by risk assessors and risk information needs of economists

Assessing risks to children and making assumptions transparent

Risk assessors rely on mathematical models to estimate potential human health risks as a function of exposure to a substance in the environment and the substance's toxicity to the exposed individual(s). For children, these estimates are generally very uncertain because children are not exposed to levels of substances that cause observably harmful effects and analysts must extrapolate from limited data on potential health effects at high doses to potential health effects at low doses. Indeed, the limited existing data that demonstrate differential effects on children compared to adults largely come from cases where high exposures led to significant numbers of cases of relatively rare diseases that could be detected (Rogan, 1995).

Using available information for risk assessment always requires making assumptions to deal with the uncertainties and with extrapolating from the available data to the information desired. The methods used for extrapolation can introduce significant errors into an analysis and current risk characterization guidance encourages risk analysts to be transparent about the assumptions used (Browner, 1995). One way to improve transparency, and to facilitate interaction between risk and economic analysts, is to provide a list of the risk assessment assumptions. Table 2 provides a checklist of common assumptions focusing on children that might serve as a starting point for such lists. When listing assumptions, risk assessors should be as specific as possible so that economists and others can be fully informed of value judgments and limitations inherent in the analysis (Henry et al., 1992). The list in Table 2 follows the traditional four parts of risk assessments (NRC, 1983):

- hazard identification (i.e., is there a potential hazard?),
- dose-response assessment (i.e., how do health effects vary with dose?), and

- exposure assessment (i.e., how large of a dose might the child get from contact with the substance?),
- risk characterization (i.e., what is the likely effect and what is the probability of it occurring?)

Risk differences between children and adults

While the same general approach to assessing risks to adults may be used to assess risk to children, several important differences may emerge. Children's risks from exposure to toxic substances can differ from adults' risks in outcome (often referred to as a qualitative difference) and in severity (often referred to as a quantitative difference) (ILSI, 1992; NRC, 1993).

In general, children represent a group that is relatively understudied toxicologically and this leads to many extrapolation issues in risk assessment. Historically pediatric populations have not been the subject of sufficient pharmaceutical trials for various reasons (DHHS, 1997) or epidemiological studies due to the relative rarity of disease (Grufferman, 1998). In a few cases, extrapolation may be required to estimate the effects on children based on limited evidence from a cohort of occupationally exposed adults. In most cases, however, the best available evidence might be that the substance might cause adverse health effects in animals, and risk assessors must extrapolate toxicological data between species as well as for age. Specific examples exist of cases where exposures of children resulted in health effects that did not occur in exposed adults (e.g., vaginal and cervical cancer from fetal exposure to diethylstilbestrol) and vice versa (e.g., sterility following adult exposure to mumps) (Wilson et al., 1991). Examples also exist of cases where adults are more sensitive to exposure than children for the same effect (e.g., liver toxicity from exposure to acetaminophen) and vice versa (e.g., neurological damage from

exposure to lead or hexachlorophene) (Kauffman, 1992; Davis and Grant, 1992; Kacew, 1992;). Also, at particular windows of development, children may be more or less sensitive or vulnerable.

As with toxicity, children's exposures can also differ from those of adults and they must also be assessed on a case-by-case basis. Childhood represents a period of rapid growth, and due to their higher metabolic activity children have higher daily requirements for food, water, and oxygen per unit of body weight than adults (ILSI, 1992; Bearer, 1995). In addition, children's activities may differ significantly from those of adults, and consequently, some exposure scenarios or conditions that apply to one group might not apply to the other (e.g., occupational exposure, extended periods of time crawling, high soil ingestion rates, large consumption of apples or brussel sprouts).

Finally, child-specific information may often be less available than information for adults, and consequently estimates of the risks to children may be relatively more uncertain. However, the default response to this uncertainty should not necessarily be an assumption that children are unequivocally more sensitive and vulnerable to adverse health effects from exposure to toxic substances than adults (i.e., that children always have higher risk). Instead, the evidence that is available for children suggests that relative risk must be assessed on a case-by-case basis (ILSI, 1992; ILSI, 1996; Goldman, 1998). Risk assessors should provide economists with the best available information on the relative risks to children regardless of whether this information is consistent with the assertion that children are more deserving of protection than adults. Should an analyst wish to incorporate such a value judgment, that decision should be made separately from the risk assessment and clearly identified in the economic analysis.

Valuation issues related to risk characterization

The issue of assumed sensitivity and vulnerability of children is often rooted in a poorly defined societal "value" that children warrant additional protection from harm than adults, which could be translated into a greater "value of statistical life" for children than adults. Like the absolute magnitude of the value of a life, the relative weights of children's lives compared to adults' lives is a controversial issue, and one that has yet to be fully explored by economists (Agee and Crocker, 1998 and Neumann and Greenwood, 1999).

The choice of the appropriate metric for risk characterization (e.g., lives saved, or life-years saved) is a very important decision from the valuation perspective. However, empirical evidence documenting preferences for valuation based on lives saved as opposed to life-years saved is limited. Thus, risk assessors need additional guidance from economists with respect to the preferred metric to serve as the basis of an economic analysis.

In the medical community, the standard for risk and cost-effectiveness analysis relies on valuation based on life-years that may be adjusted for quality or disability (Gold et al., 1996; Murray, 1994). Quality-adjusted life-years (QALYs) are typically estimated by asking a group of people familiar with the health outcomes to characterize them along a number of different states for various attributes, then asking a different group of people to assign values to the health states (Gold et al., 1996). This process has been standardized recently in the medical community (Gold et al., 1996) and the current recommendation is that values be obtained from a population-based sample of individuals. This approach avoids explicit assignment of values per life or life-year (Weinstein and Stason, 1977; Gold et al., 1996) and it recognizes that a life can be saved many times (Wright and Weinstein, 1998). By focusing on life-years saved, analysts explicitly recognize the greater life expectancy of children compared to adults.

However, adjustments for quality or disability may vary significantly in their assumptions about children. For example, QALYs are not differentially weighted as a function of age over the lifespan, while disability-adjusted life-years (DALYs) are weighted lower for children and the elderly than for middle-age adults (Murray, 1994). In particular, a DALY lived at age 2 is valued as worth only 20% of a DALY lived at the peak utility age of 25 (Anand and Hanson, 1997), and above age 25 DALY values decrease. Controversy persists associated with these choices (Anand and Hanson, 1997; Murray and Acharya, 1997). The controversy extends further to economists concerned with the validity of these measures, because the measures are not estimates of willingness-to-pay (WTP) and may not rank alternative health states in the same order as WTP (Johannson 1995).

Whatever metric is used, many assumptions in Table 2 may have significantly different implications for valuation of children's risks than they do for adults. For example, since radiation treatment can permanently damage a child's developing central nervous system (Bearer, 1995), even if treatment eliminates the same risk of dying from cancer for a child and an adult, the side effects may be much more significant for a child than for an adult. To value these effects, analysts must develop methods and models to characterize the impacts of health effects at different times on the developmental trajectories of children (McCormick, 1999). Also, since efforts to treat and manage many types of childhood cancer over the past two decades have made great progress and now many childhood cancers are successfully treated (Carroquino et al., 1998), economists valuing children's cancer cases may need to factor in a higher survival probability.

Valuation of any type of disease can also depend on a variety of factors, including the time between exposure and the emergence of the health effect (called the latency period), risk perception issues, and the baseline health status of affected individuals. Latency periods for diseases can vary from no time (i.e., immediate effects) to effects that

occur decades later in life (Henry, 1992). For diseases with long latency periods, discounting may be important in valuation of the effects. While discounting for latency may decrease the overall valuation of children's health effects, consideration of other factors affecting valuation may have the opposite effect. For example, adjusting valuation for baseline health status may increase the value of children's health effects because children tend to be healthier on average than adults. The effects of adjusting for factors related to risk perception (e.g., voluntariness, controllability, equity) on the valuation of health effects could be either positive or negative.

One of the major assumptions frequently made in risk assessment makes specification of the outcome and latency periods highly uncertain. In particular, when extrapolating from animal evidence to humans, it is not uncommon to assume that the adverse human health effect might be very different than that experienced by the test animals (i.e., no expectation of concordance of the health effect type between species). When the particular effects of concern are not clearly specified, this can dramatically impact an economic assessment. For example, cancer morbidity and mortality might be valued very differently than asthma and/or lost IQ points, and differing degrees of effects may have different values (not all cases of asthma are equally bad). Risk assessors must clearly convey what is known and unknown about the potential health effects, so economic analysts can consider the bounding cases for the size of children's health benefits.

The assumptions made related to the dose-response modeling and the type of risk metric used directly impact the utility of the risk estimate(s) for economists. While cancer risk assessment results are typically conducive to economic analysis because they can be converted into probabilities of cases of illness, non-cancer results are typically less useful for valuation because they focus only on determining whether or not a child is exposed above an acceptable threshold. Further, in some programs, emphasis has historically

centered on individual risk estimates, while others focus on population risk or both. Valuation based on individual risk estimates will typically require the economic analysts to make assumptions or collect data about the number of such exposed individuals in the population in order to aggregate to the societal level. For example, population estimates of cases of leukemia avoided per year can be more easily understood and valued by economic analysts than an individual risk estimate of the probability that a highly exposed child could develop leukemia. When individual risk estimates are provided, economic analysts will face tough questions (e.g., how can benefits be assessed based on the individual risk estimate or based on the margin between such a child's estimated exposure and the exposure that may cause an adverse effect?)

Finally, methods used to characterize uncertainty should be consistent with the need of the risk manager and the economists (NRC, 1994; NRC, 1996; CRARM, 1997). Since child-specific information may be less available than information for adults, estimates of the risks to children may be relatively more uncertain. At a minimum, analysts should qualitatively discuss the important sources of uncertainty and when possible they should quantitatively demonstrate the impacts of different plausible assumptions or provide information about the distribution of risks for children.

Data Gaps

Several recent conferences focused on identifying data gaps and research needs for improving characterization of children's risks (Carlson and Sokoloff, 1995; Carlson, 1998; Carraquino et al., 1998; Landrigan et al., 1998). Table 3 summarizes the recommendations given to address data gaps that resulted from these efforts.

With respect to the valuation side, comparable lists do not exist. Important data gaps related to societal preferences for children's lives compared to adult's lives and the use of life-years instead of lives as a metric were mentioned above. Other data gaps relate to the development of methods to get children's assessments of their own preferences and parent's assessments of preferences, and characterization of the impacts that interfere with normal growth and development as a function of the timing and reversibility of the interference. In addition, while characterization of other attributes that might impact acceptability or valuation of the risks is a risk management issue, the attributes may be different in the case of children's risks than they are for adults (e.g., voluntariness on the part of the child versus the parent, controllability by the child or parent).

Perhaps the most important methodological data gap relates to the question of what to do in the absence of risk assessment information. Several options exist, and the best choice will depend on the stakes involved and the way in which the uncertainty is managed. One option is to ignore the uncertainty and to not take any action, another option is to ignore the uncertainty and take action, and a third option is to conduct research to reduce or eliminate the uncertainty. For example, consider the case of the decision to regulate a substance that may or may not be an endocrine disruptor (i.e., it may or may not cause a non-carcinogenic response due to its ability to mimic normal human hormones). The expected net benefits of the substance depend on whether or not

it is regulated and whether or not it is an endocrine disruptor. If the decision maker assumed with certainty that no information implied absence of an effect (i.e., the probability that it is an endocrine disruptor is 0), then the optimal action would probably be not to regulate. Alternatively, if the decision maker assumed with certainty that no information implied proof of no safety (i.e., the probability that it is an endocrine disruptor is 1) then the optimal action would probably be to regulate. The optimal decisions are to regulate if it is a disruptor, and not to regulate if it is not. The presence of uncertainty means that there is some possibility that the decision maker will make a choice that is non-optimal, and it implies that there will be value in obtaining better information. However, not all information is equally valuable (e.g., some information may be more useful at reducing uncertainty than other information). Estimating the relative value of different kinds additional information is a useful tool for prioritizing data collection initiatives related to children's health risk assessment and valuation.

One issue that remains unresolved is how to incorporate and use additional information when it is collected, for example, if specific information about toxicity for children is obtained. In the case of lead, regulatory action levels have been lowered dramatically over the past two decades, as additional research identified adverse neurological effects associated with exposures below the initial regulatory levels. Risk and economic analysts must inform risk managers about the opportunities that exist to collect additional information and how additional information might alter the characterization and valuation of children's risks.

Working together and an iterative analytical process

Thinking of risk assessment as a continuum from source to exposure to health effects (e.g., Lioy, 1990) is useful because it makes clear that possibilities may exist to manage risks at many points in the continuum. Since economic analysis must build on the risk assessment, the farther along the continuum that the risk assessment can go, the easier the job of economic analysts.

One issue to which risk and economic analysts should be very sensitive is the need of distinction between the roles they serve. Risk assessors should not be biased by input from economic analysts in the assumptions that they make when they assess risks (NRC, 1983). However, risk and economic analysts should interact and their separation should not mean divorce (Wilson and Clark, 1991; NRC, 1983). Risk assessors must interact with risk managers and economic analysts to discuss what risks will be assessed (i.e., what information they care about) and in some cases to learn about the strategies that might be implemented to reduce the risks (so the risk assessors can assess changes in risk). Early discussions that identify the key receptors to evaluate (e.g., adults exposed to a pollutant that exhibits reproductive toxicity, pregnant women/fetuses, infants, adolescents, etc.) and the potential effects will focus the risk assessment and help economists plan for valuation. In those cases when information about preferences for valuation are not available, these discussions should allow enough time for economists to design surveys and collect additional data.

Table 4 provides a list of questions designed to facilitate dialogue between risk assessors and economists as they iterate through the analytical process. By discussing these questions and through regular communication, risk and economic analysts will maximize the usefulness of risk assessment data and better manage its limitations. Examples where risk and economic analysts collaborated in characterization and

valuation efforts exist, although they are sparse. Numerous risk assessments provide information about potential health risks, and numerous valuation studies provide information on how specified changes in health might be valued. However, very few examples exist that combine these. One example that does provide both estimates and valuation of the adverse effects is an analysis of lead in the environment (e.g., Schwartz, 1994).

Alternatives to monetizing benefits in the face of limited risk assessment information

Thompson and Graham (1996) provide a discussion of many different decision criteria for managing risks, including risk-only decision criteria, comparisons of risk, cost-effectiveness analysis, and decision and value-of-information analysis. For all of these, transparency in risk characterization and the implications of uncertainty go a long way on the road toward monetized estimates of benefits.

However, some problematic issues with respect to valuation can be anticipated. For example, what should an economic analyst do with a result of a non-cancer assessment using the traditional Reference Dose (RfD) approach or the Margin of Exposure (MOE) approach proposed in the EPA's 1996 Carcinogen Risk Assessment Guidelines? Both of these approaches focus on identifying a threshold dose below which adverse health effects are not expected, and comparing the estimated exposure with the threshold dose. One way to view these is as methods to address the potential lack of risk. Unfortunately, they do not provide any information about the magnitude or probability of the risk if the exposure exceeds the threshold level. If the burden falls on economic analysts to get to risk estimates from that point, they will require input from the risk assessors. In general, risk assessors should progress as far as possible toward quantitative estimates of health

risks with uncertainty characterized so economists can progress as far as possible toward quantitative estimates of monetized benefits.

Using a risk-only approach the risk estimates may not require valuation at all if consideration of economic concerns is not allowed. Some environmental statutes carried out by the agency explicitly prohibit valuation. Different strategies for dealing with uncertainty that may exist in the characterization of risks also emerge from the risk-only approach. However, this approach can lead to perverse choices in some situations.

Direct comparisons of risk can be another alternative to valuation of risks. This may involve evaluating the risk-risk trade-offs that can occur with a selected action (Graham and Wiener, 1995) or direct comparison of the risk with other similar risks. When making comparisons, many attributes of the decision may be important to consider (e.g., voluntariness, etc.). Comparative risk analysis might allow the opportunity for multiple attributes to be considered simultaneously.

Cost-effectiveness analysis (used widely in the medical field) may also provide a useful alternative to full monetization. In particular, cost-effectiveness analysis stops before assigning a value to the health effect and characterizes the cost per unit of health effect or health effect avoided. For example, analysts could report the cost per case of leukemia avoided, the cost per unit of function, or the cost by QALY. Medical decision making analysts frequently focus on identifying sub-populations for which interventions may have relatively high cost-effectiveness. This approach further characterizes variability in the population and might be very useful in analysis of environmental health risks as well.

Another alternative to assigning values to the risks is to assign risks to any costs (Keeney, 1997). This approach is essentially a benefit-cost analysis done in the common metric of health units instead of monetary units.

The use of any alternative to explicit valuation of health effects ultimately still requires the risk manager to make choices about valuation when making decisions. The only difference is these cases is that choices about values are made implicitly (i.e., without specification of a particular value per life or value per life-year), although analysts can estimate bounds on such values explicitly once the decision has been made.

Conclusion

As regulatory agencies strive to improve their characterizations and valuations of children's health risks to avoid situations that put children at unnecessary or unacceptable risk, the analysts involved will benefit from efforts to be transparent and cooperative. This paper provides tools to aid in the interactions of risk and economic analysts and highlights issues related to characterization and valuation of children's health risks. These tools should be updated and improved with use.

Many challenges remain for analysts characterizing children's risks. First, techniques to deal with uncertainty should be developed and tested using past case studies. Second, prospective research should be targeted toward reducing those uncertainties that dominate the overall uncertainties in risks to children and that can be reduced. Finally, analysts must address how exposure to a substance may impact peoples' health throughout their lives, including growth and development, and keep the element of time in the risk assessment.

Many challenges similarly exist for economic analysts. First, studies should be conducted to understand peoples' preferences about lives-saved and life-years saved and risk assessors should be informed about the appropriate characterization of risks. Second, techniques should be developed to deal with the results of threshold risk

assessments that focus on characterization of the absence of risk, especially if the agency moves toward a Margin-of-Exposure approach. Finally, economic analysts must engage in interactive dialogues with risk assessors and address the issue of identifying the attributes of the decision that are important with respect to children's health.

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Table 1: Top 10 Leading Causes of Death for Different Age Groups of Americans

Cause	All ages	Ages 1-14	Ages < 1
Heart disease	1	5	
Malignant neoplasms	2	2	
Cerebrovascular	3		
Bronchitis/Emphysema/Asthma	4	10	
Unintentional injuries	5	1	7
Pneumonia and influenza	6	8	9
Diabetes	7		
HIV	8	6	
Suicide	9	7	
Liver disease	10		
Congenital anomalities		3	1
Homicide		4	
Benign neoplasms		9	
Short gestation			2
Sudden Infant Death Syndrome			3
Respiratory Distress Syndrome			4
Maternal complications			5
Placenta cord membranes			6
Perinatal infections			8
Intrauterine hypoxia			10

Data for 1993-1995 from the National Vital Statistics System, National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention, US 30TT35, revised 7/07/98, Hyattsville, MD: NCHS, 1998. The data are also available at: www.cdc.gov/ncipc/osp/leadcaus/ustable.htm

Table 2: Common assumptions made by risk assessors

Hazard identification assumptions: Check all that apply

☐ Human (epidemiological) evidence suggests exposure may cause adverse effects to children

☐ Animal evidence suggests exposure may cause adverse effects to children

☐ Positive results (i.e., indicating an adverse effect) outweigh negative results from comparable studies for children's health effects

☐ Results that show an effect based on a 95% confidence interval are significant for children

- ☐ Results from a different route of exposure for children are directly relevant to the exposure route considered (i.e., oral data applies to inhalation exposure or vice versa)

- ☐ Short-term tests provide a mechanistic basis for disease (e.g., mutagenicity tests suggest that the substance may directly affect DNA)

- ☐ The adverse health effect experienced by humans may be different than that experienced by animals (e.g., concordance of effects between species is not needed because the tests focus on observing outcomes in animals at high doses for effects to which they are particularly sensitive)

- ☐ Occurrence of rare outcomes is considered evidence of an effect even though the results may not be statistically significant

- ☐ Results from different studies should be combined (method should be specified)

- ☐ Information about analogous substances suggests that the substance may cause adverse health effects to children

- ☐ Evidence suggests that children may be exposed to the substance

Table 2: Common assumptions made by risk assessors (continued)

Dose-response assessment assumptions:
☐ Epidemiological results for an accidentally-exposed population or a healthy worker population apply to children (perhaps with some specified adjustments)
☐ Animal test results at high doses apply to children at lower doses
☐ Doses are scaled between species according to $BW^{3/4}$ (or otherwise as specified)
☐ Differences in metabolism that might change the relative susceptibility of humans and animals are accounted for (according to the method specified)
☐ Different responses should be combined (e.g., data on different tumor types, sites, or malignancy)
☐ A linear dose-response model is appropriate (i.e., any finite dose leads to some finite risk)
☐ A non-linear (i.e., threshold) dose-response model is appropriate (e.g., Benchmark dose, Margin-of-Exposure)
☐ Evidence of tissue damage or other toxic effects among test animals does not preclude inferences about the data
☐ Selection of the most sensitive sex, strain, and species provides a protective estimate of risk
☐ Risk estimates have been adjusted properly to account for the short-follow up period (less than lifetime exposures of the test animals or exposed humans)
☐ Exposures due to other factors (possible confounding factors) have been taken into account
☐ Information that was excluded would have little to no impact on the results for children (specify any possible exceptions)

Table 2: Common assumptions made by risk assessors (continued)

Exposure assessment assumptions:
☐ The children at risk are similar in every way to the children from whom the exposure factor and time/activity data were collected
☐ Any adjustments made to the exposure data to extrapolate to children are appropriate
☐ Children exhibit behaviors and physical characteristics that are unchanged over the specified amount of time (as described in the exposure scenarios)
☐ Children do not move themselves and are not moved by others out of the risky situation
☐ A dispersion (or other specified) model is appropriate
☐ Dietary patterns and lifestyle choices have been considered appropriately for children
☐ Critical developmental windows are known
☐ Timing, duration, and/or age of first exposure are well-known and appropriately considered
☐ Children should be considered as a special sensitive sub-population based on the data
☐ Low probability catastrophic events are not expected
☐ The data support the characterization of inputs in the assessment for children
☐ Information that was excluded would have little to no impact on the results (specify any possible exceptions)
Risk characterization assumptions:
☐ The impacts of key uncertainties can be quantified
☐ Rationales for key assumptions appropriately support the assumptions
☐ Sensitivity analysis or the full distribution of risks shows range of uncertainty and impacts
☐ The potential impacts of new research have been considered
☐ The estimate of individual risk for an average individual multiplied by the number of affected individuals provides a good estimate of the population risk
☐ Risks characterized represent the most important adverse effect(s)

Table 3: Recommendations to address data gaps that inhibit better characterization and valuation of children's health risks (Paraphrased from Carlson and Sokoloff, 1995; Carlson, 1998; Landrigan et al., 1998; Carraquino et al., 1998)

General Issues
· Coordinate laboratory science, human and animal clinical, and population epidemiological studies to understand the long-term, delayed, and potential transgenerational health effects resulting from environmental exposures.
· Collect specific data for children (particularly for vulnerable sub-populations such as low income and racial/ethnic communities) related to: · differences between children and adults, the unique susceptibilities of children and critical periods of vulnerability in development, · the influence of environmental exposures on developing physiology of adolescents, · impacts of early exposures on later life disease outcomes, and · the effects of cumulative, multiple, and synergistic exposures.
· Create cost-effective data banks of exposure information (data and biological specimens) and resource and referral systems for health professionals that provide information about disease/cancer clusters, prevention, and interventions.
· Develop better and more cost-effective research tools including systemic and new approaches for exposure screening and monitoring, for assessing population-based adverse developmental outcomes, and for toxicity testing.
· Develop a coordinated research and policy program that involves all affected communities more effectively using a prevention-oriented, child-centered paradigm and through promotion of education about preventable causes of environmental disease.
· Address the ethical, social, and scientific issues associated with using and developing genetic and biomarker information, and increase development and use of many types of biomarkers in risk assessment and clinical settings.
· Develop and administer toxicity tests to infantile animals and possibly *in utero* to follow the entire life spans of the animals, better mimic the human condition of exposure in childhood, and detect unanticipated outcomes of early exposures. Based on the test results develop additional and refine existing dose-response models for child-specific health effects.
· Develop exposure assessment methods to evaluate fetal exposures and the contribution of parental exposures, characterize exposure during critical periods and to highly exposed populations, and to evaluate and improve protocols for child exposure assessment if needed.
· Improve exposure assessments for epidemiological studies, including cooperation of large international efforts, and examine the association between cancer incidence and birth defects.

Table 3: Recommendations to address data gaps that inhibit better characterization and valuation of children's health risks (continued)

Disease specific research
Asthma – Design studies to understand and characterize the linkages between: · air pollutants (outdoor, indoor, bioaerosols and chemicals) and asthma; · good medical care and the course and severity of disease; · differences in susceptibility and risk factors of individual children; · prevention strategies for pregnant women and mothers of young children and reductions in the incidence of asthma; and · interactions among exposure and infection history and the development of allergy, asthma, and airway reactivity (particularly for inner city and affluent environments)
Neurobehavioral effects (both acute and delayed) · Explore neurotoxicological mechanisms of action and health effects of neurotoxicant mixtures; · Develop multigenerational neurotoxicity tests and techniques to assess genetic-environment interactions in neurotoxicity; and · Study long-term social and behavioral responses to neurotoxicants.
Endocrine and sexual disorder effects · Study exposure to potential endocrine disruptors (perinatal and *in utero*) and their role in the incidence of hypospadias, cryptorchidism, testicular, breast, and prostrate cancers, endometriosis, and premature onset of menarche in girls.
Cancer · Initiate methods to map patterns of incidence and generate hypotheses; · Begin major biomarker-based epidemiological studies to evaluate these hypotheses; · Conduct prospective longitudinal studies of children with known exposures to carcinogens in childhood or *in utero*; · Study genetic bases for childhood cancer; · Develop a national children's cancer registry; · Develop animal models to explore toxicological differences between children and adults and to evaluate toxicity for developing organ and immune systems; · Conduct research on developmental changes and susceptibility related to immune function; · Metabolism, dietary factors, obesity, and cell proliferation; · Study the differences in DNA repair for adults and children; and · Study the role of maternal nutrition and immune protection.

Table 4: Discussion questions to facilitate interaction between risk and economic analysts

1. What are the health outcomes (that will be) characterized?
2. Who are the key child receptors (e.g., infants, toddlers, adolescents)?
3. How are the risk estimates presented or how will they be presented?
4. Is the metric specific and precise enough to support valuation?
5. How many children are expected to present with the outcome(s) without additional action?
6. How many children are expected to present with the outcome(s) with each additional action under consideration?
7. What risk factors put children particularly at risk?
8. What ages of individuals are exposed?
9. What is known about the susceptibility or sensitivity of the exposed children to the disease?
10. What, if any, trade-offs might be induced by the actions?
11. What is the latency period between exposure and disease?
12. Is the disease detectable in children? treatable? reversible?
13. Does the disease alter the child's quality of life because it changes his or her normal growth or development?
14. What is the magnitude of the uncertainty around the quantitative estimates?
15. What assumptions drive this (review list of assumptions shown in Table 2)?