This issue has been raised in relation to air pollution since this is a risk that mainly affects a smaller group, the sick and elderly, in the population. However, so far no firm conclusions on this issue have been reached.

Our conclusion however is that the valuation of mortality is not really of importance in our context. It is because premature mortality among children due to the air pollution levels found in Sweden is so far without empirical evidence. Still, we will briefly describe the methods used and the most important issues raised regarding valuation of this health endpoint since new findings may change this conclusion. As discussed in chapter 2 there are three health impacts, if empirical studies can verify a connection with air pollution, that entail using values for premature mortality for children. These are if reduced lung function in young ages due to air pollution is a chronic condition that can be related to shorter length of life, if air pollution is one of the causes of infant mortality and finally, if air pollution contributes to the development of cancer.

Similar to the development path of the valuation of morbidity, the first estimates on the value of premature mortality relied on estimation of production losses. This is the so called human capital approach. However, as discussed in the introduction, this is only part of the total value. To this an estimate of the welfare loss should be added. Contrary to the total value for morbidity, it is the welfare loss that makes up the largest part of the total value for preventing premature mortality.

An example of aspects that are important in calculations of the total value is found in the VSL used in the transport sector. The value in this context is composed of two parts, the welfare estimate equal to 16,2 million and the so called material costs (hospitalization, property losses, administration and production loss) which amounts to 1,2 million. The major part of these material costs are the production loss equal to 0,9 million. These are the estimates for 2001. Based on more recent research evidence a higher welfare estimate of 21 million is now used (SIKA, 2008).

For both of the value components, the question of children having longer life expectancy is relevant. When calculating the production loss it is quite clear that this value will be higher if a person dies at young age provided that we can expect similar income levels in the future. It is however more difficult to make firm conclusions regarding the value of the welfare loss. This is partly due to the problem that we cannot obtain willingness to pay estimates from the children themselves. The overview of the literature done in OECD (2006) however suggests that VSL estimates for children should be higher than those used for adults.

One way to arrive at an estimate that accounts for length of life in the case of premature mortality was formalised in early work in the ExternE projects. They used the estimate of value of statistical life (VSL) to obtain an estimate of the value of a life year (VOLY) using annuity calculations (Friedrich and Bickel, 2001):

$$VSL = \sum_{t=0}^{T} \frac{VOLY_{acute}}{(1+r)^t}$$

where

VSL	the value of a statistical life
$VOLY_{acute}$	the value of a life year lost
t	year
T	average expected length of life
r	discount rate.

This rests on the assumption that every year is given the same value, which is not a finding supported by empirical research. Many studies have found that willingness to pay first increases and then decreases with age. Since the debate on the use of VSL or VOLY is ongoing, in the ExternE methodology update (Bickel and Friedrich, 2005) they suggest values for both. For VSL they arrive at an estimate of 1 million euro and for VOLY 75 000 euro. Both these estimates refer to premature deaths occurring at the time of exposure (acute mortality). For deaths at a later point in time resulting from current exposure (chronic mortality), the VOLY estimate they use is 50 000 euro.

Latency is an additional complication, also in the case of mortality valuation. For adults it is expected that some pollutants will contribute to the development of heart conditions which in turn will result in premature deaths in the future. Hence, when calculating benefits resulting from exposure reductions today we need to discount the value for health gains that will occur in the future. There are several reasons for using discounting. One is that investments today will generate greater amount of resources in the future. Another is that people prefer consumption today (or health improvements today) instead of in the future, a proposition that has also been verified by empirical analysis (Cropper et al., 1994)[15].

The calculation of the discounted value is straightforward if we know the value of a life year and the discount rate. In ExternE they use the following formula to arrive at a present value for an life year expected to be lost in the future (Friedrich and Bickel, 2001):

$$VOLY_{chronic} = \frac{VOLY_{acute}}{(1+r)^t}$$

där

$VOLY_{chronic}$	the value of a discounted life year
$VOLY_{acute}$	the value of a life year
t	latency period, the time between exposure and death
r	the discount rate.

[15] Discounting is supported by empirical research but the size of the discount rate to be used in different contexts is a matter of discussion.

However, as discussed earlier, the problem is to determine VOLY. Moreover, the length of the latency period is also an estimate that is difficult to establish empirically. The present value estimate will also be influenced by size of the discount rate; a higher discount rate implies a lower present value

Since the value to be used for premature mortality for young versus old are important issues, especially in a policy situation where the policy maker often has to rely on benefit estimates from other studies and other contexts, many studies have explored these aspects in recent years. Examples include a study within the New-Ext project (Alberini et al., 2004), a study commissioned by DEFRA[16] in England (Chilton et al., 2004) and a recently published American study that include morbidity and mortality risks in the same questionnaire (Bosworth et al., 2009). Unfortunately, none of these answers the basic question if people values risk reductions for children higher than for adults and if so, by how much. They rather confirm the general finding that understanding individual choice behaviour and determinants of choice behaviour regarding changes in risk is a challenging task. For a more thorough discussion on the valuation of saving lives see for example Nerhagen et al. (2005) and Andersson and Treich (2008).

Other methods used to weigh and compare different health outcomes

There are also other methods that have been developed to weight different health outcomes. Such measurements are more common in evaluations in the health sector and can be used for example in a cost-efficiency analysis. These methods are based on non-economic preference scales. There are several different methodologies but we will describe the two most common, QALY and DALY. We include a description of them in this report since they are often put forth as an alternative to benefit estimation using economic valuation.

QALY is an index that assigns numeric values to various health states so that morbidity effects can be combined with mortality effects to arrive at an aggregate measure of health outcomes. The extreme points on the scale are death (=0) and perfect health (=1). The QALY value for a health state is found by multiplying the duration of a health state by a score reflecting the quality of a health state. This quality estimate is derived in different ways, but often using the ex ante judgement of people in good health and asking questions regarding people in general, not the person himself. When using QALY's the value of a life year is treated equally for all individuals and saving one year for ten persons is given the same value as saving ten years for one person. Income will not influence the values placed on a health outcome for an individual.

[16] DEFRA = Department for Environment Food and Rural Affairs

Empirical evidence show that QALY values obtained from parents and children differ. It is also found that children older than 8 years are able to answer the kind of ratings underlying the quality estimates. Hence, according to research older children's preferences should be sought when estimating these values.

DALY summarises the number of healthy years that are lost during a year in a specific population due to illness and death from a certain cause. It is similar to QALY since it is expressed on a severity scale ranging from 0 to 1 and that the rating depends on health states and life years. The quality index however is in this case obtained from medical expertise. Moreover, this measure incorporates an age-weighting factor but not one that gives a higher weight to young children. Instead, the weighing factor gives higher weight to persons in young adulthood and the middle ages representing the judgement that people in these years contribute more to society.

How these approaches relate to the valuation approach using willingness to pay has been discussed by different authors in different contexts, especially in the US. A thorough description of the difference between impact evaluation using willingness to pay or QALY's is given by Hammit (2006). What aspects that are important to consider in such comparisons is also presented in a special issue of Environmental and Resource Economics in 2006.

The most important conclusion from such comparisons is that willingness to pay is the only method that is based on individuals' preferences and the only method that can truly be said to reflect what is beneficial from society's point of view (Krupnick, 2004; Dickie och List, 2006; Hammit, 2006). Moreover, these measures also rely on measuring the utility, or quality, difference between different health endpoints which in turn implies a need for understanding and interpreting individuals' preferences. Hence, although based on somewhat different assumptions, these methods face similar problems in measurement as economic valuation studies based on willingness to pay.

Summary of evidence and usable values

In this overview on the economic valuation of environmental health risk reductions to children we have to a great extent relied on results from a report produced as a result of a workshop organized by OECD. We have relied on this report since it is our opinion that it gives a good overview of the current state of art. It refers to the same authors as we found references to when making a literature search and it raises issues that have also been discussed in the ExternE Methodology report (Bickel and Friedrich, 2005).

The general conclusion from OECD (2006) is that the benefit to children from improved environmental conditions is underestimated. Hence, using economic values for risk reductions derived from the general population also in the case of children will give conservative (i.e. low) estimates. In Table 5 and 6 we have summarised the findings regarding usable benefit estimates for the health endpoints that were summarised in Table 1 and 2. The rows in grey are the estimates that will be used in the benefit calculation in chapter 4. As discussed in the text, these are estimates for adults. In lack of further evidence on the economic valuation of children's health risks, the question to be considered in policy is if the values that are presented in here should be adjusted and if so, by how much.

The major concern in this respect is most likely the values used for new cases of illness as well as possible losses due to premature mortality. These are the two components where the economic value is due to accumulated impacts over time. Few studies have addressed this issue. A summary of the estimates found in the literature for the long term impacts is given in Table 5.

Table 5 **Overview current knowledge benefit estimates long term impact**

Health impacts of relevance for children	Inputs into benefit estimate			
	COI (euro)	WTP (euro)	Discounting	Reference
Lung function development	Not quantified	Not quantified	Needed	-
Sensitisation to allergens	Not quantified	Not quantified	Needed	-
Development of air-way disease	-	31 000	Done	BenMap (2008b)
Reproductive disorders	Not quantified	Not quantified	Needed	-
Cancer	Not quantified	VSL= 1 million	Done	Bickel and Friedrich (2005)

The value for the development of air-way disease is from one American valuation study and should therefore be treated with caution. Concerning premature mortality an argument for using VSL is that it is likely to ascertain an equal treatment between premature mortality in different policy areas. The question however is which VSL to use in a Swedish context. The VSL proposed in the ExternE methodology update (Bickel and Friedrich, 2005) was 1 million euro to be compared with the value used in the Swedish transport sector of about 2 million euro. The main reason for the difference in these estimates is that the former is the median estimate while the latter is the mean. Sticking to the conventions normally used in cost-benefit analysis, we recommend using the Swedish mean estimate as a basic value for VSL. There are examples in the literature where children's welfare loss is valued twice as high as adults. Hence, two times these estimates may be used as an upper bound in a benefit calculation.

We want to stress though that the importance of these two components for the total benefit for children's health is an issue that is left for future research. It is still unclear how relevant these health endpoints are since the epidemiological evidence is sparse and since there is no or little empirical evidence on the valuation of these endpoints for children.

For the short term (acute) health impacts, the values proposed in the ExternE methodology update (Bickel and Friedrich, 2005) are according to our opinion currently the most relevant estimates also in a Swedish context. The estimates found in the literature are summarised in Table 6.

Table 6 Overview current knowledge benefits estimates short term impacts

Health impacts of relevance for children	Inputs into benefit estimate			
	COI (euro)	WTP (euro)	Discounting	Reference
Hospital admission	1600	400	No	Bickel and Friedrich (2005)
Emergency care (=asthma attack)	450	220	No	Bickel and Friedrich (2005)
General practitioner visit	42	15	No	Bickel and Friedrich (2005)
Medication	1	-	No	Bickel and Friedrich (2005)
Restricted activity days	84	46	No	Bickel and Friedrich (2005)

No firm conclusion can be drawn on how these adult values should be adjusted when used for children. We however believe that it is more reasonable with a smaller markup than twice the estimate for these short term impacts. The reason is that approximately the same consequences are due to sick children as to sick adults. That some premium could be reasonable is because illness may affect future income for the child in a different way than an adult but also because there can be some disutility to account for on the behalf of parent or other concerned relatives when children are sick.

Few Swedish economic valuation studies on environmental health risks have been undertaken and hence it is not possible to state how relevant the estimates presented in Table 5 and 6 are in a Swedish context. Therefore, economic valuation of health risks in general, particularly for morbidity, is an area in need of further research. While willingness-to-pay studies are more demanding we believe it would be quite easy to derive Swedish estimates for cost of illness. There are databases that collect this type of cost information so what is needed is an adaptation of the data to this kind of benefit calculation (i.e. cost per doctors visit or symptom day etc).

Children's health and the benefit of reducing air pollution – calculations for two cities

In this chapter we will apply the dose-response method that was described in chapter 1. We have done these calculations for two health endpoints where reasonable exposure-response functions and economic values could be derived from the literature. The health endpoints are *development of asthma* and *hospital admission due to respiratory problems* (for details see chapter 2 and 3, especially the rows shaded grey in Table 1, 5, 2 and 6). We make the calculations for two different cities, Umeå and Stockholm. They were chosen because information about the number of children and some underlying data on their health status that is needed for the calculations was readily available. The reason for making calculations for two different cities, using only a few endpoints, is to give an illustration of how different components used in the calculation influence the final estimate. Since traffic is possibly the most important source for population exposure in cities, the discussion is based on the influence of this source.

As seen from equation 1 on page 11, an assessment of the change in population exposure is needed in these types of calculations. For policy purposes, what is relevant is to assess the influence of a certain policy measure on air pollution concentrations and population exposure, in this case regarding children. The population exposure is an important component since the benefit estimate will be a function of the population density close to the emission sources. Data with this level of detail however is not available for the two cities. Therefore, what we calculate is the benefit that would result from a reduction in the children's average exposure in each city of 1 $\mu g/m^3$ of NO_2 per year. We use this estimate since it is common in economic analysis to consider *marginal changes* and this change has been evaluated in other studies such as the study on Swedish data by Samakovlis and Svensson (2004)[17].

No detailed exposure estimates resulting from traffic was available for the two cities. Therefore, we cannot assess what policy measure or emission reduction that is needed in each city to achieve a reduction in average exposure of 1 $\mu g/m^3$ of NO_2 per year, not for the general population and hence not for children. Instead, to give some indication on what this would require, we use available data for the two cities to illustrate how the concentrations vary within a city and how they are influenced by traffic. This information is presented in the next section. Thereafter we present the benefit calculation for the two health endpoints. The chapter ends with

[17] One reason why economists commonly use marginal estimates is due to the problem with non-linearities as discussed by Viscusi and Gayer (2005). Another reason is that marginal estimates are used as the basis for policy evaluations where the changes in air pollution concentration (or other changes) are small. The basis for transport policy in the EU is also "marginal cost pricing" (EU Commission, 2008).

a discussion of the results, how they can be used and the uncertainties related to them.

Exposure quantification

The exposure-response functions we will use are based on concentrations of NO_2 but the available data is modelling and measurement of NO_x. The concentrations of these two pollutants are quite closely correlated and it is possible to convert the concentration for NO_x to NO_2. In a study for Stockholm (Naturvårdsverket, 2005) the following conversion formula was estimated:

NO_2= NO_x^(0.66+34/(NO_x +100)).

As will be shown in the example provided below, the concentration of NO_2 is generally somewhat lower than the concentration of NO_x.

The concentrations in the urban background (roof level) of NO_x within a city will vary depending on the emissions from traffic and other local sources. They are also influenced by the background levels (those found in the countryside without influence of local emission sources). In Sweden this concentration is about 4 µg/m³ and somewhat lower in the north than in the south.

To give an illustration of how the concentrations can vary in a city we have included information from modelling done in Umeå, see Figure 1. The data presented in the figure is modelled estimates of average yearly exposure to NO_x for children between 5 and 18 years old, obtained with recent traffic data and the Airviro dispersion model, adjusted using monitoring data[18]. Every dot in the figure represents a child and the modelled exposure for this child. As seen in the figure there are quite a few places, especially in the city centre, where the average yearly concentrations are above 20 µg/m³ (the highest estimate is 60.79 µg/m³)[19].

The estimate that is the basis for the information in the figure has also been used to calculate the average population weighted exposure for children in this age group in Umeå. According to this calculation it was 13.5 µg/m³ per year. This information can be used to calculate an approximate estimate of the *total* external health cost for exposure to NO_x in Umeå. If we deduct the concentrations found in the background, we can conclude that emissions from local sources in Umeå, mainly motor vehicles, result in an average exposure among children of about 10 µg/m³ per year. This is the concentration that can be reduced by local policy measures.

[18] The estimates are the results of modelled concentrations based on traffic emissions in Umeå using the Airviro model that has been developed by SMHI (Swedish Meteorological and Hydrological Institute). To these modelled concentrations are added the regional background. Traffic emissions are the main source to the NOx concentrations since district heating is used and there are no emissions from maritime transport in the area. There are a few point sources but these emissions are released at high altitude and therefore have limited influence on local concentration levels. Additional details about the data can be provided by Bertil Forsberg (bertil.forsberg@envmed.umu.se).

[19] The yearly air quality limit value for NO_2 is 40 µg/m³.

Unfortunately, for Umeå we do not have data available to illustrate the influence on concentrations of specific policy measures. Instead, some information on this issue is given in the following using data from Stockholm.

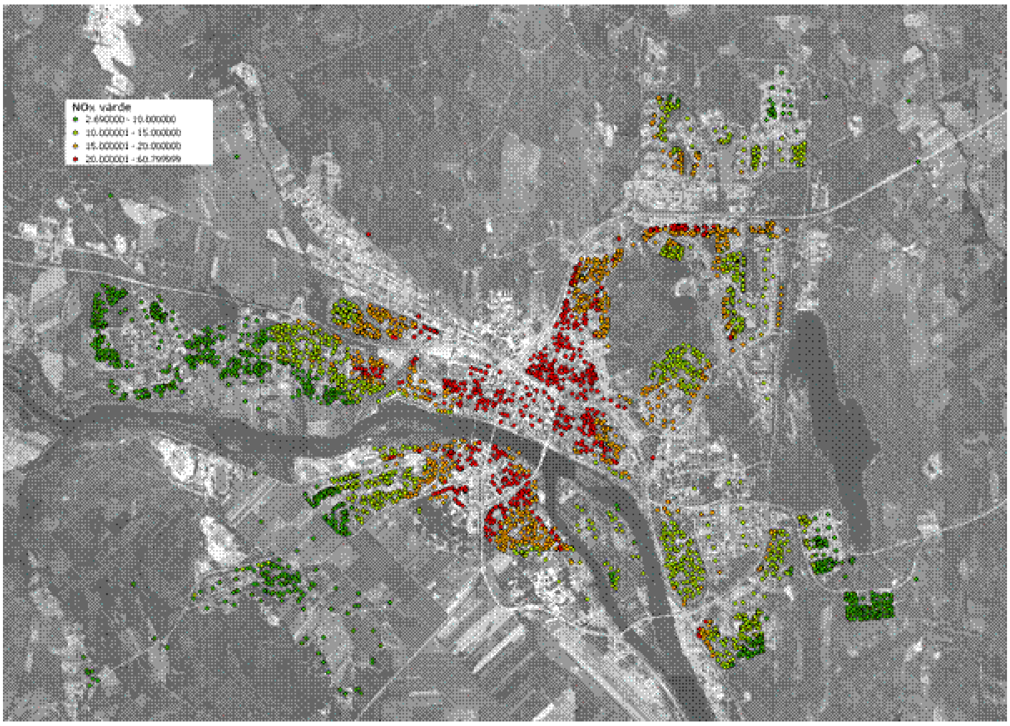

Figure 1 Results of exposure modelling of children's exposure to NO_x in Umeå using the Airviro model.

In the inner city of Stockholm in 2006 the *measured* average yearly estimate of NO_x in the urban background was 21 µg/m³ (SLB Analys, 2007)[20]. This estimate however cannot be used as an estimate for the average exposure to traffic exhausts since it is influenced by many sources. An estimate of the influence from traffic on average population exposure for the *whole* population is instead given in a study done about the effect of the trial with congestion charges in Stockholm (SLB Analys, 2006). According to this report the contribution from traffic to average exposure in the inner city was 8.41 µg/m³ before the congestion charges and the reduction in traffic emissions (about 8.5%) reduced population weighted exposure in this area by 0.81 µg/m³ (10%). Using the conversion formula we arrive at a change in NO_2 of about 0.71 µg/m³

The influence of the congestion charges on air quality in the greater Stockholm region was more limited. The contribution from road traffic to NO_x levels in *greater* Stockholm was estimated at 4.42 µg/m³ before the implementation of congestion charges, evaluated as a population-weighted urban background level (Johansson et al., 2009). The decrease in traffic due to the congestion charges was estimated to reduce the NO_x level by 0.23 µg/m³ (5.2%) to 4.19 µg/m³. This equals a reduction

[20] They also measure NO_2. The average yearly concentration was 17 µg/m³. There are also measurements per hour and the highest estimate was 264 µg/m³ on the 13th of October, 2006.

in NO_2 of 0.17 µg/m³. Hence, the congestions charges mainly contributed to reduced population exposure in the inner city which is because this is the area were charging was used.

As illustrated in this section the exposure to NO_x (and NO_2), and the influence of policy measures that reduce these emissions, will be highly context dependent. The influence on average population exposure of a policy measure will be higher if the emissions are reduced in areas with high population density such as city centres. However, the influence such measures will have on children's health depends on the number of children living in the city centre. If children to a greater extent live outside of city centres then exposure estimates for the general population will overestimate the exposure of children.

Another thing to notice from these estimates is that *measured* concentrations cannot be used to assess the influence from a specific source. According to the modelling in Stockholm the contribution of local traffic to average population exposure in the inner city is about half of the concentration level that was measured in the urban background in the same area. As for the influence of reductions in traffic it was found that an 8.5% reduction in the emissions in the inner city resulted in a reduction in average population exposure of less than 1 µg/m³ NO_2. Hence what we have illustrated in this section is that in order achieve an average reduction in population exposure of 1 µg/m³ NO_2, which is what we will assume in our calculations in the next section, quite important reductions in traffic emissions in a city are required.

Health impact and benefit of reductions in long-term exposure

The health endpoint where we found most usable exposure-response functions was wheeze. It is expected that some children with this diagnosis will also develop asthma in the future. The estimate we use in this calculation is a meta-OR of 1.38 (95% CI 1.16-1.64) for an exposure difference of 10 µg/m³ NO_2, based on the result of five cross-sectional studies studies, see page 18. This estimate is relevant for children in the age from 5 to 18 years, hence our calculations may underestimate the total impact for this diagnosis. Of these new cases of wheeze we expect that at least 50%, but maybe as many as 75%, will develop asthma in the future.

Since this estimate is a change in the likelihood of observing a symptom in the population, we have to know the underlying prevalence of the diseases in the population. Unfortunately we could not obtain an up to date estimate for this baseline risk from the National Board of Health and Welfare within the time frame of the project so we make an assumption based on results from another study (Bjerg et al., 2010)[21]. In both Stockholm and Umeå we make the assumption that 13000/100 000

[21] An application was made in the autumn of 2009 but there were problems in the ethical judgement that stopped the delivery of data.

children currently have wheeze symptoms; hence the current individual risk is 13%. Under the assumption of a linear relation between exposure level and prevalence of wheeze, the estimated meta-OR above corresponds approximately to a decrease in prevalence by (1.38-1)/10*13 = 0.49 percent units for each 1 µg/m³ decrease in NO_2. In greater Stockholm there are 220 000 children age 5-18 and reducing their exposure with 1 µg/m³ would imply 1087 (=0.49/100*220 000) fewer cases per year in Stockholm[22]. In Umeå there are 10 500 children in this age. Here the reduction in number of cases would be 52 per year.

To calculate the benefits over time for this reduction in exposure we make the assumption that 50% of these children will develop asthma in the future, hence 544 cases in Stockholm and 26 cases in Umeå. For these cases we use the estimate presented in BenMAP that was based on willingness to pay to avoid asthma in the future (US EPA, 2008b). The estimate per case was 38 947 USD in price level 2000[23]. Assuming an exchange rate of 8SEK/USD, we arrive at an estimate for this outcome of about 310 000 SEK. The benefit from reducing the average exposure to NO_2 by 1 µg/m³ would therefore be 168 million SEK (=544*310 000) in Stockholm and 8 million SEK (=26*310 000) in Umeå.

Health impact and benefit of reductions in short-term exposure

For the short-term effects the endpoint most suitable to use in this study of traffic pollution is the influence on the number of respiratory hospital admissions during an average year. The study by Fusco et al. (2001) is here assumed to be representative for Europe, see page 20. The relative risk associated with a 10 µg/m³ increase in NO_2 is a 1.77 % increase in admissions in the age group 0-14 years (95 % confidence interval 0.27 - 3.30).

Also in this calculation we need an estimate of the occurrence. According to official statistics, approximately 800/100 000 children in the age 0-19 years in Stockholm County were admitted to hospitals for respiratory problems in 2008 (http://www.socialstyrelsen.se/statistik/statistikdatabas). This implies that the annual risk for an individual to be admitted for such problems is 0.8%. We assume this risk in our calculations.

In Greater Stockholm there are 330 000 children in this age group[24]. According to the estimates above, a reduction in exposure of NO_2 of 1 µg/m³ results in a risk reduction of 0.177% which would imply 4.7 (=0.00177*0.008*330 000) fewer

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[22] The preventive potential in Stockholm for decreasing the influence of NO_2 on wheeze is estimated for the following population: 220 000 in the 5-18 age group (whole population: 1 400 000) in Botkyrka, Danderyd, Huddinge, Järfälla, Lidingö, Nacka, Salem, Sollentuna, Solna, Stockholm, Sundbyberg and Täby, in 2006

[23] Approximately equal to 31 000 euro, the estimate presented in Table 5.

[24] In the 0-19 age group in Botkyrka, Danderyd, Huddinge, Järfälla, Lidingö, Nacka, Salem, Sollentuna, Solna, Stockholm, Sundbyberg and Täby, in 2006.

cases yearly in Greater Stockholm. In Umeå there are 14 500 children in this age living in the City. Here the reduction in number of cases would be 0.2.

To estimate the benefit from this reduction we have to determine the implications of hospitalization in terms of costs. This will be influenced by the average time each child spends in hospital. In this case we make the assumption that the average days in hospital are 2.5. The ExternE estimate of 2000 euro per admission is an estimate assuming 3 days in hospital and 5 days at home. We therefore use half this sum, 1000 euro or 10 000 SEK, as an estimate for the cost of hospitalization. Using this estimate we find that for this health endpoint a reduction of 1 µg/m³ NO_2 gives a benefit of 47 000 SEK per year in Stockholm and 2000 SEK per year in Umeå.

Discussion of results and uncertainties

In Table 7 we have summarised the inputs that were the basis for the calculation in the previous section. The final result is the product of the values in column *b* to *f*. This table gives a good illustration of the data required for these calculations. The final result is dependent on the accuracy of the input in every part of this calculation chain. We will therefore end this chapter with a discussion of the assumptions made in our calculations and on the uncertainties related to this type of calculation in general. As in other socioeconomic evaluations the robustness of the results should be clarified using sensitivity analysis when used in policy analysis.

Table 7 Overview over inputs in cost calculation for Umeå and Stockholm

	Pollutant	**Δ Exposure**	**Population***	**Baseline**	**Exposure-Response Function****	**Economic value**
	a	b	c	d	e	f
Development of air-way disease						
Umeå	NO_2 as indicator	1 µg/m³	50% of 10 500	13%	0.038	310 000 SEK
Greater Stockholm	NO_2 as indicator	1 µg/m³	50% of 220 000	13%	0.038	310 000 SEK
Respiratory hospital admission						
Umeå	NO2 as indicator	1 µg/m³	14 500	0.8%	0.177%	10 000 SEK
Greater Stockholm	NO2 as indicator	1 µg/m³	330 000	0.8%	0.177%	10 000 SEK

* For air-ways disease we make the assumption that 50% of the children are likely to develop a chronic condition. The population is different for the two health outcomes because the dose-response relationships are relevant for different age groups.

** For air-ways disease the odds-ratio is used while the relative risk is stated for respiratory hospital admission.

Regarding our calculations, the first things to notice is that for the same exposure reduction we get much higher benefit estimates for the long term effects in both cities (for Stockholm 168 million SEK vs 47 000 SEK). Since we have omitted a number of short term health impacts affecting asthmatic children, the estimates for the two endpoints are not directly comparable. Still, it appears that it is the risk of developing chronic conditions that give rise to the highest external cost for children. Similar results are found in calculations for the adult population. Hence, as in other health care it may be better to prevent a disease from occurring instead of reducing the symptoms afterwards. This finding may have implications for the design of policy measures since it may be more important to reduce the average concentration levels rather than reducing short-term episodes in local hot spots.

A second thing to notice is that when using these calculations for policy purposes it is important to assess the size and the extent of the impact. To give an illustration we will assess the impact of the congestions charges on children's health in Stockholm. The example we use is the probability of developing an air-way disease. To do this we have to modify our previous calculations. First of all we should only include the children living in the inner city in the calculation since this is where we had the main influence on the concentration levels. About half of the 220 000 children in the age 5-18 living in Greater Stockholm live in the inner city. Secondly we have to account for the actual reduction in this area which was estimated to be 0.71 μg/m³ for NO_2. Hence the estimated impact of the congestion charging trial in Stockholm is less than half of the estimated cases of wheeze that we used in the previous calculation, 386 (=1087*0.5*0.71) per year. If half of these develop asthma then the benefit for children of the congestion charges would be about 60 million SEK (386*0,5*310 000) per year instead of the 168 million that a general reduction of 1 μg/m³ for the children in Stockholm would result in.

A third thing to notice is that there are a number of uncertainties related to these results. For development of air-way disease we have assumed that 50% of those exposed will develop the disease. There is however not an exact relationship determined for the share of children with wheeze symptoms that may develop asthma. Hence the expected health impact may be higher or lower. The same applies to our assumption on the impact of hospitalization due to respiratory problems. Our baseline data are also rather crude. The baseline may for example vary geographically. More accurate data is available from registers collected by the National Board of Health and Welfare, but we were not able to use it in this project because it was subject to ethical judgement.

As for the economic values we have used, they are taken from the models developed for external cost calculations in the EU and the US. Although these values have been based on careful evaluation of the state-of-the art research, there is the question of how relevant they are in a Swedish context. As discussed by Viscusi and Gayer (2005), using benefit transfers is this type of extrapolations to other groups or contexts is based on strong assumptions. Moreover, given that we have used economic values for adults it may be that we have underestimated the benefit, at least for asthma attacks. Finally, as can be seen from Table 5, little is known about how to value long term health impacts.

It is also to be remembered that we in this study have used NO_2 as an indicator for emissions from traffic. This does not imply that reductions of emissions in NO_x will bring about these benefits. The cause and effect between single pollutants and health impacts is maybe the most important uncertainty. This however is not only a problem for the calculation of external costs but for health impact assessment as such. For policy purposes this is problematic since efforts may be made that mainly reduce pollutants that are not causing the health impacts.

A final comment concerns the use of these estimates for policy evaluation. When deciding whether or not a reduction in emissions is beneficial from society's point of view, the cost needed to achieve the reduction in the emissions also needs to be considered. In our case reducing emissions can be achieved by reductions in traffic in the two cities. Our benefit estimates are based on an average reduction in exposure of 1 $\mu g/m^3$of NO_2. As discussed above, this change in exposure is quite large. According to the findings from the results of the congestions charges trial, a reduction of traffic of 15% in the inner city resulted in a exposure reduction of this size.

Final remarks and future research

This is a first attempt to calculate the benefits for children in Sweden of reducing air pollution. Due to lack of data we have only been able to give an indication of the size of the benefits per µg/m³ decrease in the mean concentration of NO_2. Further research is needed in order to determine the accuracy of these estimates, the size of the benefit for other endpoints and all children in Sweden and how the benefits vary between different geographical areas. We however consider such research to be warranted since our estimates suggests that reducing air pollution is important particularly because it reduces the risk of the development of chronic conditions such as asthma.

In the study, we have surveyed the literature both regarding air pollution and health impacts on children and economic valuation of children's environmental health risks. Based on the findings we have calculated the benefit of a reduction in children's exposure of 1 µg/m³ of NO_2 in Stockholm and Umeå. The difference between the cities that we could account for is the number of children that are exposed. As expected, the estimated cost was higher in Stockholm because more children live there. There will be other inputs that differ and that will influence the results, such as the share of asthmatics in the child population and the change in exposure due to a certain change in emissions, but this information is not currently available.

The calculation was done for two endpoints, developing an air-way disease (asthma) and hospital admissions due to respiratory symptoms. According to our estimates this reduction in exposure in Greater Stockholm per year would generate a benefit to society of 168 million SEK because of fewer cases of asthma, and 47 000 SEK due to fewer hospital admissions (for the price levels in 2000). These figures can be compared to the results in Huhtala and Samakovlis (2003) that arrived at an estimate for acute respiratory problems in the adult population in Sweden, for the same reduction in pollution, of 745 million SEK per year (for the price level in 1999). These figures suggest that the health benefits from a reduction of this size are quite important.

We however want to caution that both these studies are the first of their kind in Sweden and therefore the results needs further validation. Regarding the calculations in this study the exposure-response functions used are based on the results of a few studies. Moreover we have made assumptions regarding the share of children that develop asthma which should be verified scientifically. Regarding the economic values used they are estimates used in models in other countries so their relevance in a Swedish context also needs to be studied. As for the study done by Huthala and Samakovlis (2003) their results are based on a survey of self-reported symptoms in the general population. How well reported data correspond to other types of quantifications of health impacts should also be assessed.

In addition, the benefit estimates presented above cannot readily be used for policy analysis. As discussed in the end of the previous chapter, the effects of a policy measure needs to be assessed on a case to case basis. The benefit estimates we have presented are based on a quite large reduction in air pollution. 1 µg/m³ is about 10% of the contribution to NO_2 from local sources in Swedish cities. This is approximately the reduction that resulted in the inner city of Stockholm from the trial with congestion charges where traffic in this area decreased by 15%. Hence, in order to determine whether or not to take action to reduce traffic, the costs and benefits of such measures needs to be compared on a local scale. The result will for example be dependent upon the impact a certain measure has on exposure. A general conclusion from studies in this area shows that the benefits are expected to be high if emissions are reduced in densely populated areas.

We have in this report shown that it is possible to undertaken benefit calculations also for children. Being the first attempt of its kind in Sweden we however have been limited by the data available. To our knowledge no estimates are available on children's exposure to air pollution resulting from traffic and other sources. Moreover, we ran into problems when trying to obtain relevant baselines on the prevalence of illness in the child population in the two cities from The National Board of Health and Welfare. Hence, in addition to the uncertainties related to the inputs in these calculations there are also other problems. The latter however we believe should be quite easy to overcome. There are models developed that should be possible to use for exposure quantification and regarding the denial for baseline data, it could well be due to a misunderstanding of the intended purpose.

As for future research we suggest that the following should be considered:

First and foremost, more studies of benefit calculations should be done since it is in the actual practice that what is known and not known about the different parts of the calculation chain are clarified. There are now models developed for exposure assessment but they need to be combined with other models such as those for transport to assess the influence of different policies.

There is also a need for more research on health impacts and the economic value placed on reducing these health risks. Of particular importance is to try to determine which of the different emissions from traffic that gives rise to these and other health impacts. Furthermore, the same main sources and a similar geographical resolution should be used in the studies that produce the exposure-response functions as in the exposure model used for the health impact assessment.

References

Alberini, A. Hunt, A. and Markandya, A. (2004) Willingness to Pay to Reduce Mortality Risks: Evidence from a Three-Country Contingent Valuation Study. Environmental & Resource Economics 33: 251–264.

Andersson H. and Lindberg G. (2009) Benevolence and the Value of Road Safety. Accident Analysis and Prevention 41: 286-293.

Andersson, H. and Treich N. (2008) The Value of a Statistical Life. In De Palma A., Lindsey R., Quinet E. and Vickerman R. (eds) Handbook in Transport Economics.

Bickel P. and Friedrich, R. (2005) Externalitites of Energy – Methodology 2005 Update. European Commission EUR 21951. http://www.externe.info.

Bickel P., Friedrich R., Link H., Stewart L and Nash C. (2006) Introducing environmental externalities into transport pricing: Measurement and implications. Transport reviews Vol. 26, No. 4: 389-415

Bjerg A, Sandström T., Lundbäck B. and Rönmark E. (2010) Time trends in asthma and wheeze in Swedish children 1996–2006: prevalence and risk factors by sex. Allergy, 65: 48–55

Bolin K. and Lindgren B. (2004) Rökning – produktionsbortfall och sjukvårdskostnader. Rapport R 2004:3. Folkhälsoinstitutet (in swedish)

Bosworth R., Cameron T.A. and DeShazo J.R. (2009) Journal of Environmental Economics and Management No. 57: 293-308

Bråbäck L and Forsberg B. (2009) Does traffic exhaust contribute to the development of asthma and allergic sensitization in children: findings from recent cohort studies. Environ Health. Apr 16;8:17. Review

Brännlund R. and Kriström B. (1998) Miljöekonomi. Studentlitteratur (in swedish).

Chilton, S. Covey, J. Jones-Lee, M. Loomes, G. and Metcalf, H. (2004) Valuation of Health Benefits Associated with Reductions in Air Pollution. DEFRA, UK.

Cropper M.L., Aydede S.K. and Portney P.R. (1994) Preferences for Life Saving Programs: How the Public Discounts Time and Age, Journal of Risk and Uncertainty Vol. 8 No. 3: 243-265.

Delucchi M.A. (2000) Environmental Externalities of Motor-Vehicle Use in the US. Journal of Transport Economics and Policy, Vol. 34 part 2: 135-168.

Dickie M. and List J. (2006) Economic Valuation of Health for Environmental Policy: Comparing Alternative Approaches. Introduction and Overview. Environmental and Resource Economics 34: 339-346.

Eftec (2004) The Health Benefits of Pollution Control: a review of the literature on mortality and morbidity effects. Paper prepared for the DEFRA Workshop, HM Treasury, Horse Guards Road, London, 21 June 2004. Revised and Extended version : August 2004.

EU Commission (2008) Strategy for the internalisation of external costs. Communication from the commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions, COM(2008) 435 final.

http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52008DC0435:EN:NOT. Downloaded 2010-06-18

Friedrich, R. and Bickel, P. (2001) Environmental External Costs of Transport. Springer-Verlag, Berlin Heidelberg, Germany.

Fusco D., Forastiere F., Michelozzi P., Spadea T., Ostro B., Arcà M., Perucci CA. (2001) Air pollution and hospital admissions for respiratory conditions in Rome, Italy. The European Respiratory Journal 17(6):1143-50.

Gauderman W.J., Avol E., Lurmann F. et al. (2005) Childhood asthma and exposure to traffic and nitrogen dioxide. Epidemiology; 16:737–743.

Gehring U., Wijga A.H., Brauer M., Fischer P., de Jongste J.C., Kerkhof M., Oldenswening M. , Smit H.A., Brunekreef B. (2010) Traffic-related air pollution and the development of asthma and allergies during the first 8 years of life. American journal of respiratory and critical care medicine 181(6):596-603

Götschi T., Heinrich J., Sunyer J. and Künzli N. (2008) Long-term effects of ambient air pollution on lung function: a review. Epidemiology. Se.p;19(5):690-701

Hammitt J.K. (2006) Willingess to Pay and Quality Adjusted Life Years. In OECD, Economic Valuation of Environmental Health Risks to Children

Hoffman S., Krupnick A. and Adamowicz V. (2006) Economic Uncertainties in Valuing Reductions in Children's Environmental Health Risks. In OECD, Economic Valuation of Environmental Health Risks to Children

Huhtala A. and Samakovlis E. (2003) Green Accounting, Air pollution and Health. Working paper no. 82. Konjunkturinstitutet (in swedish).

Janssen N.A. *et al*. (2003) The relationship between air pollution from heavy traffic and allergic sensitization, bronchial hyperresponsiveness, and respiratory symptoms in Dutch schoolchildren. Environmental Health Perspectives, 111:1512–1518.

Jensen S.S., Willumsen E., Brandt J. and Kristensen N.B. (2008) Evaluation of exposure factors applied in marginal external cost analysis of transportation related air pollution. Transportation research part D. 13: 255-273

Johansson C., Burman L. and Forsberg B. (2009) The effects of congestion tax on air quality and health. Atmospheric Environment 43: 4843-4854

Krämer U., Koch T., Ranft U. et al. (2000) Traffic-related air pollution is associated with atopy in children living in urban areas. Epidemiology; 11:64-70.

Krupnick A. (2004) Valuing Health Outcomes: Policy Choices and Technical issues. RFF Report. Resource for the Future.

Muller, N.Z. and Mendelson R. (2007) Measuring the damages of air pollution in the United States. Journal of Environmental Economics and Management 54. pp 1-14

Naturvårdsverket (2005) Kvävedioxid och ozon i tätortsluft. Rapport 5519 . Naturvårdsverktet (in swedish).

Naturvårdsverket (2010) Air pollution and children's respiratory health. Rapport 6353. Naturvårdsverket (in swedish).

Nerhagen, L., Forsberg, B., Johansson, C. och Lövenheim B. (2005) Luftföroreningarnas Externa Kostnader. Förslag på beräkningsmetod för trafiken utifrån granskning av ExternE-beräkningar för Stockholm och Sverige. VTI rapport 517. Statens väg- och transportforskningsinstitut (in swedish).

Nerhagen L., Bergström R., Forsberg B, Johansson, C and Eneroth K. (2009) External health cost on a local and regional scale of emissions from road traffic and other sources in Stockholm, Sweden. Paper presented at the 17th Annual Conference of the European Association of Environmental and Resource Economists. Amsterdam 24-27th of June, 2009.

Nicolai T., Carr D., Weiland S.K. et al. (2003) Urban traffic and pollutant exposure related to respiratory outcomes and atopy in a large sample of children. Eur Respir J; 21:956-963.

OECD (2006) Economic Valuation of Environmental Health Risks to Children. OECD Publishing

Oftedal B., Brunekreef B. et al. (2007) Residential outdoor air pollution and allergen sensitization in schoolchildren in Oslo, Norway. Clin Exp Allergy; 37: 1632-1640.

Olofsson S. (2008) Cost of Illness – Teoretisk genomgång. NCO 2008:4. Räddningsverket (in swedish).

Olsthoorn X., Amann M., Bartonova A., Clench-Aas J., Cofala J., Dorland K., Guerreiro C., Henriksen J.F., Jansen J. and Larssen S. (1999) Cost benefit analysis of European air quality targets for sulphur dioxide, nitrogen dioxide and fine and suspended particulate matter in cities. Environmental and resource economics 14: 333-351.

Ostro B. and Chestnut L. (1998) Assessing the health benefits of reducing particulate matter air pollution in the United States. Environmental research, Section A 76: 94-106

Ostro B., Lipsett M., Mann J., Braxton-Owens H. and White M. (2001) Air pollution and exacerbation of asthma in African-American children in Los Angeles. Epidemiology. Mar;12(2):200-8.

Park H., Lee B., Ha E.H., Lee J.T., Kim H. and Hong Y.C. (2002) Association of air pollution with school absenteeism due to illness. Arch Pediatr Adolesc Med. 156(12):1235-9.

Ready, R., Navrud S., Day B, Dubourg R., Machado F., Mourato S., Spanninks F., and M. X. V. Rodriquez (2004) Benefit Transfer in Europe: How Reliable Are Transfers Across Countries? Environmental & Resource Economics, 29: 67-82

Ritz B. and Wilhelm M. (2008) Ambient air pollution and adverse birth outcomes: methodologic issues in an emerging field. Basic Clin Pharmacol Toxicol. 102(2):182-90.

Roemer W., Hoek G., Brunekreef B., Clench-Aas J., Forsberg B., Pekkanen J., Schutz A. (2000) PM10 elemental composition and acute respiratory health effects in European children (PEACE project). Pollution Effects on Asthmatic Children in Europe. Eur Respir J. Mar;15(3):553-9.

Rondeau V., Berhane K., Thomas D.C. (2005) A three-level model for binary time-series data: the effects of air pollution on school absences in the Southern California Children's Health Study. Stat Med. 15;24(7):1103-15.

Samakovlis S. and Svensson L. (2004) Värdering av hälsoeffekter från luftföroreningar. Miljöräkenskaper Rapport 2004:2. Konjunkturinstitutet. (in swedish)

Sahsuvaroglu T., Jerrett M., Sears M.R., McConnell R., Finkelstein N., Arain A., Newbold B. and Burnett R. (2009) Spatial analysis of air pollution and childhood asthma in Hamilton, Canada: comparing exposure methods in sensitive subgroups. Environmental Health 1;8:14.

Shima M. and Adachi M. (2000) Effect of outdoor and indoor nitrogen dioxide on respiratory symptoms in schoolchildren. International Journal of Epidemiology 29:862-870.

SIKA (2008) Samhällsekonomiska principer och kalkylvärden för transportsektorn: ASEK 4. SIKA PM 2008:3 (in swedish).

SLB Analys (2006) The Stockholm Trial. Effects on air quality and health. SLB rapport 4:2006. SLB Analys (in swedish).

SLB Analys (2007) Luften i Stockholm. Årsrapport 2006. SLB rapport 1:2007. SLB Analys (in swedish).

Small K.A. and Kazimi C. (1995) On the cost of air pollution from motor vehicles. Journal of Transport Economics and Policy Vol 29. No 1. pp. 7-32

Titenberg T. (2007) Environmental Economics & Policy. Pearson Addison Wesley.

US EPA (2008a) BenMAP User Manual Appendices. Appendice F: Particulate matter health impact functions in U.S. setup.
http://www.epa.gov/air/benmap/models/BenMAPappendicesSept08.pdf

US EPA (2008b) BenMAP User Manual Appendices. Appendice H: Health valuation functions in U.S. setup.
http://www.epa.gov/air/benmap/models/BenMAPappendicesSept08.pdf

Viscusi K. and Gayer T. (2005) Quantifying and valuing environmental health risks.. In Mäler K-G and Vincent J.R. (eds): Handbook of Environmental Economics, Volume 2. Elsevier B.V.

Vredin-Johansson M. and Forslund J. (2009) Klimatanpassning i Sverige - Samhällsekonomiska värderingar av hälsoeffekter. Miljöekonomi specialstudie no. 20. Konjunkturinstitutet (in swedish).

Vägverket (2009) Vägtransporternas folkhälsoeffekter och –kostnader. Redovisning av två delprojekt. Vägverket Publikation 2009:3 (in swedish).

WHO (2005) Health effects of transport-related air pollution. Copenhagen, WHO Regional Office for Europe (http://www.euro.who.int/document/e86650.pdf, accessed 2 June 2008).

WHO (2008) Economic valuation of transport-related health effects. Review of methods and development of practical approaches, with a special focus on children. Copenhagen, World Health Organization, Regional Office for Europe (in press).

Zhao Z, Zhang Z, Wang Z, Ferm M, Liang Y and Norbäck D. (2008) Asthmatic symptoms among pupils in relation to winter indoor and outdoor air pollution in schools in Taiyuan, China. Environtal Health Perspectives 116(1):90-7.

Air pollution and children's health in Sweden

REPORT 6585

SWEDISH EPA
ISBN 978-91-620-6585-0
ISSN 0282-7298

An enquiry into how the economic benefit of improvements in children's health resulting from reductions in air pollution can be assessed

LENA NERHAGEN, TOM BELLANDER AND BERTIL FORSBERG

Frisk luft är ett av de 16 miljömål som antagits av Sveriges riksdag för att styra samhället mot en hållbar utveckling. Detta projekt bidrar till arbetet med att genomföra detta miljömål. Mindre är känt när det gäller luftföroreningars påverkan på barns hälsa än när det gäller vuxna. Syftet med projektet har varit att fastställa hur hälsovinster med minskad exponering för luftföroreningar kan kvantifieras i ekonomiska termer.

För att svara på denna fråga ger vi inledningsvis en kort beskrivning av den metod som vanligtvis används för att beräkna hälsovinster i ekonomiska termer. Därefter illustrerar vi genom två fallstudier hur dessa beräkningar genomförs och vad som påverkar resultaten. Rapporten avslutas med en sammanfattning över områden där vi ser att fortsatt forskning behövs.

När det gäller ekonomisk värdering av hälsoeffekter på barn är det svårare att hitta uppgifter om kostnader för påverkan på hälsan av luftföroreningar på barn än när det gäller vuxna. Eftersom få svenska ekonomiska värderingsstudier har genomförts kring miljörelaterade hälsorisker rekommenderar vi användning av ekonomiska värden från framförallt europeiska studier.

Baserat på slutsatserna i litteraturöversikterna har vi, som ett exempel, beräknat hälsovinsten av att minska barns exponering för NO2 med 1 µg/m³ i Stockholm och i Umeå. Enligt våra beräkningar skulle hälsovinsten för samhället av denna minskning i exponering i Storstockholm vara 168 miljoner SEK per år p.g.a. färre fall av sjukdomen astma samt 47 000 SEK p.g.a. färre inläggningar på sjukhus (i prisnivån för år 2000). Hälsovinsten i Umeå är betydligt lägre, 8 miljoner SEK och 2000 SEK per år.

Detta är det första försök att i ekonomiska termer beräkna hälsovinsterna för barn av minskade halter av luftföroreningar som genomförts i Sverige. Slutsatsen av vår genomgång är att det finns kunskapsluckor när det gäller luftföroreningar och barns hälsa vilket får konsekvenser för möjligheten att genomföra beräkningar av detta slag. Beräkningar ger därför endast en indikation på hur stora hälsovinsterna kan vara.

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