EVIDENCE BASED PUBLIC HEALTH POLICY AND PRACTICE

Quantitative health impact assessment: current practice and future directions

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Study objective: To assess what methods are used in quantitative health impact assessment (HIA), and to identify areas for future research and development.
Design: HIA reports were assessed for (1) methods used to quantify effects of policy on determinants of health (exposure impact assessment) and (2) methods used to quantify health outcomes resulting from changes in exposure to determinants (outcome assessment).
Main results: Of 98 prospective HIA studies, 17 reported quantitative estimates of change in exposure to determinants, and 16 gave quantified health outcomes. Eleven (categories of) determinants were quantified up to the level of health outcomes. Methods for exposure impact assessment were: estimation on the basis of routine data and measurements, and various kinds of modelling of traffic related and environmental factors, supplemented with experts' estimates and author's assumptions. Some studies used estimates from other documents pertaining to the policy. For the calculation of health outcomes, variants of epidemiological and toxicological risk assessment were used, in some cases in mathematical models.
Conclusions: Quantification is comparatively rare in HIA. Methods are available in the areas of environmental health and, to a lesser extent, traffic accidents, infectious diseases, and behavioural factors. The methods are diverse and their reliability and validity are uncertain. Research and development in the following areas could benefit quantitative HIA: methods to quantify the effect of socioeconomic and behavioural determinants; user friendly simulation models; the use of summary measures of public health, expert opinion and scenario building; and empirical research into validity and reliability.

Many of the determinants of health lie outside the medical realm. Public health protagonists seek to influence policy making outside the healthcare sector in favour of health. Derived from environmental impact assessment, an emerging tool for this is health impact assessment (HIA). HIA is defined as ''a combination of procedures, methods and tools by which a policy, programme or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population'' (Gothenburg consensus paper, 1999).[1] In practice, the emphasis is often placed on community consultation and on formulation of recommendations for a health maximising implementation of the policy or project at stake, with less attention for the actual health consequences that might result.

Quantification of health effects in HIA has a number of advantages. Firstly, knowing the size of an effect helps decision makers to distinguish between the details and the main issues that need to be addressed and facilitates decision making by clarifying the trade offs that may be entailed.[2] Secondly, adding up all positive and negative health effects into a net effect permits the use of economic instruments such as cost effectiveness analysis, which further aids decision making.[3]

However, there are two difficulties in quantification: the availability of valid data, and the availability of methods to analyse the data and translate them into information on the health effect of the proposal under scrutiny. In this contribution we focus on the second problem and analyse reports of HIAs performed to date, using a framework similar to that proposed by Joffe and Mindell[4] in which policy decisions influence health via its determinants (see fig 1). This divides the HIA process in two steps, which for brevity we will refer to as ''exposure impact assessment'' and ''outcome assessment'' respectively. This paper addresses two questions: Firstly, what methods are used in quantitative exposure impact assessment, and secondly, what methods are used for quantitative outcome assessment?

METHODS

Search strategy

HIA case studies were obtained by searching (1) electronic sources (http://www.who.int/hia and the links it contains, accessed 20 Jul 2004), (2) the reviews analysed in Taylor and Quigley's ''HIA review of reviews'',[5] and (3) the complete collection of Dutch national level HIA cases provided by the national coordinating agency for intersectoral health policy (Ondersteuningsfunctie Integraal Gezondheidsbeleid). (4) To include recently published cases we searched PubMed for the period 2002 until 1 August 2004. Strings used were ''health AND impact AND assessment'', and ''impact AND (assess* OR eval*) AND (policy OR policies)''. Resulting articles were first judged by title and abstract, and obtained in case of possible reference to case studies. Promising reports were requested from the authors.

Selection

We included reports of primary studies that were prospective and assessed the impact of non-health sector policy decisions. Descriptions of case studies in published articles and reviews were used if they contained sufficient information, but in most cases the original reports were obtained. We excluded reports of studies that had not been completed at the time the report was written, reports that were very restrictive in the health outcomes they presented (such as studies on the effect of bicycle helmet use on fatal injuries), and studies that only screened whether a particular proposal was health relevant. We also excluded reports in languages other than English, French, German, Spanish, or Dutch.

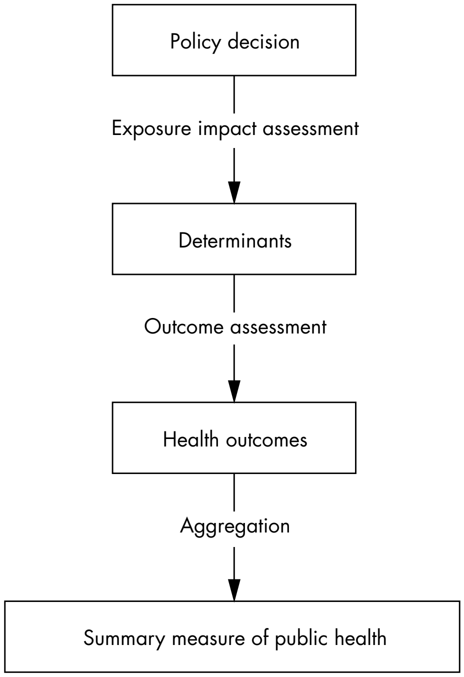

Figure 1 Conceptual model for health impact assessment.

Analysis

We distinguish between methods used to estimate the effect of policy on determinants, and methods that calculate health impact given those changes in the exposure to determinants. The estimates of exposure to determinants and of health outcomes were assessed for quantification. Quantification was defined as the expression in numerical terms of the change in health status of a specific population that can be attributed to a specific policy decision.

RESULTS

Figure 2 shows the results. The electronic sources yielded 83 cases of prospective HIA; 12 possible cases could not be obtained. This partly overlapped with the 25 studies obtained from the reviews, of which two possible cases could not be obtained. Out of the collection of Dutch HIA cases 12 studies were included. The search in PubMed added eight cases; two possible cases were not obtained. Of the total of 98 cases, 72 were from the UK, and 12 from the Netherlands (table 1). The Dutch HIA studies focus on national level policy, while all but one of the other studies assess local or regional level projects or programmes.

Of the 98 studies, 17 gave quantified estimates of the effect on determinants of health. Table 1 gives a description of the studies. Ten of the studies deal with physical infrastructure for industry or transport, the remaining seven focus on a variety of projects and policies. Sixteen studies proceed to present health outcomes.

Table 2 provides an overview of the determinants that were quantified, and on what sources of information the estimates were based. We will now discuss the methods used for the assessment of exposure impact and outcome for the 10 (categories of) determinants for which quantified health outcomes were presented.

Carcinogens

For carcinogens and other environmental factors computerised dispersal models were used to predict spread and subsequently the exposure of human populations was estimated.[6 10 20] In the outcome assessment phase, existing computer programs and toxicological data were used.[6 10]

Particulate matter

Particulate matter with a diameter less than 10 μm in size (PM10) was used as proxy for air pollution.[14 18 21 22] Models similar to those for carcinogens were used to estimate future exposure. For the outcome assessment authors made use of epidemiological data.[26]

Road transport: vehicle kilometres

The common determinant used in most predictions of traffic injuries and fatalities is vehicle kilometres—that is, the total number of kilometres driven by vehicles. In four of nine cases no independent exposure impact assessment was done: the estimates are obtained from the project planner without mention of the methods used. The methods to estimate health effects given the number of vehicle kilometres differ. In three studies the expected increase in vehicle kilometres is simply multiplied by the local or national accidents rates per kilometres[14 15 17] while others use more complex methods and take into account road type and mode of transport[25] or traffic flows and types of intersections.[7 18] Jobin uses data from the US and multiplies the accident rate by 10 to estimate the number of truck related casualties in Cameroon.[19]

Employment

Five studies provide estimates of the employment effects of plans. In four cases no independent assessment was done and the estimates were obtained from documents pertaining

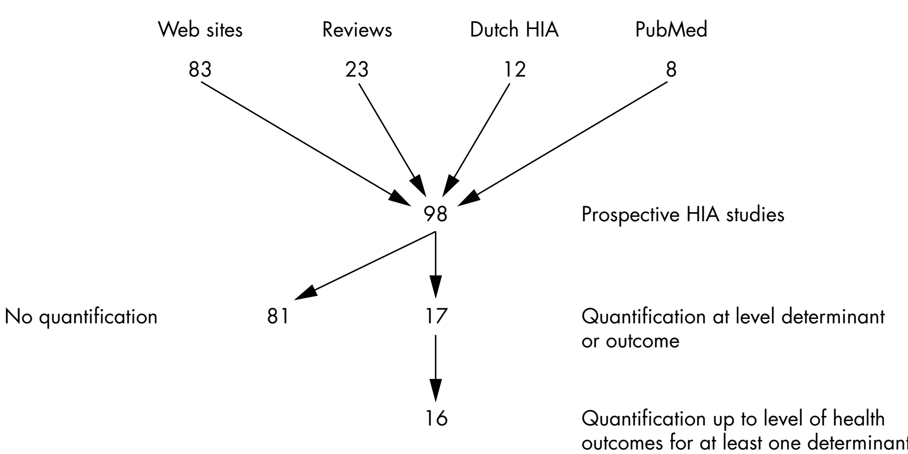

Figure 2 Results search strategy. Ninety six prospective HIA studies were found. Because of overlap, the results of the different sources seem to add up to more than that.

Table 1 Analysis of methods for quantification in health impact assessment

	Exposure impact assessment	Outcome assessment	Health outcomes
Waste to energy facility (Hallenbeck, 1995)[6]	Pollution levels based upon worst case emission factors derived from existing similar facilities; computerised air pollution dispersal model.	Carcinogens: maximum annual average ground level concentrations were used to compute maximum theoretical cancer risks due to lifetime inhalation, using risk factors from USEPA (that is, quantitative risk assessment).	Lifetime cancer risks resulting from each pollutant separately (for example, maximum theoretical cancer risk due to lifetime exposure to PCBs: 10^{-8}).
Freeway Melbourne (Dunt, 1995)[7]	Literature study; baseline data on accidents, pollution and noise levels; models predicting traffic flows.	Literature study; model to predict traffic accidents; extrapolation on basis of data on current percentage of road traffic accidents with casualties.	Road traffic accidents (−154) and resulting injuries (−100 to 110 separate injuries).
Law on alcohol and hotel and catering industry (Zwart 1997)[8]	A (separate) economic effect analysis gave an estimate of the change in revenue from sale of alcohol. This was interpreted as a decrease in per capita consumption.	Ledermann formula to estimate the number of excessive drinkers on basis of per capita consumption.	Excessive drinkers (−11000 persons drinking >7 E alcohol/day; −5000 persons with >11 E/day; −3000 persons with >15 E/day).
HIA on tobacco policy (Mooy, 1998)[9]	Economic literature gave an estimate of the change in amount sold as a function of price (price elasticity) of tobacco. This was equated with a corresponding decrease in smoking prevalence.	Computer simulation model (PREVENT), a dynamic multi-state life table based model.	Deaths from lung cancer in absolute numbers prevented per year; life years gained (both graphically depicted as numbers per calendar year).
Extension of waste disposal site (Fehr, 1999)[10 11]	Expected emissions based on extrapolation of measurements at other sites, supplemented by data from technical literature; pollution dispersal models for chemicals including eight carcinogens (by external agency); noise from technical statement.	Quantitative risk assessment (QRA) for carcinogens using health risk assessment computer program.	Individual additional lifetime cancer risk (graphically depicted per village and pathway); estimated additional cancer burden (<0.01 additional cases in 70 years).
City bypass road Krefeld (Fehr, 1999)[10 12]	Changes in traffic flow (including resulting changes in noise) estimated in environmental impact assessment report; air pollution dispersion models.	Quantitative risk assessment (QRA) for two carcinogens using health risk assessment computer program.	Individual additional lifetime cancer risk; additional cancer burden.
Home energy efficiency scheme (Kemm, 2000)[13]	Expert opinion (of authors) to estimate the increase in the home ''comfort range'' (the range of outside temperatures at which indoor temperature can be kept at or above 16˚C, below which mortality starts to rise); CO_2 emission using emissions inventory and estimated energy savings; expert (authors?) estimate of effect on employment on basis of financial investment.	Ecological data on the effect of (outside) temperature on mortality were combined with climate data for Wales after applying an increase in the home comfort range for the number of people benefiting.	Number of deaths per year (1 or 2, on basis of 30000 homes treated).
Alconbury airport (France, 2000)[14]	Used estimate of project planner for vehicle movements and planning application estimates for increase in PM_{10} (2.5% increase; assumed base level at 50 $\mu g/m^3$)	Application of rates of death/illness resulting from PM_{10} from WHO study; three methods/models for prediction of road traffic accident injuries on basis of vehicle movements; application of regional data on fatality of road traffic accidents.	Injury-only accidents (1 to 19 per year); RTA induced fatality (1 per 3–57 years); ''long term mortality'' from air pollution (0.2 deaths/y); respiratory hospital admissions (0.1/y); cardiovascular hospital admissions (0.3/y; chronic bronchitis incidents in adults over 25 (0.2/y); bronchitis in children under 15 (0.7/y); restricted activity days (170/y); asthma attacks in children under 15 (0.4); asthma episodes in adults over 15 (4.3/y).
Woodprocessing plant (Kemm, 2000)[15]	Used estimates from environmental impact report.	Application of national accident rates (per 100 million vehicle km).	Deaths due to road traffic accidents (1 per 10 years) and injury only accidents (1 per 2 years).
Finningley airport (Abdel Aziz *et al* 2000)[16]	Data from planning application (employment) and environmental statement (noise, air pollution); estimate air craft risk by MRC environment and health (method not stated).		
National Botanic Garden of Wales (Kemm 2000)[17]	Business plan (employment); (uncomplicated) economic estimates to estimate income rise; estimates of numbers of visitors travelling by car, and average distance travelled.	Estimation on basis of UK data on income and mortality rates by income decile; application of national accident rates (per 100 million vehicle km).	Reduction in overall mortality (2%) resulting from income rise; annual car user and pedestrian casualties, including deaths and severely injured (for example, 0.063 car user deaths/y).

Table 1 Continued

	Exposure impact assessment	Outcome assessment	Health outcomes
Port Southampton Dibden Bay (Taylor 2001)[18]	Used pollution data (PM_{10}) and noise levels from EIA report; used traffic projections and estimates on amount of employment generated from technical statements.	COMEAP dose-response curves for PM_{10}; traffic projections are combined with present traffic accident rates and literature on effects of mitigation measures; Scott-Samuel's method of estimating effect of (un-) employment on mortality.	Annual respiratory deaths due to air pollution (0.01); hospital admissions for respiratory problems (one per 3–4 years); personal injury road traffic accidents (17.3 per year, which equals a 12% rise—assuming no mitigation measures are taken. Possibly an additional one due to more heavy traffic). Estimates of effect of speed limits (−4.7% or 1–2 reported personal injury accidents) and street lighting (−9% or 2–3 personal injury accidents/y) are also given, as are premature deaths due to unemployment (just over 3 avoided annually).
HIA Chad-Cameroon oil pipeline project (Jobin, 2003)[19]	Estimated truck miles on basis of preliminary project plans; applied data from malaria study in Nigeria to estimated population exposed; used computer simulation model with estimates on HIV seroprevalence and frequency of sexual contacts based on previous epidemiological studies, and estimated change of partner due to project.	Applied US accident data multiplied by 10 to account for road conditions; applied Nigerian malaria death rates, and assumed effects of prevention and curative services; computer simulation model included HIV transmission risk.	Road traffic deaths (2.5 per year); deaths due to malaria (3 per year); deaths due to HIV/AIDS (70 per year).
HIA drinking water privatisation (Fehr, 2003)[20]	Difference between current levels of six carcinogens in drinking water and maximum permitted levels is calculated; exposure is estimated using population number, and standardised estimates and measured data on tap water intake and body weight.	"Standard methodology of quantitative risk assessment"	Additional cancer cases from a lifetime of exposure (maximum 10938 cases for population of 18 million)
Foot and mouth disease disposal options (UK Department of Health, 2001)[21]	Air emissions calculated for arbitrary numbers of cattle disposed of; data on percentage of BSE infected older cattle.	Dispersal modelling for BSE	Cases of variant Creutzfeldt-Jakob disease as function of %—age older cattle disposed of by pyre burning or burying.
Foresight vehicle initiative (Abrahams *et al*, 2002)[22 23]	Used consensus panel, email discussion, and other methods with expert groups to estimate changes in determinants due to new technologies.	An epidemiological model (ARMADA)[24] was used to estimate consequences of road traffic accidents and air pollution.	Over period 2000–2029: number of deaths (±20) and serious injuries (±2000) (traffic accidents); first hospital admissions for respiratory and cardiovascular disease (±23,000) (air pollution).
Regional planning guidance transport chapter (Pitches and Kemm, 2003)[25] and West Midlands local plan	Uses scenarios to estimate effect on physical activity, vehicle miles and air pollutant emissions (not exposure); draft assessment report of Highways Agency for traffic flows.	Estimates of health consequences of physical activity increases; model for traffic accident injuries as function of vehicle miles.	All cause mortality, cardiovascular and colon carcinoma deaths, cardiovascular events (physical activity); slight, serious and fatal injuries (traffic accidents)

Table 2 Determinants of which quantified estimates were given, the evidence base and methods or sources used, whether a quantified estimate of health outcomes was provided and if so, what method was used to obtain this estimate

	Method 1: from policy to determinants (exposure impact assessment)					Other reports pertaining to plan			Method 2: from determinants to health outcomes (outcome assessment)				
Determinant	Literature review	Data, own measurements	Existing models	Expert opinion	Own assumptions	From planner	Independent	Quantified health outcomes	Literature review	Data, analogy	Modelling	Expert opinion	Own assumptions
Environmental pollutants													
Air (10 carcinogens, 13 non-carcinogenic substances)[6]		X	X					Partly: carcinogens	X (tox*)				
Air (25 gasses)[11]		X	X					Partly: carcinogens	X (tox)				
Air (6 substances)[12]		X	X					Partly: carcinogens	X (tox)				
Air (14 substances + odour)[16]							X	No					
Air (PM10)[14]						X		Yes	X (epi†)				
Air (PM10)[18]							X	Yes	X (epi)				
Air (SO_2, PM)[21]			X					No					
Air (PM10)[22 23]		X		X				Yes			X		
Range of pathways (carcinogens)[10]		X	X					Yes	X (tox)				
Water (6 carcinogens)[20]		X			X			Yes	X (tox)				
CO2 emission (greenhouse effect)[13]		X			X			No					
Noise[11]		X				X		No					
Noise[12]							X	No					
Noise[16]						X?		No					
Noise[18]							X	No					
Traffic accidents													
Vehicle kilometres[7]		X	X					Yes		X Local data	X		X
Vehicle kilometres[14]						X		Yes		X Local data	X		X
Vehicle kilometres[15]							X	Yes		X Nat. data‡			
Vehicle kilometres[17]					X	X		Yes		X Nat. data			
Vehicle kilometres[18]						X		Yes		X Local data			
Vehicle miles[25]					X			Yes		X Nat. data			
Truck miles[19]					X	X		Yes		X Int'l. data§			X
Vehicle safety[22 23]		X		X				Yes		X Nat. data	X		
Air craft crash risk[16]							X	No					
Socioeconomic													
Employment[13]					X			No					
Employment[15]							X	No					
Employment[17]						X		No					
Employment[16]						X		No					
Employment[18]						X		Yes	X				
Income[17]					X			Yes		X Nat. data			X
Behaviour/addictions													
Alcohol consumption[8]					X		X	Partly	X	X			
Smoking[9]	X							Yes (mortality only)	X		X		
Physical activity[25]		X			X			Yes	X		X		

Table 2 Continued

Determinant	Method 1: from policy to determinants (exposure impact assessment) Literature review	Data, own measurements	Existing models	Expert opinion	Own assumptions	Other reports pertaining to plan: From planner	Independent	Quantified health outcomes	Method 2: from determinants to health outcomes (outcome assessment) Literature review	Data, analogy	Modelling	Expert opinion	Own assumptions
Physical environment													
Housing: in-house temperature range[13]					X			Yes	X	X			X
Infectious disease													
Malaria infection[19]					X	X		Yes					X
Sexual contact with possibility for HIV transfer[19]			X					Yes		X	X		
BSE/variant Creutzfeldt-Jakob disease[21]			X					Yes			X		
Total	1	11	8	2	10	11 19	8	Yes: 21 (57%) Partly: 4 (11%) No: 12 (32%)	12	12	8	0	6

*Tox, toxicological literature; †Epi, epidemiological literature; ‡Nat, national; §Intl, international.

to the project plan.[15–17] In one case it was estimated on the basis of financial investments.[13] Only one author provides an estimate of the effect on health (in the form of premature mortality) based on extrapolation from a longitudinal study.[18 27] Others cite this study but conclude that the size of the effect is difficult to estimate.

Income

Kemm estimates the effect of the cash injection into the local economy represented by the creation of a botanical garden and divides this by the number of residents in the population. In the outcome assessment phase data on the relation between income deciles in the UK and mortality are used to estimate the reduction in mortality.[17]

Alcohol

Zwart equates the alcohol sales decrease predicted in an independent economic analysis with alcohol consumption decrease on a population level.[8] In the outcome assessment phase he applies the Ledermann formula to estimate the number of excessive drinkers. This formula supposes a log normal distribution of alcohol consumption in a population.

Smoking

Mooy and Gunning-Schepers use economic literature on the price elasticity of cigarettes (that is, the relation between price and sales) to estimate the change in the number of smokers resulting from increased tobacco taxing. For the outcome assessment the Prevent model is applied, a macro-simulation model with a dynamic population that incorporates epidemiological data.[9]

Physical activity

Pitches and Kemm estimate the effect of changes in transport infrastructure on the annual distance cycled and walked. This is translated into the number of people that would move from being sedentary to physically active. For the outcome assessment phase they constructed a simple model using survey data on physical activity, mortality and morbidity statistics, and relative risk estimates from meta-analyses and estimate the number of lives (or cases of disease) saved if 1000 persons would increase their activity level.[25]

Housing

Kemm *et al* estimate the effect of home insulation on the "comfort range", the lowest outside temperatures at which the in-house temperatures can be kept at or above 16℃. In the outcome assessment this estimate is linked to ecological data on the effect of outside temperature on overall mortality to arrive at the number of deaths avoided.[13]

Infectious disease

To estimate the burden of malaria attributable to the construction of an oil pipeline in Cameroon, Jobin used Nigerian data in combination with assumptions on the effectiveness of preventive and curative measures. For HIV a computerised transmission model and epidemiological data on prevalence were used.[19] Finally, chances of causing variant Creutzfeldt-Jakob disease by burning cattle carcasses were estimated using a dispersal model.[21]

Type of evidence

Table 2 shows that in exposure impact assessment most assessors used the results of other reports pertaining to the policy under scrutiny, such as environmental impact assessments for exposure to chemical substances or project plans for the expected amount of employment generated. Other sources of evidence are (routine) data, measurements by the researchers, and pre-existing models (which contain data

Table 3 Analysis of quantitative HIA studies: types of determinants, health outcomes and modelling, source of risk measures, and uncertainty

	Study	Proximal/distal determinants*	Type of health outcomes	Type of modelling in outcome assessment	Source of risk measures linking determinant to health	Time horizon	Uncertainty
1	Hallenbeck (1995): waste facility	Proximal	Life time cancer risks	Quantitative risk assessment (QRA)	Toxicological risk assessment based upon animal experiments	70 years	Point estimates of maximum exposure only
2	Dunt (1995): highway	Proximal	Road traffic injuries	Traffic accident model	Local historical data on accidents by type of crossing	10 years	Report includes sensitivity analysis
3	Zwart (1997): alcohol	Proximal	Number of excessive drinkers	Simple algorithm (Ledermann formula)	Cross country comparison	Unclear	Point estimate only
4	Mooy (1998): tobacco	Proximal	Disease-specific death rate, life years gained	Macro-simulation model with dynamic population (PREVENT)	Epidemiological evidence	50 years	Point estimates only
5	Fehr (1999): waste facility	Proximal	Additional lifetime cancer risk, additional pop. cancer burden	Quantitative risk assessment (QRA) computer program	Toxicological risk assessment based upon animal experiments	70 years	Point estimates only
6	Fehr (1999): highway	Proximal	Additional lifetime cancer risk, additional pop. cancer burden	Quantitative risk assessment (QRA) computer program	Toxicological risk assessment based upon animal experiments	70 years	Point estimates only
7	Kemm (2000): home insulation	Proximal	Deaths per year	Innovative method	Ecological studies	Unclear	Point estimate dubbed "no more than a possible figure"
8	France (2000): freight distribution centre	Proximal	Mortality, morbidity, restricted activity days, hospital admissions.	Epidemiological risk assessment; three formulas for prediction of traffic accidents	Epidemiological studies; regional data.	Unclear	Air pollution: average and max. rates. Road traffic accidents: 3 point estimates.
9	Kemm (2000): woodprocessing plant	Proximal	Road traffic accident deaths and injury-only accidents	Analogy	National historical data on average number of accidents per distance travelled.	Unclear	Point estimate, uncertainty expressed by prefix "about".
10	Kemm (2000): botanic garden	Proximal (accidents) and distal (income)	Road traffic accident injuries and deaths and %-age change in overall mortality (income)	Analogy (accidents); extrapolation from national data	National historical data on average number of accidents per distance travelled.	Unclear	Point estimates based upon "very uncertain assumptions".
11	Taylor (2001): port extension	Proximal (air pollution, accidents) and distal (employment)	Respiratory deaths and hospital admissions; road traffic accident injuries; premature deaths (due to unemployment)	Epidemiological risk assessment (air pollution, employment); analogy (accidents).	Epidemiological studies (air pollution); local data (traffic accidents); single epidemiological (longitudinal) study (employment)	Unclear	Point estimates only (air pollution); terms like "3–4" and "<1" (traffic casualties); "just over three deaths" (employment).
12	Jobin (2003): Chad pipeline	Proximal	Deaths per year	Analogy (accidents, malaria), infectious disease model (HIV)	USA historical data (accidents); epidemiological study Nigeria (malaria), ? epidemiological data (HIV transmission rates)	Unclear	Point estimates of "likely" effects, intended to rank issues.
13	Fehr (2003): drinking water	Proximal	Additional lifetime cancer risk, additional cancer cases in pop.	Quantitative risk assessment (QRA)	Toxicological risk assessment based upon animal experiments (?)	70 years	Point estimates and 5th and 95th centiles per increase of exposure (uncertainty in degree increase not quantified)
14	UK Dept. of Health (2001): foot and mouth disposal	Proximal	Additional variant Creutzfeldt-Jakob Disease infections as function of %-age of older cattle destructed.	Unclear	Unclear	Unclear	Point estimates with 95% confidence range.
15	Abrahams *et al*, (2002): foresight vehicle initiative	Proximal	Annual deaths and serious injuries (traffic accidents); first hospital admissions (air pollution)	Macro-simulation model with dynamic population (ARMADA)[24]	Epidemiological evidence	2000–2029	Point estimates, uncertainty expressed by prefix "approximately"
16	Pitches and Kemm 2003): regional planning guidance transport chapter	Proximal	All-cause, cardiovascular and colon carcinoma deaths per year(s), acute myocardial infarction cases per year(s) (physical activity); slight, serious & fatal injuries (traffic accidents)	Epidemiological risk assessment (physical exercise); analogy (traffic accidents)	Epidemiological evidence (physical activity); national historical data on average number of serious personal accidents per distance travelled and mode of transport	Unclear	Mainly estimates in terms like "one death per 2 or 3 years", and general word of caution: "estimates have very wide margin of error"

*Distal determinants affect health through intermediary factors. An example is income, which affects health via material circumstances, access to care, self esteem, etc.

and assumptions). In some cases the evidence is supplemented with the author's own assumptions, and in two studies expert opinion was sought. A review of the literature was used explicitly in only one study. In contrast, outcome assessment was commonly based on literature reviews, as well as on routine data and pre-existing models. Expert opinion (other than that of the authors) was not used in outcome assessment.

Analysis of methods
Table 3 gives a further analysis of the 16 studies that presented health outcomes. This shows that the types of health outcomes used differ greatly between studies. Furthermore, 14 of the assessments are limited to the effects of proximal determinants, while two studies also include effects of determinants that may be considered distal (defined as exerting their influence via intermediate factors): increased income and employment. The methods used for outcome assessment vary, but are generally similar for comparable determinants. In most studies, the risk measures were the result of epidemiological research, while in three studies toxicological risk measures (derived from animal experiments) were used. The time horizon is unclear in most assessments. In three of the studies in which it is clear, it is determined by the risk measure used: toxicological risk assessment assumes lifetime exposure (70 years by convention), while in one study the properties of the simulation model limit the time horizon to 50 years. Uncertainty in outcomes is seldom made explicit by more than qualitative terms like "about".

DISCUSSION
From policy plan to determinants of health: exposure impact assessment
The methods used to estimate effects on determinants of health are quite diverse, which is not surprising considering the diversity in factors that influence health. For physical and chemical factors methods are well developed, and also for traffic flows and accident rates models are available.

As a consequence of a narrow evidence base no such models are available for many other determinants. In the cases we reviewed, estimates were commonly made on the basis of (unpublished) data or information provided by project developers. The latter source may introduce systematic bias. Author's assumptions and expert opinion are options of last resort. In the absence of standardised, validated methods and readily applicable data, some authors display substantial creativity in quantifying socioeconomic determinants. These efforts should be critically evaluated so that they may contribute to the development of a more uniform and robust approach.

From determinants to health outcomes: outcome assessment
From the 17 studies that quantify the effects of the policy decision on determinants of health, 16 proceed to give estimates of the effect on health outcomes, although only five do so for all the determinants they identified as relevant. This compares favourably with the findings of a study on the inclusion of health in environmental impact assessments, which concluded that most studies quantified up to the level of determinants (or pollutants) and compared these with limit values, thus not extending the analysis to health aspects.[29] In the case of non-carcinogenic pollutants that do not reach the limit value, this is justified by the generally accepted assumption that for these substances there is a threshold, below which there is no health effect.[30] However, in case this threshold is exceeded an estimate of the health effects would be desirable.

Few socioeconomic and behavioural determinants are quantified up to the level of health outcomes. One of the problems may be that a stable evidence base is lacking. Unlike physical and chemical substances, socioeconomic and behavioural determinants are context dependent. For example, being unemployed in Russia is not the same as being unemployed in Germany. This means that the evidence is only to a limited extent generalisable across time and space, and that the degree of standardisation achieved in environmental HIA will be hard to match in HIA that focuses on other policy areas.

Outcome assessment is often done for different risk factors separately as in Hallenbeck and Fehr's assessments of waste facilities, and in other models such as Mindell and Joffe's instrument for predicting the health consequences of air pollution.[6 10 31] However, the separate health effects resulting from a policy cannot always simply be added up as this may result in double counting.[32] A possible method for the integration of different effects is used in the HIA on tobacco policy (the PREVENT model)[9] and in McCarthy's ARMADA model for environmental HIA.[24] Both use simulation models that combine epidemiology and demography to assess various effects of a proposal on the health of a population. Differences by age and sex and competing risks can be accounted for. Further development of such models that can be used "off the shelf" could do much to improve quantitative HIA.[4]

Indicators for health outcomes
The measures of health outcome used in the different studies are quite diverse, ranging from numbers of deaths in a specified population, to hospitalisations for asthma and injury only accidents. This diversity is justified by differences in the research questions that need to be answered, but it hinders comparison of effects. It would be useful to additionally express health outcomes in a summary measure of public health such as the disability adjusted life year (DALY).[24 33 34 37 38] DALYs combine life years lost (or gained) and time spent with disease, adjusted for the severity of that

What this paper adds

This paper provides an overview of what has been quantified in prospective HIA in terms of exposure and health outcomes, and what methods were used. It assesses what can currently be expected from quantitative HIA, and what further research may contribute.

Policy implications

The paper identifies a number of areas in which research and development could benefit quantitative HIA:

- methods to quantify the health effects of socioeconomic and behavioural determinants;
- the development of user friendly simulation models for outcome assessment in HIA;
- the use of summary measures of public health in HIA (in addition to disease specific outcomes);
- the use of expert opinion and scenario building in HIA;
- empirical research into the validity and reliability of methods for HIA, and of complete HIA studies.

particular disease, into a single indicator. The concept has been criticised[35 36] and should not replace more conventional health outcomes, but for decision making on population level it can be a useful tool. A limitation for use in HIA is that disability weights are only available for diseases as distinguished in the international classification of diseases (ICD), so that, for example, annoyance effects attributable to noise or odour cannot at present be expressed in DALY. Ideally, the aggregate health impact is subsequently differentiated for (vulnerable) subgroups: health inequalities impact assessment.

Data requirements

Whatever shape it takes, quantification in HIA will be limited by the availability of relevant and reliable data. The more detailed the techniques, the higher the information requirements. For example, demographic computer simulation models can cope with differences by age and sex, but the model has to be filled with data that specify these differences. Taking into account health inequalities also increases information needs. Our review confirms Joffe and Mindell's finding that the evidence base is especially narrow when it comes to linking policy options to health determinants. The creation of databases containing evidence for both the exposure assessment and outcome assessment phases of quantitative HIA would greatly facilitate HIA practice.[4]

What to do when the data do not permit quantification?

Data problems commonly hamper attempts at quantification. If that is the case, robust qualitative work may be the best option. However, before concluding that quantification is not possible it may be worthwhile to bear in mind that the perspective of a decision maker differs from that of an epidemiologist. Not taking any decision is not an option for a decision maker, while the cautious epidemiologist may conclude that further study is needed. An expert's guess may still be better than no guess at all. The use of a structured process to obtain expert opinion can improve its validity and credibility. A suitable method for obtaining the collective opinion of experts is the Delphi process. Characteristics of this method are anonymity, iteration, controlled feedback, and statistical summarisation of the group responses. It has been used in ''future studies''.[39] The outcome of a Delphi study may serve as input for outcome assessment, together with the epidemiological evidence and local data.

In HIA of policies that are broadly formulated, or where there is much uncertainty over trends and future developments, the analysis of a number of scenarios might be more informative than a single estimate of the most probable impact. This permits various assumptions to be made without losing scientific credibility, and may convey to decision makers an understanding of the dynamics of the mechanics described by the model.

Validity and reliability

Little is known about the validity and reliability in HIA. For some of the methods used in HIA, validity and reliability have been assessed,[40 41] but for many methods no such research has been done. Likewise, methods to assess the validity and reliability of complete HIA studies are yet to be developed, and even agreed upon definitions suitable for HIA are lacking. We would tentatively define the validity of HIA studies as the degree to which the predicted health effects are confirmed by empirical research. This implies a need for outcome evaluation, notwithstanding the difficulties this will entail.

Standardisation

Once methods for quantitative HIA have been developed and their validity is becoming clear, the need for standardisation will arise. Similar to developments in the field of health economics (for example cost effectiveness analysis), guidelines will be needed to determine what effects to include, what time horizons are appropriate, how to deal with uncertainty, and what are suitable indicators of health outcomes. Standardisation will increase comparability among studies and promote HIA as a reliable and credible instrument for intersectoral health policy making.

Limitations of this study

The HIA reports included in this review do not give more than an indication of what is done in the field. Reports of HIA studies are difficult to obtain as they seldom appear in peer reviewed literature and are not always made public. In Canada for example, HIAs are performed by proponents of projects and incorporated into environmental impact assessment (EIA) reports. Several other countries are probably underrepresented in our sample for similar reasons. In contrast, in the UK there is a tradition of local level HIA separate from EIA and of making studies available via the internet. This results in the inclusion of many small scale studies with little emphasis on quantification. As we did not exclude cases on the basis of thoroughness or amount of resources invested, this partly explains the preponderance of studies from the UK in our sample, and the low proportion of HIA reports with quantified effect estimates.

Conclusion

We conclude that quantification in HIA is useful but not often achieved and that validity is often uncertain. Quantitative HIA would benefit from research and development of (1) methods to quantify the effect of socioeconomic and behavioural determinants; (2) the development of user friendly simulation models for outcome assessment in HIA; (3) the additional use of summary measures of public health; (4) the use of expert opinion and scenario building in HIA; (5) empirical research into the validity and reliability of methods for HIA, and of complete HIA studies.

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APHORISM OF THE MONTH

Beware of healthism

For most people, health is not life's goal. Public health is not a religion, or, as recently seen in the United States of America, health is a journey, not a destination. Health is a means to an end, it is a resource for living the full life, not something to be pursued in an obsessive way that denies risk enjoyment and testing limits.

JRA and Lowell Levin