The science of integrated assessment

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The need for integrated assessment

The crucial question that faces us all, most of our lives, is what to do. In the context of environment and health, this is as important to the lay-person as it is to the professional, for how we act as individuals affects our exposures to risk just as do the decisions of policy-makers or others acting on our collective behalf.

The question of what to do, however, is rarely singular or simple. It implies, first of all, recognition of an issue that needs to be addressed. Given that, it involves asking a series of slightly different questions. Should I act? If so, where and when? How? Nor do the questions end with that decision, for once implemented, the decision inevitable provokes further questions: how have things turned out, was my decision right, are corrective actions needed? And, of course, if they are, I am back to the questions of where, when and how. Decision-making, as every professional knows, is therefore not a linear journey to a defined conclusion, but a repeating cycle, until we are sure things are alright – or until our attention is diverted elsewhere.

Speaking loosely, it is clear that assessments are an integral part of every step along this pathway. The act of making a decision implies some form of deliberation – some assessment – in order to make a (however badly) informed choice. Without that our decisions are just random tosses of the coin.

More formally, however, and in the context of policy, three types of assessment can usefully be recognised, representing different links within the decision-making cycle:

1. Diagnostic assessments, that help us to decide whether there is a problem that needs our attention, and if so what the nature and magnitude of that problem is?
2. Prognostic assessments, which help us to decide what action to take (if any) – and to choose between the different options available;
3. Summative assessments, which help us to evaluate the effects of our decision, and thus to decide whether the problem has been satisfactorily addressed.

Different ways of doing these assessments have been devised over the last few decades. In very general terms, these can be categorised into two main approaches: risk assessment and impact assessment. The first has traditionally been aimed at telling us whether there are potential risks from some substance or situation, and giving an indication of its level. As such it is largely diagnostic. The second, impact assessment, has the purpose of defining and quantifying the consequences of actions – either in the future or in the past – and thus inherently prognostic or summative in approach.

These methods of assessment are now well-established in the arenas of health policy. The extent to which they are able to meet the needs of policy-making in the face of modern threats to health, and in the context of modern policy institutions, can nevertheless be questioned. Both, for example, tend to be applied in a relatively singular and narrow way. Risk assessment typically is used to assess individual risk factors (specific agents or situations), usually in isolation. For the most part, risk assessments also focus on more immediate or proximal risks, and do not attempt to track very far back along the causal chain. Health impact assessments usually focus on individual policy actions (or simple comparisons), within a tightly defined framework.

Many of the problems and policy issues that face us, on the other hand, are much more convoluted and wide-ranging. They involve what OECD and Otwin Renn and his colleagues have termed 'systemic risks': complex threats to health embedded within wider, interacting environmental, social, economic and political systems. Examples are many: not just climate change, but energy policy, waste management, transport, housing, and indoor air pollution. In each and every case, effects on health do not operate simply via one or two risk factors, operating directly and alone, but through a complex web of interaction and interdependence, stretching far back to often remote and historic sources, and forward to a wide range of different effects, and to long-term and indirect consequences for human wellbeing. These systems, it also has to be emphasised, are fundamentally and powerfully dynamic. They do not lie is a form of stasis or even steady state, but evolve and change over time, in part because of their own, internal dynamics, but in part because of perturbations caused by external events – including policy action. Moreover, these changes do not only occur through bio-chemical and physical processes; they involve people, responding either individually or collectively to the risks, to the changing circumstances, to the instructions and guidance given by those in authority, and to their expectations about how they should, or others might, act. They are, it has to be said again, social and behavioural systems, as much as environmental ones.

This reality has important implications both for policies and for the assessments on which they are based. In terms of policy, for example, they mean that:

1. adaptation (the response of the environmental and social systems involved) is crucial in determining the effects of any policy intervention;
2. impacts of action are likely to be wide-ranging and long-term, as the effects of any intervention spread out through the wider system;
3. many health-related problems and issues have their roots (and their solutions) in different policy areas – not just the environment, but all the different sectoral and structural policies that come to bear on the environment and human behaviours;
4. most policy (and other) interventions do not only affect risks to human health, but have much wider goals and implications, including effects on positive aspects of human well-being and health (e.g. on environmental services such as food and water resources or open space);
5. effective action thus requires policies that are both more integrated and precautionary in approach, and which thus involve collaboration between the different policy areas and agencies, acting in advance.

The implications for assessment are no less far-reaching. If these sorts of policy are to be developed and pursued they need methods of assessment that go beyond consideration of risks or policy actions in isolation. Instead, assessments are needed which:

1. are multivariate and systemic in approach – i.e. consider the full causal chain, including all relevant sources, agents, pathways, setting and health effects;
2. extend beyond mere considerations of risks and adverse effects, and evaluate the positive impacts of policies;
3. are forward-looking and divergent, in that they do not simply assess how best to meet a specific policy objective, but consider the <u>consequences</u> of the interventions and actions involved;
4. are dynamic and behavioural – i.e. consider the ways in which policy interventions or other changes might play out across the system;
5. can nevertheless translate all the complexities and trades-off that this implies into simple, robust and valid measures of impact, which policy-makers can readily understand.

In other words, policies need to be based upon methods of <u>integrated assessment</u>.

In the area of environmental policy, this approach is relatively well-established.

Integration and precaution have long been underpinning principles of the EU Environmental Action Plan, and integrated assessment has been adopted as a unifying framework by the European Environment Agency. The requirement for strategic environmental assessments has also recently been introduced for major programmes and plans (though not policies), while a large and growing number of integrated assessments have been undertaken of issues such as climate change, air pollution, catchment management and land use change.

In the arena of health, in contrast, the concept of integration has been slower to catch on. Probably the most significant example is the work of WHO to quantify the environmental burden of disease at global and regional level, using so-called methods of comparative risk assessment. These assessments, however, are essentially diagnostic in approach and do not consider the forward-looking, what-if questions which ultimately need to inform policy. Methods of integrated risk assessment have also been proposed, albeit in rather contradictory forms, but these have not yet been implemented to any significant extent.

The evidence is thus that integrated assessments can be done, and can usefully inform policy. The need now is to develop and apply these approaches to some of the systemic policy issues in the arena of environmental health. This is the goal of the INTARESE and HEIMTSA projects. Out of these projects has arisen a concept of integrated integrated assessment (or what we rather ponderously integrated environmental health impact assessment), which can be represented as follows. As can be seen, this extends more traditional methods of risk assessment and health impact assessment in a number of ways: by spanning different policy issues, by incorporating dynamic changes, by bringing together results in a simple and aggregated form, and by extending the causal chains to more distal origins and more remote impacts.

The process of integrated assessment

The aim of integrated environmental health impact assessment, therefore, is to provide a means of assessing the health implications of complex Integrated environmental health impact assessment is defined as a means of assessing health-related problems deriving from the environment, and health-related impacts of policies and other interventions that affect the environment, in ways that take account of the complexities, interdependencies and uncertainties of the real world. If one is looking for a scientific paradigm behind the concept it is thus realism rather than reductionism. Integrated assessment deliberately attempts to recognise and model the complexities and interdependencies that characterise the real world, rather than to ignore them.

Not every environmental health problem merits such an approach: many can be assessed more narrowly, using traditional methods of risk assessment or health impact assessment. But many do: indoor air is just one such issue. Typically, these are those systemic policy questions that require the understanding of either:

1. the causes of the problem (e.g. to help target action) not just in terms of the proximal exposures but how these exposures have arisen; or
2. the consequences of interventions not only in the narrowly defined sense of ‘will this meet my policy goal?’ but, more broadly, when we need to know what will happen.

The principle behind the approach is that, in the field of policy, both of these are often vital questions. Indeed, one can question how we can make policy decisions in most situations without being able to answer them.

The question still remains. Can this be done? Given the very complexities that integrated assessment tries to address, can we actually do the science in a way that can give useful, and sufficiently reliable, evidence on which to act?

Issue-framing

No-one would suggest that integrated assessment is easy. The first problem, as the example of indoor air clearly illustrates, is encountered right at the start: how to frame the issue that is to be assessed. This is a vital consideration, for it determines everything that follows: not just the scope of the assessment but, equally, the policy choices that are considered and the actions that might thus follow. Delimiting complex systemic issues is especially challenging, for – as has been seen – these issues are ramifying in both their causes and their consequences. Much therefore has to be agreed at this stage: which exposures and health effects should be included and which excluded; what measures of outcome should be used to describe and compare the impacts; what scenarios should be used as a basis for assessment. Each of these may look different from different perspectives, and may change over time. The boundaries of the issue are thus ambiguous and porous.

As such, issue-framing cannot be a wholly scientific process, but requires input and expertise from the social sciences. Rarely, also, should it be left either to the lead policy-makers or to the assessors. Instead, it demands a more collective and collaborative approach: one that involves (directly or indirectly) the different stakeholders who either contribute to, or might be affected by, the policy issue. Such participatory processes are not easy to devise, especially in the context of international and wide-ranging issues that may affect large numbers of people from different walks of life. Imaginative methods and tools – such as web-based platforms - are needed to bring these people together, in virtual if not real space, and with a common language and means of expression.

Scenarios

The result of the issue-framing process should, in most cases, be a conceptual model of the system that is to be assessed: the issue in context. For the purpose of analysis, this needs to be translated into a more formal structural model and protocol, defining the exposures and health outcomes that are to be assessed, the detailed scenarios through which this will be done, and the data and modelling methods to be used.

Amongst these, definition of the scenario is especially important – and challenging. It needs to be emphasised that all assessments are comparative, and all comparisons are between two or more scenarios – i.e. assumed or selected states or storylines, from a range of possible alternatives. In a diagnostic assessment, the comparison is typically between the current situation and some ideal alternative (that without the pollutant, or that assumes that concentrations were at a tolerable level). In a summative assessment the scenarios represent the current situation and that which either did exist before the present policies were introduced, or would have developed without them. In a prognostic assessment, the scenarios usually represent a number of policy options, one of which may be a business-as-usual projection.

How these scenarios are defined is crucial, for they define the comparisons that will be made – and thus determine the outcomes. Moreover, while it might be easy to see the scenarios as fixed states, the reality, as we have seen, is that the world does not switch disjunctly from one state to another, but elides, adapts and evolves. Lots of things change in the process, and lots of later changes are triggered off. If we ignore these, we ignore a large proportion of the impacts that are likely to arise. We bias the assessment. Thus, it is not sufficient for the scenario to be, for example, 'a 10% reduction in ambient $PM_{2.5}$ concentrations': that is merely the goal. The scenario must include the mechanisms by which this will be achieved – and their consequences, both intended and unintended.

Developing such dynamic and divergent scenarios is difficult, and one has to say is rarely done in any very rigorous way. The example of biofuels, mentioned above, perhaps illustrates the consequences. Along with issue-framing it is probably one of the main areas of integrated assessment where advances in methodology are essential. It would make a very worthwhile focus for future EU research calls.

Execution: source to exposure

The execution phase, which follows is, of course, where the assessment is actually done. To some extent, this phase is not that much different from the analyses involved in more traditional approaches of risk and impact assessment: the assessment of exposures across the target population, and the translation of these into some measure of health impact through the use of exposure-response functions. As such, it is able to upon a strong body of information and methods: databases of many different sorts; monitoring systems including ground-based monitoring, biomonitoring and remote sensing; many different methods of modelling, including statistical, GIS and mathematical techniques; and a wealth of results from previous studies.

Two things are, however, different. The first is that the links in the causal chain tend to be longer and more complex, both from source to exposure and from exposure to health outcome. The second is that the assessment involves the 'co-analysis' of all the relevant agents, pathways and outcomes, across the entire causal chain. This poses special difficulties, for it implies the ability to analyse everything, at least to an appropriate level of accuracy. That means that gaps in knowledge, or the lack of suitable data or models, can act as major limitations. It also implies knowledge about how all the different elements of the system combine and interact, and interactions are something about which the sciences of epidemiology and toxicology have so far made very limited progress.

What do we do, therefore, when data or knowledge are missing? One thing we can't do is simply ignore the factors concerned. To do so will, again, bias the analysis, often quite substantially and (because it will involve exclusion of possible effects) towards the under-estimation of the overall impacts. Instead we have to do the best we can with the materials and tools we have to hand.

There are many areas in which this is likely to become necessary. In exposure assessment, for example, we have a repeated problem of inadequate data. Environmental monitoring remains geographically sparse, and ground-based monitoring networks have rarely been designed for the purpose of exposure assessment, so they often do not reflect population distribution. Remote sensing has promised much in the way of exposure assessment for a long time, but has still to prove its worth. More fundamentally, human exposures depend to a large extent on personal behaviours, including time spent indoors, so ambient environmental concentrations, however obtained, are often extremely poor predictors of exposure. Because they relate to people, rather than the wider environment, biomarkers would seem to offer much more specific measures of exposures, but the number of biomarkers remains small and surveys are costly. Like other forms of measurement, however, biomonitoring is inherently retrospective: it gives information on what has happened rather than what will. As a consequence, while it provides an increasingly valuable tool for *post hoc* analysis of policy measures (i.e. for summative assessments), it has limited use in prognostic analyses.

By necessity, therefore, modelling is the primary tool for most integrated assessments. It is needed, at the very least, in order to extrapolate from the limited survey data to the wider population. It offers the only means of estimating future exposures, under prognostic scenarios. A wide range of models are available for this purpose, including deterministic propagation models (e.g. dispersion models), GIS techniques and statistical methods such as Monte Carlo modelling. All are increasingly proving their worth, though their use is often constrained by two factors: lack of rigorous validation (especially against exposure data) and the availability of the necessary input data needed to run them.

Exposure assessment by all of these methods also faces another constraint – namely the character of the exposure response functions into which they have to feed. To be reliable, the exposure metrics derived from the models have to match those used in the exposure response functions – not just in term of the definition of the risk factor (e.g. the pollutant species) but also the time period of exposure and the characteristics of the study population. Often they do not, so some form of approximation becomes necessary. This implies the ability to translate between different exposure metrics and methods – for algorithms that allow us, for example, to convert between different measurement techniques, marker pollutants or averaging times for air pollution. This type of research is not often done: it is seen as 'non-scientific' – the pressure is always for more sophistication and greater specificity. In the world of integrated assessment, however, exposure assessment typically involves the need to 'make do and mend', we have to approximate.

Exposure to health outcome

Similar challenges arise in relation to the link between exposure and health outcome. The crucial bridge here is provided by the dose-response function: the means of translating exposures into magnitude and severity of health effect. Information on these relationships come, typically, from two main sources – epidemiology or toxicology. Each has limitations. While epidemiological research usually provides explicit dose-response functions (i.e. a measure of the rate of change in the risk per unit change in exposure) across large human population groups, the exposure metrics used are often crude and categorical. Many studies are subject to major uncertainties and potential biases, due to the observational (and often aggregate) nature of the studies, difficulties in controlling for the effects of potential confounders (which may lead to either over- or under-adjustment of the estimated risks), and poor exposure characterisation. A large number of studies may thus be needed to obtain reliable exposure-response functions; sadly, differences in study design then hinder attempts to synthesise the results. Uncertainties therefore persist.

Toxicological studies – through their more controlled, experimental design – might seem to offer better information, but this is rarely the case. A major limitation for most studies is that they are based on animals, rather than humans, so translating results to human populations is inherently difficult. Only rarely, also, do toxicological studies give direct exposure-response functions; more commonly they are designed to define seeming thresholds or safe limits – often in the form of 'no observed adverse effect levels' (NOAELs) or similar metrics. Translating these into continuous functions is problematic.

Both toxicological and epidemiological studies have also, so far, been done on a relatively small range of pollutants, and in relation to a limited range of health outcomes. For many, even common, exposures (e.g. noise, disinfection by-products in drinking water) the number of studies is small. Gaps thus exist in the knowledge offered by each. Unfortunately, differences in principle and design mean that combining data from epidemiology and toxicology remains difficult: we still do not know how to do it, reliably, in most instances.

Added to this, the strong tendency in both disciplines has been towards narrowly defined studies, looking at individual risk factors in isolation. The effects of multiple exposures have rarely been thoroughly explored. It is also important to recognise that these multiple exposures do not just involve exposure mixtures – or what might be termed compound exposures (i.e. combinations of exposures of pollutants with a broadly common mode of action, such as different air pollutants). That is the least of our problems, not least because the effects are, in most cases, likely to be no more than additive. It also involves conjoint exposures – i.e. combinations of exposures with different modes of action (e.g. air pollution and noise, radon and particulates) – for these are more likely to behave synergistically. Synergy is also, perhaps, characteristic of exposures that aggregate over time – what we might call cumulative and consecutive exposures. It is also important to note that these may involve complex processes of predisposition or sensitisation to later, different exposures and effects. Our knowledge about all these remains sparse.

In addition, as already noted, the exposure-response functions need to match the data we have for exposures, and to do so for all the exposure-health relationships of interest. This is not always the case.

As with the link from source to exposure, therefore, integrated assessment at this stage involves the need for approximation. We will rarely have all the data we need, in the form we would like, and to an optimal level of accuracy. We need to be able to compromise – again to make do and mend – and cope with the uncertainties this implies. Where possible, we might use methods of quantitative systematic review to bring together the knowledge from all the relevant studies. Often, we will need to resort to more crude methods, such as extrapolation from analogy, or expert judgement.

Conclusions

As all this implies, integrated assessment is a pragmatic, not a pure, science. It relies on approximation, it demands flexibility, it inevitably involves uncertainty. These uncertainties come at every stage in the process. While it is common amongst scientists (and perhaps others) to focus on, and emphasise, the more 'scientific' uncertainties in the assessment phase, in reality these may actually be minor compared to those that occur in the earlier steps, of issue-framing and scenario development – or, indeed, the later stage of appraisal. Many of the uncertainties in the assessment are, at least, roughly quantifiable, and amenable to study. Those in deciding what the issue is, and under what conditions it should be assessed, or what the results mean, are far more ambiguous and difficult to specify. They involve social values more than physical mechanisms.

That said, it would be erroneous overly to dwell on the uncertainties. All assessments, including the most narrow traditional risk assessment, involve uncertainties. But integrated assessment has two major advantages. Te first is that, while expanding the scope of the assessment increases the scope for uncertainty, it also tends to increase the degree of tolerance of those uncertainties. In many cases, therefore, the mass of evidence is likely to outweigh the uncertainties - the overall balance of impacts, and the rank order of different scenarios (if not their absolute costs and benefits) will at least be clear. Secondly, and in many ways more importantly, integrated assessment helps to make explicit what we know and what we don't. It encompasses the uncertainties, and in doing so liberates them, rather than hiding them in the issue-framing simply by ignoring what we don't know (or don't want others to know). That, in the end, may be its greatest strength, for by being honest it empowers those who need to know.