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Developing Guidelines for Economic Evaluation of Environmental Impacts in EIAs

PART I

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Developing Guidelines for Economic Evaluation of Environmental Impacts in EIAs

PART I

Commissioned by
SEPA and NORAD

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Acronyms

ADB	Asian Development Bank
B[a]P	Benzo(a)pyrene
CBA	Cost-benefit analysis
CO	Carbonmonoxide
COI	Cost of Illness
CV	Contingent valuation
D-R function	Dose-response function
ECM	(Chinese) Environmental Cost Model project
EEEI	Economic Evaluation of Environmental Impacts
EIA	Environmental Impact Assessment
EIF	Environmental Impact Form
EIR	Environmental Impact report
EIRF	Environmental Impact Registration Form
EPA	Environmental Protection Autority
EPB	Environmental Protection Bureaus
EPL	Environmental Protection Law
E-R function	Exposure-response function
F	Flouride
FECO	Foreign Economic Co-operation Office of State Environmental Protection Administration
GHGs	Greenhouse Gases (the most important of which is CO_2)
GIS	Geographical Information Systems
HA	Hospital admission
NOx	Nitrogen oxides
O_3	Ozone
Pb	Lead
PM_{10}	Particulate Matter of size 10 μg/m^3 less
$PM_{2,5}$	Particulate Matter of size 2,5 μg/m^3 or less
REIA	Regional Environmental Impact Assessment
SEA	Strategic Environmental Assessment
SEPA	State Environmental Protection Authority
SO_2	Sulphur dioxide

SOPS	State office of Price Stabilisation
TSP	Total Suspended Particles
VOC	Volatile Organic Compounds
VOSL	Value of statistical life
WDL	Work Day Loss
WHO	World Health Organisation
WTA	Willingness to Accept
WTP	Willingness to Pay
WWTP	Waste Water Treatment Plant

Executive Summary

Abstract

Is the time right to introduce environmental evaluation into the Environmental Impact Assessment (EIA) system for large construction projects in China? The report analyses gaps to introducing environmental evaluation into EIAs and recommend how to bridge the gaps. The report also provides suggestions to the State Environmental Protection Administration on core elements of a guideline for environmental evaluation to include in the existing EIA guidelines.

The report draws on international and Chinese research and best practice and conducts four case studies of environmental evaluation based on EIAs of investment projects (a power plant, a waste water treatment plant, regional waste water irrigation, and a road construction project).

Background

This report is the follow-up of the ECON project CHN 0044 "Handbook and training programme for Economic and Financial Analysis of Projects" carried out in 1998-99 for the Foreign Economic Co-operation Office of State Environmental Protection Administration (FECO). The handbook was developed to guide the evaluation of projects under the Trans-Century Green Project Programme in China. Following this work, considerable interest for a follow-up project on economic aspects of Environmental Impact Assessments (EIA) was expressed by various Chinese stakeholders.

Recently, national laws and regulations, the most important of which is the EIA law from 2002, have introduced requirements to include economic analysis of environmental impacts (EEEI) as part of EIAs. However, existing EIA guidelines and practice in China are currently void of economic analysis. There is therefore a strong need for more knowledge of how economic analysis of impacts can be integrated with the existing EIA system, and a set of detailed guidelines on economic evaluation for EIA institutions and agencies to follow. This would both satisfy the legal requirements and, even more importantly, improve the information content of EIA reports and their potential for influencing decision-making.

Purpose

The purpose of this report is twofold:

- *To assess gaps to introducing economic analysis of environmental impacts (EEEI) into EIAs in China, and provide recommendations on how to bridge the gaps; and*
- *To provide suggestions to SEPA on core elements of a guideline for EEEI*

To achieve this dual purpose, the report draws on international and Chinese research and best practice and conducts four case studies of EEEI based on EIAs of investment projects (a power plant, a waste water treatment plant, regional waste water irrigation, and a road construction project).

The study utilises a range of research methods, including literature reviews of Chinese and international research, interviews and consultations with stakeholders in EIA institutions in China and internationally, and primary and secondary data collection coupled with quantitative and qualitative analyses. Two previous guidance documents, ADB (1996)[1] and ADB (1999)[2], have given particular inspiration.

The report has been prepared over the period November 2002 to May 2005 as a cooperation project between the *Institute of Environmental Economics at Renmin University, College of Environmental Sciences at Peking University, Policy Research Center for Environment and Economy of SEPA* (all based in Beijing), and *ECON Analysis* (based in Oslo, Norway). State Environmental Protection Administration (SEPA) has been beneficiary of the project. Financial support for the project from the Norwegian Agency for Development Co-operation (NORAD) is gratefully acknowledged.

Conclusions and recommendations

We summarise the conclusions and recommendations first by describing projects suitable for EEEI and how EEEI can be carried out (core elements of an EEEI guideline). Second, we discuss some of the challenges or gaps involved in introducing EEEI into EIAs in China.

Projects applicable for EEEI

Based on the lessons learned in this project, we have found that not all projects are applicable for EEEI. In our view the following projects should be made subject to EEEI:

- *Construction projects with significant impacts on a large area, region or river basin.* Large construction projects often have environmental impacts on a large area, often far beyond the area where the project makes economic influence. If the environmental impacts are not evaluated in the project EIA, it is very likely that the severity of the impacts will not be taken into account in the final decision.

1 "Economic Evaluation of Environmental Impacts. A Workbook. Asian Development Bank"

2 "Environment and Economics in Project Preparation. Asian Development Bank".

- *Plans on economic development, natural resources exploitation, environmental protection and industry development on national, regional, and local levels.* The reasons are:
  - Plans have potentially large environmental impacts over a wide area, involving large populations,
  - The area of environmental impacts from the plan is often almost the same as the area of economic impacts;
  - Plans are normally comprised of many projects, which means that resources (related to those projects) can be re-allocated optimally through the design of a plan;
  - Economic evaluation will be helpful for achieving the comprehensive goals of the plan, because plans come earlier in the cycle than individual project decisions, so that economic evaluation of plans can force EIAs to be integrated into decision making process at an earlier stage.
- *Policies on economic development, natural resources exploitation, environmental protection and industry development on national, regional, local levels* for the same reasons as above. In addition, at the policy formulation stage, there may be even more options for changing environmentally detrimental aspects, than for plans and programmes where more of the parameters have been decided. However, the EEEI may be more uncertain for a policy than for a project since it is harder to predict impacts for policies.

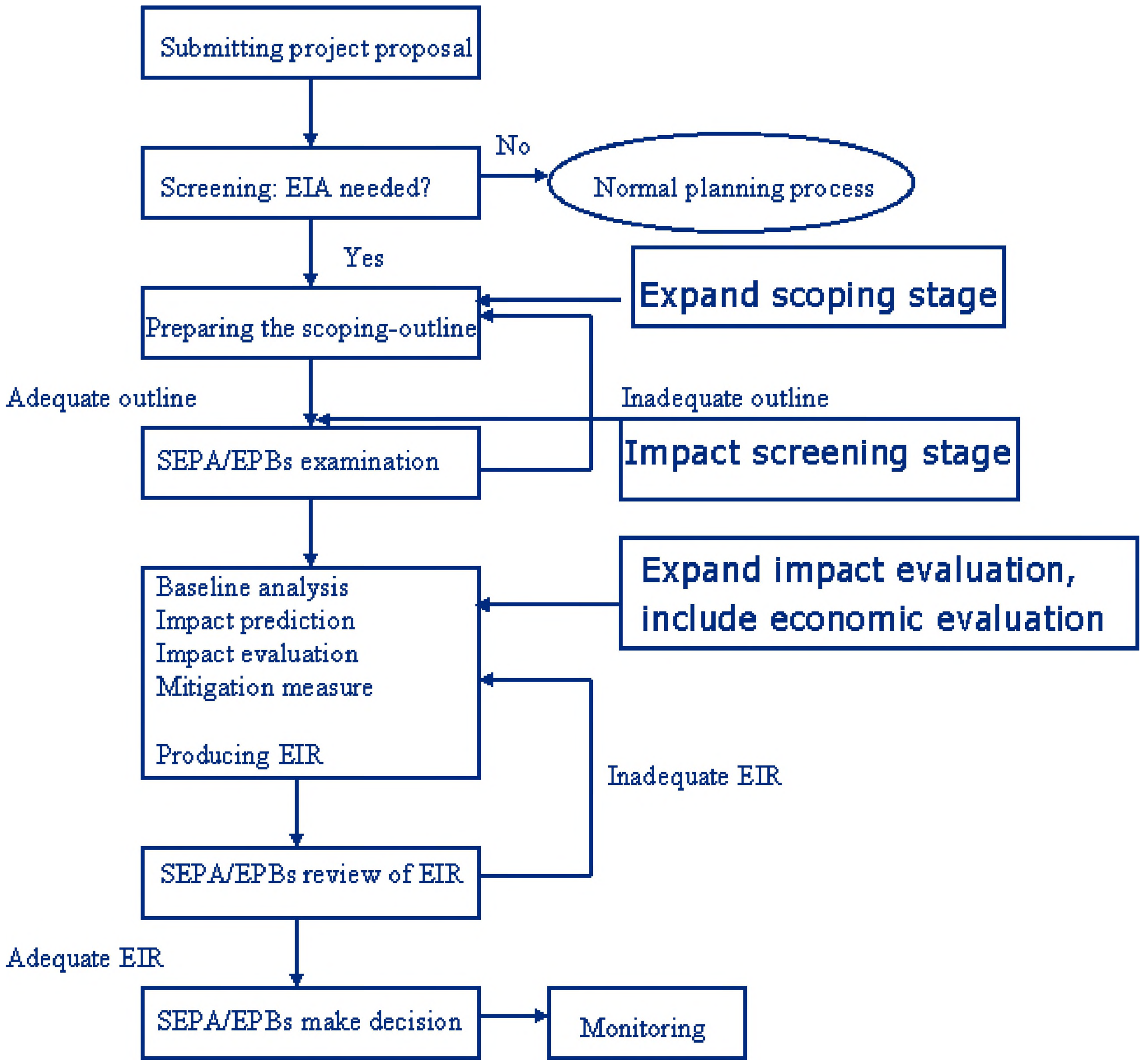
The case of Wangxinzhuang Waste Water Treatment Plant (WWTP) can justify these ideas. The WWTP has removed a large amount of COD, so it is successful as a pollution reduction project. But the construction of the plant did not bring environmental benefits large enough to improve the quality of Jialu River below class V (the lowest quality). The EEEI shows that the environmental benefits of one WWTP are relatively modest, but as part of a wider plan for the watershed which included maybe five WWTPs the plant would potentially have high benefits.

How to conduct EEEI - Core elements of a guideline

The EEEI of suitable projects should follow the steps of the Chinese EIA process, and cover only the most important impacts that can be valued in economic terms based on the current state of knowledge. Project types that may not follow the standard EIA process, as for example some plans and policies, may need to utilise EEEI in a different way than the standard large, individual investment projects. We have not assessed specific procedures for plans and policies in this report.

We suggest below the core elements to include when performing an EEEI as part of EIAs of investment projects. The suggestions may make it easier to carry out an EEEI by agencies assigned to do EIA's with an EEEI included (the "EIA agencies"). The suggestions are for SEPA's consideration, and might prove useful should SEPA decide to work out detailed guidelines for EEEI as part of EIA. Figure 1 shows how these new core elements could affect the existing EIA process.

Figure 1. Core elements to include in the existing EIA process to carry out an EEEI.



Scoping stage

In existing EIA procedures, after projects have been screened, whenever an Environmental Impact Report is required the EIA agency prepares an EIA outline. One step in the outline is to 'identify significant impacts'. In order to satisfy the needs of an EEEI we suggest to carry out the impact identification part in two steps:

1. Identify environmental stressors.

2. Identify potential impacts related to each stressor, and identify linkages.

Tables for these two steps are provided in Chapters 3, 5-7, and their use been demonstrated there.

As will be seen from the tables, the concept of impact, in the vocabulary of an EEEI, means *impact on* human health, human welfare, environmental resources or global systems.

Impact screening stage

The impact screening stage is a new stage required by the EEEI that is fitted between the scoping stage and the baseline analysis stage in the ordinary EIA. Environmental impacts should be screened in order to identify whether they should be subject to further, quantitative study.

3. In the screening, identify impacts that are the subject of further, quantitative study on the basis of the following criteria:

    a. Importance, which often is related to an impact being large in physical terms

    b. Concreteness, that is whether the impact relates to a physically concrete phenomenon (if the tables we provide to help the impact identification stage are used, the impacts are in general sufficiently concrete)

    c. Certainty, that is whether the impact is possible to assess with any degree of certainty and confidence.

Impact prediction stage

In an EIA that includes an EEEI, the impact prediction stage is significantly expanded compared to an ordinary EIA. The first new aspect of the impact prediction stage is:

4. Identify impacts that should be the subject of monetary evaluation. The identification should consider, on the one hand,

    a. which impacts are especially important for the subject under study (project, plan, program), and on the other hand,

    b. which impacts have available methods and tools for evaluation. The identification should also consider

    c. the amount of resources available for the EIA/EEEI study and

    d. the importance of the subject (project, plan, program).

5. Experience from this study and other studies in China and worldwide suggest that the following impacts are among the candidates for monetary evaluation:

    a. Impacts on human health from air pollution, in particular air pollution in the form of emissions of SO_2, NO_x and soot/dust (PM_{10}, $PM_{2.5}$)

b. Impacts on materials from air pollution, in particular emissions of SO_2.

c. Impacts on vegetation and crop growth, in particular emissions of SO_2.

d. Impacts on human welfare from noise. Noise is not covered in our report.

e. Impacts on human health from water pollution, in particular impacts in the form of biological water-borne diseases (acute/short term impacts).

f. Impacts on water reliant crops, fish and industries from low water quality and pollution induced water shortage.

g. Impacts of land use changes.

h. It is sometimes possible to estimate benefits of a combination of impacts, and sometimes all impacts (i.e. total benefits) by using special methods.

6. To value in monetary terms the impacts a-g we suggest a three-step approach

   a. First, the linkage between emission/stressor and exposure to the change in environmental quality is estimated. For this linkage it is important that the surveyed area covers all or most of the exposed area. Simple dispersion models over the exposed population may be used to estimate the linkage. Practical examples can be found in the case studies of this study.

   b. Second, the linkage between exposure and impact is estimated, using so-called exposure-response methodology. The research on exposure-response methodology and exposure-response functions is rapidly evolving. A survey of current research results for air and water pollution is given in Part II of this report. For this linkage background data on health status, crop production etc. are needed, and data limitation may sometimes be a problem. Above we have recommended to increase the efforts to make available additional exposure-response functions.

   c. Third, the price of impacts is estimated. Many end-points have a market price, but some have not, and the price must be derived from e.g., cost data or similar. A survey of selected research results on this issue is provided in this study.

7. To value in monetary terms the impact h we suggest one or more of the following methods (see chapters 3, 4 and 5-7 of the report for a more comprehensive description):

   a. *Contingent valuation*, whereby the willingness to pay of subjects for changes in environmental quality is obtained. The concept "environmental quality" should be made as precise in the questionnaire as the subject allows, but will often cover more than one impact. Contingent valuation may also be suitable for step 6c above, especially when end-points primarily have a subjective aspect (morbidity and mortality risk, biodiversity loss etc)

b. *Defensive and averting expenditures.* Averting expenditures are expenditures designed to prevent or mitigate environmental degradation *before* it occurs. Corrective expenditures abate or reduce the impacts of pollution *after* it occurs. They may include the replacement or restoration of damaged assets. Actual defensive expenditures reveal the minimum amounts that producers and households are willing to pay to prevent environmental degradation.

c. *Hedonic pricing.* The method for estimating implicit prices is known as hedonic price analysis. Prices of housing location, wage compensation for risky jobs etc. are examples of implicit prices that provide much evidence on willingness to pay values for environmental quality.

d. *Travel cost method* is based on the common observation that the use of environmental services varies inversely with the costs of access to them. In effect, travel costs act as implicit prices for access to non-priced services. From variations in travel costs and use, we can deduce what individuals would be willing to pay for the services.

To the extent possible observed prices and costs in various markets should be used.

Use and reporting of environmental cost results

As discussed in Chapter 1, the EEEI should be designed, conducted and reported with the four main uses of the results in mind:

- *Enter into Cost Benefit Analysis:* This study gives guidance on how to estimate and calculate the environmental costs and benefits.
- *Motivate and prioritise mitigation options:* For this use, the environmental benefits can be estimated for different mitigation options to assist in the decision of level and type of mitigation.
- *Contribute to a compare significance of different impacts:* If the environmental costs/benefits of a construction project have been estimated, their significance can directly be compared since the unit of measurement for the impacts is RMB.
- *Make it easier to analyse alternative project designs, locations, etc.*: According to the EIA law alternatives to the project in question should be considered. EEEI results for different alternatives can be used to compare the significance of impacts between alternatives.

Bridging the gaps in the current EIA system

Through this project many challenges for the increased use of economic evaluation of environmental impacts in EIA have been identified. Some of the challenges are related, but we go through them area by area: the role of EEEI, procedures and methodology, institutions and data requirements.

The role of EEEI

In terms of which role EEEI should play in China, the main gap is that both the EIA law and the regulation[3] require an EEEI as part of the EIA process, but there are no clear descriptions of the role of EEEI nor implementing guidelines. The main purpose of developing an EEEI approach is to strengthen the influence of EIA on decision-making, both through:

- Improving the information content of the Environmental Impact Report for the use by decision-makers
- Strengthening the decision making support for national economic evaluation (cost-benefit analysis) of projects (and suitable plans and programs)

Therefore, we recommend that SEPA, as the executive body of the EIA law, should provide precise and detailed requirements for economic evaluation according to the Chinese situation, on the basis of an overall assessment of policy objectives, the role and specific needs of the existing EIA system, following the law and relevant regulation of the State Council.

These precise requirements should clarify the roles of EIA and EEEI at the project level and the levels of plans and programmes. A result from our study is that EEEI in many cases would be more useful for a program or plan (e.g. assessing a plan to clean up a watershed) because projects assessed in isolation have marginal impacts and because the geographical scope in the EIA often is too narrow. Another example of this, in addition to the WWTP described above, is the assessment of air pollution impacts from a coal-fired power plant, where the substantial impacts outside the defined project area were not assessed.

EEEI procedures and methodology

The first required steps of a good EEEI are identical to those of a good EIA report, i.e. understanding the physical relationships between stressors (pollutants) and impacts on receptors. A serious gap in the EIA practice in China is that the impacts are often indicated roughly, i.e. the EIA only reports the emission levels and not the impacts on receptors. As long as this shortcoming exists, the information provided is not very useful for decision-making and it is difficult to utilise the advantages of EEEI to assess impact significance. Other gaps identified in chapter 8 are the lack of a detailed guideline for EEEI as part of EIA (as also touched upon above), and that dose-response functions and economic valuation methodologies are under constant development and improvement.

3 "Management for Environmental Protection for Construction Projects" State Council Regulation. 1998.

SEPA, as executive body of the EIA law, should also provide precise and detailed directives for improving the current EIA practice. The following items should be considered:

- Require the EIA to assess impacts on receptors for the most important impacts, and not just report stressor levels (e.g. tonnes of emitted pollutants)
- Extend the evaluation scope of environmental impacts including health, vegetation and material damage considerations
- Develop a proper practical economic evaluation guideline for large projects, and for plans and programmes that are suitable for EEEI. This report gives a good research basis for going ahead with designing this detailed guideline.

Institutions

Some of the institutional gaps are related to the gaps in current EIA practice (geographical scope of EIA, insufficient information in EIA reports etc) and gaps related to the environmental management bureaucracy (lack of staff trained in EEEI, and EEEI manuals, difficulties in getting hold of information from relevant institutions etc). SEPA should adjust its institutional arrangements to enhance the capacity of EEEI in the following aspects:

- Enlarge the geographical scope of the environmental impact assessment. This can either be done by extending the geographical scope of individual EIAs or (better) by conducting higher level EIAs, e.g. a regional EIA, rather than many individual EIAs that miss the cumulative and regional impacts (which are often very important).
- Strengthen the requirements that EIAs have to assess impacts on receptors and not just levels of emissions etc. All good EIAs should do this, regardless of EEEI. This point is also mentioned as part of the procedures and methodology section above.
- Strengthen the competence of EIA implementing institutions and practitioners in EIA, both through:
  - Organising training for EIA practitioners. The current project has started this process through conducting several training workshops, but more are clearly needed.
  - Drafting supporting manuals and materials on EEEI to guide practitioners who shall conduct EEEI.
  - Basing training and manual drafting on international best practice EIA and EEEI (e.g. as conducted in the EU and USA).

Data availability

Data availability is an area with many challenges related to the insufficient information about impacts provided in EIA reports, general lack of data, statistics and knowledge in China related to exposure/dose response relationships, and difficulties in obtaining data from the relevant institutions in China for use in EIA/EEEI. A thorough discussion of these challenges is given in chapter 8.5. Our policy recommendations are:

- Develop China's own Exposure-response functions based on large statistical samples to match with China's social and economic statistical data (health, population, labour etc) and natural resource accounting data. This is however a long-term project. At present, the best approach is to use the existing data and information from Chinese and international sources to get the best possible picture of the environmental impacts. When research and data availability are improved over time, the environmental impact estimation can also be refined and improved to become more accurate.
- Establish a mechanism of public health information sharing, at least among the relevant ministries of the Chinese government. It is often difficult to get hold of the relevant data even when they are collected by government institutions. A streamlining of procedures for getting hold of data for EIA practitioners would be of tremendous help.

1 Introduction

1.1 Background and purpose

This report is the follow-up of project CHN 0044 «Handbook and training programme for Economic and Financial Analysis of Projects» carried out in 1998-99 for the Foreign Economic Co-operation Office of State Environmental Protection Administration (FECO). The handbook, which was developed to guide the evaluation of projects under the Trans-Century Green Project Programme in China, has been translated to Chinese, and is now being used by several government departments.

Considerable interest for a follow-up project on economic aspects of Environmental Impact Assessments (EIA) was expressed by various Chinese stakeholders. Recently, amended national laws and regulations have focused on economic analysis when new construction projects are considered. On 29. November 1998 the State Council of China released the amended document «Regulation of Environmental Protection and Management of Construction Projects» that requires appropriate environmental economic analysis alongside the traditional EIA. The regulation is expected to increase the importance of economic analysis in EIAs in the future. Another important milestone for the use of economic analysis is the EIA law from 2002.

This report has been written with the overall goal of enabling better EIAs to be carried out. This will be achieved through developing a sound basis for proposing new EIA guidelines with environmental economic analysis as an integrated component of the framework of China EIA Technical Guidelines that is prepared by the State Environmental Protection Administration of China (SEPA) on behalf of the State Council.

The traditional EIA methodology as described in the existing Chinese laws and guidelines, and current EIA practice is advanced at identifying the potential stressors or pollutants of a project. However, the assessment of impacts in the receptors and the *significance* of these physical impacts have traditionally been less emphasised. Physical impacts are measured in many different units and fall into a range of different impact categories. It is difficult in practice to use this complex information in decisions about the project, for example regarding mitigation measures.

Economic evaluation of environmental impacts (EEEI) is a methodological framework that can be used to strengthen the assessment of the significance of environmental impacts and the effects of mitigation measures, and generally enhance the information content of EIA reports. Economic evaluation in EIAs can also be used for other purposes, see next section. The EIA law of 2002, accompanied by the recently revised EIA guidelines, has been put in place to enforce and guide the use of economic evaluation methods in EIA reports. However, there are currently no detailed guidelines on economic evaluation of environmental impacts for EIA agencies to follow.

The purpose of this report is twofold:

- *To assess gaps to introducing economic analysis of environmental impacts (EEEI) into EIAs in China, and provide recommendations on how to bridge the gaps; and*
- *To provide suggestions to SEPA on core elements of a guideline for EEEI*

To achieve this dual purpose, the report draws on international and Chinese research and best practice and conducts four case studies of EEEI based on EIAs of investment projects (a power plant, a waste water treatment plant, regional waste water irrigation, and a road construction project).

The study utilises a range of research methods, including literature reviews of Chinese and international research, interviews and consultations with stakeholders in EIA institutions in China and internationally, and primary and secondary data collection coupled with quantitative and qualitative analyses. Two previous guidance documents, ADB (1996)[4] and ADB (1999)[5], have given particular inspiration.

The report provides general guidance on how economic evaluation can be carried out for projects that have impacts through the media of air, water and land, and demonstrates the use of the general methodologies in four case study projects. Further, based on the experience from the case study work, the report assesses the gaps in current Chinese EIA practice to introducing economic evaluation procedures, and proposes how these gaps can be filled. Finally, the report ends with our recommendations to SEPA on what should be the next steps and the key contents of a detailed guideline on economic evaluation of environmental impacts in EIA. The main body of the report is contained in Part I, while the four case studies and an overview of reviewed literature linking air and water pollution with environmental and health impacts are provided in Part II.

1.2 How can economic valuation be used?

All public and private projects have costs and benefits to society. This report limits the analysis to the environmental and health impacts of projects. Economic evaluation of environmental impacts can be used to improve the information content of the EIA report and the economic assessment of the project as a whole, in four main areas. Environmental costs can:

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4 "Economic Evaluation of Environmental Impacts. A Workbook. Asian Development Bank"

5 "Environment and Economics in Project Preparation. Asian Development Bank".

- Enter into Cost Benefit Analysis
- Motivate and prioritise mitigation options
- Contribute to a compare significance of different impacts
- Make it easier to analyse alternative project designs, locations, mitigating measures etc.

Enter into Cost Benefit Analysis

The environmental costs can be included in a Cost Benefit Analysis (CBA). A CBA is a comprehensive evaluation of costs and benefits to society in monetary terms of a proposed project. The main criterion for evaluation is economic efficiency, i.e. that a given policy objective is achieved at least cost to society. When all impacts of the proposed project have been established and measured in monetary terms, the project should be carried out if the net benefits (benefits less costs) to society are positive.

If environmental costs are estimated in the EIA report, these costs could therefore be included in an overall CBA on equal terms with other cost and benefit elements. In that way the information from the EIA report can contribute to a better and more balanced economic analysis of the project and its alternatives, before a decision is made. A project based on a comprehensive CBA will normally achieve a policy objective at lower overall costs to society than a project where the environmental costs have been left out of the economic project analysis.

Motivate and prioritise mitigation measures

A less ambitious, but nonetheless important, use of the estimated environmental costs from the EIA report is to motivate and prioritise between mitigation measures. The EIA report should estimate the extra, or *incremental*, environmental costs caused by the project, both with and without mitigation measures. Implementation of each mitigation measure, or combination of measures, involves a cost. But the mitigation also entails environmental benefits, in that mitigation prevents environmental costs to materialise.

Therefore, comparing the costs and benefits of mitigation serves two purposes:

- If the environmental benefits are higher than the costs of implementing some mitigation measures, it will motivate and make clear to decision-makers that some mitigation is justified, and
- If there is a range of possible mitigation measures, the EIA specialist can recommend the combination of measures, which yield the highest net benefit. If it is hard to find the optimal combination, individual mitigation measures can be ranked.

Thus, this second use of economic evaluation of environmental impacts means making a CBA for the mitigation measures only, and not for the project as a whole. Even so, it may be very useful in practice to have a more consistent procedure for prioritising between several possible mitigation measures. This type of analysis would only be relevant for projects where mitigation options are not already decided by law in the form of required emission standards etc (see also Chapter 2).

Compare significance of different impacts

A third use of economic evaluation is to compare the significance of various environmental impacts. Traditional EIA has developed several approaches for evaluating and comparing the significance of environmental impacts, often of a very different nature. Most of these approaches lack a common denominator, and often have to resort to very subjective statements of significance. Economic evaluation of impacts can be used to strengthen this part of the EIA report by facilitating comparison. Economic evaluation introduces a consistent method of measuring environmental costs across different impact categories. Since environmental costs are all measured in RMB they can be compared and their relative significance established. Using economic evaluation of environmental impacts in this case improves the information content of the EIA report for decision-makers.

Make it easier to analyse project alternatives

A fourth and final use of economic evaluation in the EIA report is in the analysis of alternatives to the project in question (e.g. alternative project site, technology, operation), i.e. beyond the mere analysis of different mitigation technologies for a particular project.

Some type of assessment of different alternatives should be a part of the EIA process. As will be shown in chapter 2 it has not been common to assess such alternatives by the project developers. The EIA process should make sure that there are no other project alternatives with substantially lower environmental impacts. As a minimum the analysis of alternatives should cover the situation with and without the project. This is essentially the same as only assessing the project's *incremental* environmental costs, i.e. as compared with the situation where the project is not developed.

However, ideally other alternative sites, technologies and ways of reaching the objective should also be considered. The environmental costs with and without mitigation for the different project alternatives can then be compared and a recommendation made regarding the most sensible option from an environmental perspective. However, these results would have to be included in a full CBA of the different alternatives for a decision to be based on total project costs and benefits.

1.3 Outline of the report and authors

The full report is divided into two parts;

- Part I: Main body of the report
- Part II: Four case studies and overview of reviewed literature on air and water pollution and health

Part I is divided into nine main chapters. The next chapter explains the EIA concept and discusses the history and the typical steps of the EIA process in China. The detailed requirements for EIA in China are included as an annex. Chapter 3 on principles and methods for economic evaluation then first explains what environmental valuation is, then links the steps of a typical EIA report with economic valuation of the environmental impacts. The second part of the chapter discusses the most common economic evaluation methods and key issues in deriving values. After the general introduction to economic principles and methods, the report presents important international experiences with the use of economic evaluation of environmental impacts in EIAs (Chapter 4).

Based on chapters 1-4, the next three chapters look specifically at how to value typical environmental impacts through the three media of air, water and land. Chapter 8 discusses some shortcomings of the current EIA system and practice for the introduction of economic evaluation of environmental impacts. Chapter 9 recommends how the shortcomings can be resolved. The report ends with a proposal for key elements in a detailed SEPA guideline for economic evaluation.

Case study reports for a wastewater treatment plant, a power plant, a road project and use of wastewater for irrigation are presented in Part II of the report.

Parts of the report (and especially the case studies) draw from and follow the guidance given in ADB (1996) and to some extent the follow-up ADB (1999).

This guidance document has been prepared by a team of researchers over the period November 2002 – May 2005 from the following institutions:

- *Institute of Environmental Economics at Renmin University, Beijing:* Ma Zhong, Song Guojun, Wu Jian, Wang Dongpu, Gu Yizhen Wu Min, Chen Jing, Mao Xiaofei, Zeng Xiangang;
- *College of Environmental Sciences at Peking University, Beijing:* Zhang Shiqiu, Chu Jingjie, An Shumin, Su Kai
- *Policy Research Center for Environment and Economy of SEPA, Beijing:* Hu Tao
- *ECON Analysis, Norway:* Haakon Vennemo, John Magne Skjelvik and Henrik Lindhjem.

Financial support for the project from the Norwegian Agency for Development Co-operation (NORAD) is gratefully acknowledged.

2 The EIA system in China

This chapter gives an introduction to the Chinese EIA system, both the historic development of the system and the current practice.

2.1 The EIA concept

EIA is a process which *identifies, predicts and evaluates* environmental[6] impacts of a proposed project, plans for mitigation of effects, and provides this information to decision-makers in an EIA report prior to major decisions about the project are made. The overall goals of the EIA process are therefore to:

- Take environment into account in decisions about project development
- Anticipate and avoid, minimise or offset adverse impacts of projects
- Protect productivity and capacity of natural ecosystems
- Promote sustainable development and optimise resource use

2.2 The history of EIA in China

EIA has been an important part of China's environmental protection efforts. The concept of EIA was introduced in 1973 during the First Conference for National Environmental Protection. In May 1974, the State Council approved to set up a group bureau led by the State Council. However, the trial implementation of an Environmental Protection Law (EPL) in the late 1970s was the formal introduction of EIA in China, and the first official EIA was carried out in 1979 for a copper mine. The draft EPL set out conditions under which an EIA would be required, but did not prescribe how it should be conducted. Therefore, in 1981 the "Management for Environmental Protection of Capital Construction Projects" was released to provide the detailed guidance on how EIAs were to be carried out. Supplementing the EPL, the government introduced legislation dealing with the prevention and control of water pollution in 1984, and air pollution in 1987.

The EIAs were conducted by research institutes and reviewed by local Environmental Protection Bureaus (EPBs). Project decisions were then made by the local Planning Commissions, with the EIA as part of the information used in the process. The scope of these early EIAs was largely restricted to pollution

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[6] The term *environmental impacts* also includes socio-economic and health impacts

issues, and to major construction projects receiving external funding of over USD 5 million.

By the end of the 1980s, the statutory framework for environmental protection at the national level had been expanded by introduction of laws dealing with specific natural resources, including among others, minerals, grasslands, forestry, fisheries and land. Ministries in charge of managing the various environmental and resource sectors started to introduce in-house environmental protection units, which developed EIA procedures for projects that fell within the decision-making responsibility of the respective ministries. At the local level, the EPBs and local authorities were developing regulations and standards to interpret the laws for provincial and municipal application. However, the bureaus still retained a strong emphasis on pollution control within specific areas. In 1989, after a 10-year trial period, the EPL was revised and then formally enacted.

In the early 1990s China's economy grew rapidly and many new projects were approved without and EIA due to lack of specific legal provision to cover them. When an EIA was carried out, the assessments were generally poor and mitigation or abatement measures often lacking. The status of many county EPBs was downgraded as a result of administrative reforms. As a response to this the State Council issued more regulations and ordinances, including the "Technical Guidelines for Environmental Impact Assessment" in 1993. The concept of Category Management was also introduced at this time, categorising projects according to whether they required a full Environmental Impact report (EIR), a less detailed Environmental Impact Form (EIF) or a basic Environmental Impact Registration Form (EIRF), see more about these below. In addition, a process for Regional Environmental Impact Assessment (REIA) was introduced in 1993 so that EIA could be extended from individual projects to wider development zones, in order to address larger scale impacts and cumulative effects of existing or proposed developments. In the early 1990s some EIAs were beginning to address impacts on ecosystems, not just air, water and soil pollution as had previously been the case.

Since 1996 EIA has been further enhanced as the main regulatory instrument for environmental protection, culminating in the new EIA law approved in October 2002 entering into effect from September 2003. The new law requires economic evaluation of environmental impacts, but previous laws and guidelines also make references to economic evaluation. The law also introduces the concept on Strategic Environmental Assessment (SEA) of plans and programmes. Institutional restructuring at both state and local government level in 1998 elevated the power of environmental protection authorities, and consequently promoted the implementation of EIA. Steps were taken to improve performance mechanisms.

2.3 Framework of EIA legislation

Overview of EIA legislation

An overview of the EIA legislation in China is given in the table below. A more detailed description of the central EIA law (2002) is given in the next paragraph.

Table 2-1 Name list of EIA law and regulation in China

Type of law or regulation	**Name**	**Enacted authority**	**Implementing agency**
Law	EIA law (2002)	Standing committee of National Congress	SEPA
Administration regulations	Administrative Act of environmental protection for Construction programme (1998)	State council	SEPA
Department regulations	Administrative measures of EIA censor experts (2003)	SEPA	SEPA
	Graded examination and approval of regulations of Construction programme EIA (2002)	SEPA	SEPA
	Environmental protection administrative measures of Construction programme completion	SEPA	SEPA and local EPB
	Administrative measures of Construction programme EIA qualification (1999)	SEPA	SEPA
	Principles and measures for Construction programme EIA charge standard (1989)	SEPA	SEPA, SOPS (Office of Price Stabilis.)
Criteria and guiding principles	Environmental protection administrators of Construction programme (1990)	SEPA	SEPA and local EPB
	General principles of EIA technology guidance rules (HJ/T 2.1-93)	SEPA	Same as above
	EIA technology guidance rules—surface water environment (HJ/T2.1)	SEPA	Same as above
	EIA technology guidance rules—atmosphere environment (HJ/T2.1)	SEPA	Same as above
	EIA technology guidance rules—non-pollution ecological influences (HJ/T2.1—93)	SEPA	Same as above
	EIA technology guidance rules—sound environment (HJ/T 2.4-1995)	SEPA	Same as above
	EIA technology guidance rules of development area (HJ/T131-2003)	SEPA	Same as above
	Technical Guidelines for Environmental Risk Assessment on Projects (HJ/T 169-2004)	SEPA	SEPA and local EPB
	Criteria of petrochemical Construction programme EIA	SEPA	Same as above
	Criteria of port Construction programme EIA	SEPA	Same as above

EIA law (2002)

The formulation and implementation of the EIA law has been important for the refinement of the legislation of the EIA law in China, and the development of the

EIA system, preventing environmental pollution and ecological devastation. The EIA law has the following characteristics compared with the former legislation:

(1) Expanded range of EIA application

EIA law item 2 regulates that "the EIA applied in this law, refers to the analysis, prediction and assessment of the possible environmental impacts of planning and construction projects in order to provide precautionary measures to alleviate adverse environmental impacts, and methods and systems for tracking and monitoring." This text expands the application of EIA from specific construction projects to macro-level planning EIA. Further, the EIA law has a special section to regulate the EIA for planning.

(2) Requirement for public participation

EIA law item 5 regulates that: "The government encourages that all related units, organizations, experts and the public participate in an appropriate way." Item 11 regulates that: "For planning that has potential adverse impacts on the environment and the breach of the public interest, the implementing department of the specific plan should hold a conference, public hearing or other form of meeting to collect views and opinions on the draft of the EIA report before the draft is sent for authorization or approval. The department must seriously consider the opinions of the related units, experts or the public, and must incorporate the acceptance or the rejection of the opinions within the EIA report before it is sent for inspection." It is the first time that this law specifies public participation as a necessary and feasible mechanism in China.

(3) EIA for plans and programmes

The EIA law item 7 regulates that: "The related departments of the State Council and the municipal government that consists of districts or related departments should conduct an EIA during a land-use plan, regional construction, sea area construction, exploitation plan under its lead. The environmental impact part or narration in the plan should have an analysis, a prediction and an assessment of the potential impact on the environment after the plan is implemented. This should be an essential part of the whole plan to be sent to the superior authorization unit". This item introduces elements of SEA, as mentioned above.

(4) Personnel in charge of projects that violate the EIA law can be prosecuted

The EIA law adds to existing regulations that the chief executive or other responsible personnel of a project that have direct responsibility of EIA law violations can be prosecuted. This strengthens the enforcement of the law.

(5) The EIA law regulates monitoring and ex-post evaluation of impacts

The EIA law item 27 regulates that: "If a project does not accord with the approved EIA document in the construction and in the operation of the project, the construction unit should arrange a post-assessment of the EIA to take measures for improvement".

Regulations, rules and documents for implementation of EIA

Some specific regulations and administrative procedures that would make the implementation of the EIA law effective have not yet been developed. Examples include the regulations of the administrative procedures, the specific procedures and measures regarding the involvement of other governmental departments, relation among the EIA institutions, the acceptance of the project and the license, etc.

The number of executive documents and technical guidelines is relatively large (see table 2.1).

Institutions and their responsibilities

(1) Government agency

There is an EIA division in SEPA, which chiefly is in charge of the EIA process. Its duties are to establish the policy and the criteria of implementing the EIA, supervise the certification of the EIA, inspect the implementation of the EIA policy operated by the local environmental protection bureaus, and examine and approve the EIA of important construction projects.

SEPA authorises the EIA document of the following environmental projects:

- Special construction projects such as a nuclear facility or top-secret project;
- Projects in the trans-provincial region, autonomous region or the district of the municipality under direct jurisdiction of the central government;
- Construction projects approved by the state council or by related departments authorised by the state council.

The principle is: transfer the approval jurisdiction to the lower level if the environmental impact is not significant, withdraw the approval jurisdiction to SEPA if the environmental impact is significant. Following this rule, the number of projects examined by the SEPA is reduced by 15 to 20%, to about 150 each year.

Usually there is an EIA department in the provincial or autonomous regional EPA whose function consists of inspecting the implementation of the environmental policy established by the municipal EPA and examining and approving the EIA of relatively large construction projects.

The municipal EPA is the main body of the implementation of the EIA process. Usually there is an EIA department in the municipal EPA, which mainly presides over the management of the construction project. Most EIA examinations and approval work of the construction project is done by the municipal EPA. The function of the county EPA is similar with the municipal EPA and in some areas; the construction project is directly managed by the municipal EPA in cooperation with the county EPA.

(2) Affiliated agency and its business

The main duty of the environmental engineering assessment centre of SEPA is to take on the technological inspection of the SEPA EIA, to engage in the qualification of the EIA entity and personnel qualifications and to take on the technology training of EIA nationwide, and to do the research work on the EIA-related technology and consultancy. The expenses of the technology inspection are paid by the EIA corporations.

(3) EIA corporations

The EIA corporations are classified into 2 levels: level A and level B. Relatively large construction projects are assessed by the corporations of level A, which is mainly constituted by the engineering and technology research body of the state, while EIA level B is mainly focused on the city level, usually the municipal research institute.

2.4 EIA management and process

Overall EIA process and content of EIR

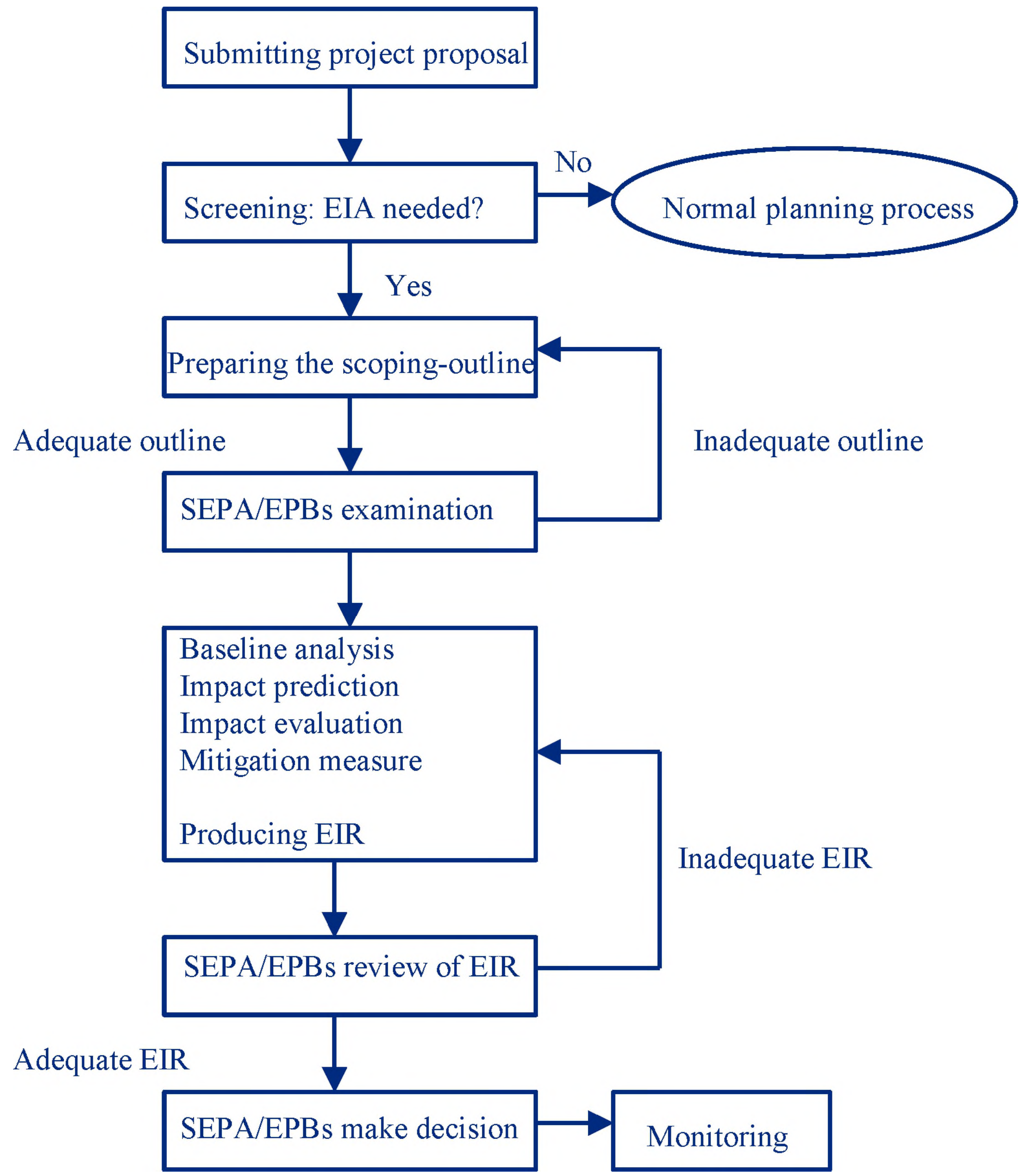
The EPL requires that construction projects causing pollution to the environment must observe the state provisions concerning environmental protection for such construction projects. The environmental impact report on a construction project should assess the pollution the project is likely to produce and its impacts on the environment and stipulate preventive and curative measures.

Not all construction projects require a detailed environmental impact report. Three categories of projects are now recognised:

- *Category A*: projects which are likely to cause a range of significant adverse environmental impacts need to produce an Environmental Impact Report (EIR)
- *Category B*: projects which are likely to cause a limited number of significant adverse environmental impacts need to fill in an Environmental Impact Form (EIF).
- *Category C*: projects not expected to cause significant adverse environmental impacts do not require EIA, but should fill in an Environmental Impact Registration Form (EIRF).

The formal EIA process is shown below.

Figure 2.1 Formal EIA process.



Source: Wang et. al. (2003)

The various steps in the EIA process could be described the following way:

1. *Screening*. After a developer submits the project proposal, the EPBs must decide whether an EIR, and EIF or an EIRF is required. SEPA has issued a list of projects in each of the three categories A, B or C. Thresholds relating to project features, size, output and environmental parameters are used to classify projects into categories. These again are focussing on two main areas: 1) pollutant discharge, relating to emission volume, types and complexity of pollutants and the possibilities of abatement; and 2) sensitive areas, based on the importance of ecological, archaeological and cultural values, and numbers and sensitivity of the humans affected. The guidelines help EPBs make screening decisions quickly and easily, often in less than a day.

2. *Scoping*. If an EIR is required, the developer must request a licensed agency to prepare an EIA action-outline. A five-step scoping process should be followed: 1) the initial analysis of the project, 2) investigation of

environmental baselines, 3) identification of significant impacts, 4) establishment of the action-classes for each individual impact and 5) preparation of an EIA action outline.

3. *Baseline analysis*. The purpose of environmental baseline investigation is to provide a clear picture of the current state of the affected environment, in both physical and socio-economic terms. Environmental information held by local environmental monitoring stations, typically air and water quality data, must be provided to the impact assessment team if requested, but there is a charge for the data.

4. *Impact prediction*. This part should predict possible changes in key indicators for those environmental components identified in the action-outline, as a consequence of the proposed project. The analysis should identify potential impacts during the construction, operational and decommissioning phases of the project. The guidelines for these investigations promote the use of simple, commonly used methods, including comparative investigation and professional judgement where appropriate. However, in practice impact prediction is often a highly technical procedure involving extensive use of mathematical and physical models according to Glasson et. al. (1999). Furthermore, the standardised practises may lead to an inflexible approach in which methods are used inappropriately in a given situation (Wang et. al., 2003).

5. *Evaluation of significance*. There is no explicit reference in the system to the need to evaluate the significance of the impacts. In practice pollution is the main criterion for evaluating significance. The dominant approach is to compare the likely impacts with legislative and regulatory requirements, established environmental standards or pollution abatement requirements. If there is no relevant legislation or regulation against which to compare likely impacts, expert opinion is used. Cost benefit analysis is required to evaluate the monetary value of environmental protection measures and economic benefits. However, according to Wang et. al. (2003), because there is no guidance on how to use this tool, assessors often simply estimate how much will have to be spent on abatement facilities as a way of valuing negative impacts, and how much profit and tax will be generated by the project as an estimate of benefits.

6. *Mitigation*. Mitigation measures for each likely adverse environmental impact should be considered during scoping and designed into the action outline. The consideration of appropriate mitigation measures should be further developed in the EIR. During the project construction and operational phases, the EPBs monitor the implementation of the mitigation measures described in the EIR. If the measures are not implemented effectively, the project can be suspended and the developer can be fined up to RMB 100,000.

    - *Impact documentation/communication*. The licensed impact assessment agencies are required to produce an EIR summarising the findings of the analysis on which EPBs or SEPA can base their decision-making. The content of the EIR, EIF and EIRF should includes the following:
    - Description of the proposed project

- Baseline environmental conditions
- Prediction and evaluation of environmental impacts
- Economic and technical analysis of mitigation measures
- Cost benefit analysis of environmental impacts
- Proposal for monitoring
- Conclusions of the EIA

When producing the EIR in practice, many assessment agencies follow the requirements strictly, with little outside consultation or adjustments to the actual project. (SEPA, 1998).

7. *Review of EIR*. The EIR is reviewed by the EPB, in consultation with other relevant authorities involved with the construction project. For example, for an irrigation project, the relevant authority is the local department of water resources. Normally, an authority will conduct an initial examination of an EIR and provide review comments to the EPB within one month, at which point the EPB undertakes its own review. The EPBs consults with experts from different research backgrounds, usually through workshops, to seek their comments.

8. *Decision-making*. SEPA and EPBs use the review process to make a decision on whether or not permission should be granted for a project to proceed from an environmental point of view. This is a separate decision-making procedure from any permissions given by the planning and land management authorities, and there is no appeal against the decision. If the conclusion of the review is negative about either the EIA-process or the quality of the final statement in the report, the report will be rejected and the proponent invited to resubmit an improved impact statement. Otherwise, and assuming the EIA supports the project, approval will usually be given to a project.

9. *Monitoring*. Monitoring is a compulsory part of the process and is to be undertaken during both project construction and operation. The outcome from monitoring during the construction phase can influence the EPBs decision whether to allow the project operations to commence. The EPBs and project developers share the responsibilities for monitoring. In most cases developers undertake routine monitoring of pollution sources and normally concentrate on the four priority issues, air and water pollution, waste and noise. Generally, EIA monitoring is dominated by compliance monitoring and there is a lack of broader impact monitoring particularly as the EIA system is weak on the assessment of ecosystem and landscape impacts (Wang et. al., 2003).

Targets and classification of the EIA system

The EIA law regulates the EIA as follows:

"Item 7: The related departments of the State Council and the municipal government that consists of districts or related departments should conduct an EIA of any land-use plan, regional construction, sea area construction, or exploitation plan under its lead. Compile the related chapter or narration of the EIA."

"Item 8 The related departments of the State Council and the municipal government that consists of districts or related departments should conduct an EIA and hand over a report on the EIA to the department which is specifically in charge of the approval of the certain project when they make the special plan of the industry, agriculture, grazing, forestry, energy, water conservancy, transportation, urban construction, tourism and the exploitation of natural resources."

The EIA of the construction projects is managed through a detailed classification system. This system is given in an annex to this report.

Certification management

The EIA technology-support institution for the construction project must be qualified by the environmental protection direct department of the state council, and must have a license after being qualified, and must engage in the EIA service strictly according to the ranking and scope defined by the license certificate.

The license has two levels: level I and level II, the operation range is divided according to industry and environmental elements, or according to the specialty and the working capability of the licensed unit. The period of validity of the license is 5 years.

Item 4 of the law says that the unit with level I certification can take on EIA work of construction projects that are to be examined and approved by the governmental environmental protection departments of all levels, and make the EIA report or EIA report table.

The unit with level II certification can take on EIA work of construction projects that are to be examined and approved by the local governmental environmental protection departments of all levels, and make the EIA report or EIA report table.

SEPA awards the EIA certifications of level I and level II.

Supervision and approval

Below are the elements of the law of relevance to supervision and approval.

"Item 13, the municipal government should designate an environmental protection execution department or other departments to convene an inspection group consisted of representatives and experts to examine the EIA report before the municipal government examine and approve the draft and make the decision. The inspection group should give their opinion in written form. The experts within the inspection group should be decided randomly from the list set by the environmental protection executive department of the state council. The examination procedure of the EIA report of special plans that are to be examined by the government superior to province level is set jointly by the environmental protection department and the other related departments of the state council."

"Item 14, when the municipal government or the related department of the government superior to province level examines the draft of the special plan, the decision should be based on the conclusions of the EIA report and the conclusions of the examination. If the conclusions of the EIA report and the conclusions of the examination are not accepted, an explanation should be made and be documented for further inspection."

"Item 15, when plans that have significant impacts on the environment are implemented, the drafting-out unit of the EIA should arrange the pursuant assessment of the environment impact, and give the result of the assessment to the examination unit. If any negative impact is found, specific measure for improvement should be given."

A table of categories and sub-categories of projects are given in an annex to this report.

Procedures of EIA management

"Management Procedure for Construction Projects Environmental Protection" released by SEPA in June, 1990 regulates the environmental management procedures for the 5 main stages in project construction:

- Stage 1: Project Proposal Stage, during which environmental protection departments do on-spot inspection and make comments;
- Stage 2: Feasibility study period, during which the construction enterprises authorize EIA institutions to do EIA, and submit the report to the environmental protection departments for approval;
- Stage 3: Initial designing period, during which the initial design shall be examined and approved by the environmental protection departments;
- Stage 4: Construction stage, where the construction enterprises shall report the construction progress regularly to the environmental protection departments;
- Stage 5: Trial operation and construction checking period, during which the construction enterprises shall submit trial operation appliance reports to environmental protection departments and submit project checking appliance after the monitoring by environmental monitoring institutions. The projects can only be put into operation after being examined and checked by the environmental protection departments.

Audit and post-evaluation

EIA law item 15, 19, 27, 28, 29, 33: supplemented the related contents on the pursuant examination and the post-assessment. It made clear that in the pursuant examination, if any problem is found, the amendment measures should be implemented. For any inaccuracy, falsehood or the delinquency, malpractice, the approval department will be legally prosecuted.

Item 15: after the implementation of the plan that has significant impact on the environment, the compilation department should arrange the pursuant EIA in time. And report the result to the approval department. If any negative effect is found, measures for improvement should be raised.

Item 28: the executive department of environmental protection should have the pursuant EIA of the construction projects that is put into production or use. If the negative effect on the environment or the destroy of ecology is found, an investigation should be made, and the responsibility should be clarified. If any falsehood of the EIA document from the technological support unit is found, the unit should be prosecuted according to item 33 of this law. If any delinquency or malpractice of the staff that led to the approve of the unqualified construction project of the approval department is found , the related personnel should be prosecuted according to item 35 of this law.

The EIA law made regulations on the pursuant EIA and the post-assessment of the EIA. But the law is enacted in September, 2003. The statistical documents of this year are not published yet, so, we can't get to know the real aftermath of the implementation of the pursuant EIA and the post-assessment.

2.5 Responsibilities and framework – A complex EIA process

Jurisdiction for approving an EIR is split between SEPA and EPBs in the following way (as also touched upon above):

SEPA approves the EIRs for four types of construction projects:

1. Projects involving nuclear facilities or high confidentiality
2. Projects that involve more than one province, autonomous region or municipality (cross-boundary projects)
3. Projects approved by the State Council or by departments authorised by the State Council, i.e. currently the projects with a value of more than RMB 20 million.
4. Projects which are likely to produce cross-boundary environmental impacts and the relevant EPBs cannot agree on the EIR.

Apart from these cases, EPBs at provincial, autonomous region and municipal levels coordinate and share approval authority with county EPBs according to the size of investment and nature of the project. For example, projects constructed within natural conservation areas can only be approved by municipal EPBs.

As can be seen from this chapter and the few excerpts from the law, the current framework for EIA is very complex. The EPL sets out basic requirements for impact assessment, but this is then elaborated in more than a dozen specific sector laws, and numerous regulations and ordinances (as listed in a previous table). This is matched by a complex environmental protection bureaucracy, with a hierarchy of environmental protection administration down to village level, together with the environmental protection units in the various sector ministries, the licensed EIA agencies and the environmental monitoring units. The lines of responsibility and accountability are often confusing.

Moreover, China's varying geography and regional imbalances in economic development and level of education mean that central government has to allow local government a certain level of discretion to interpret national legislation and regulations to suit local situations and meet local needs. As a result, across the country there are many local decrees, defining local ways of operating the environmental protection mechanisms.

The considerations of alternatives to a specific project are in general absent from the Chinese EIA system as it is practiced. There are usually no assessments of effects of variations in location, scale of the project, processes and technology, site layout, operating criteria and mitigation measures (Wang et. al., 2003). Also there is no consideration of not going ahead with the action or project. Furthermore, social and ecological impacts, as well as indirect and cumulative impacts are not generally given the same attention as other direct impacts.

Effective public involvement is largely missing from the current EIA system. (Wang et. al., 2003), despite the provisions in the law mentioned above. Questionnaires are sometimes used to get feedback from local people about a project, but there is no further legal provision for public participation in the EIA procedure.

3 Principles and methods for economic evaluation

As explained in chapter 1, economic evaluation of environmental impacts (EEEI) can be very useful in EIAs and more broadly. But what is the basis for economic evaluation and the methodologies we propose in this report? This chapter first briefly explains what economic evaluation is, and introduces some key concepts and principles. As mentioned in chapter 1, we only look at the environmental and health impacts of projects. A more detailed discussion of cost benefit analysis and environmental evaluation can be found in standard environmental economics textbooks. In 3.2 we discuss physical and economic steps of an economic evaluation. Subsection 3.3 presents general valuation methodologies we will use in later chapters, and 3.4 discuss some special issues in deriving economic values.

3.1 What is environmental valuation?

Total economic value of the environment

Clean air and rivers, forests, wetlands and other so-called environmental goods provide a stream of benefits to people over time, either in the form of direct use of fish, drinking water, recreation etc, or because people care about the environment even if they don't use it directly. These two categories are sometimes called *use-* and *non-use (or passive) values*, or taken together *Total Economic Value*.

Of use values, we often distinguish between actual use and option value. The latter is the value of preserving the option of using the environmental good in the future. This value can be important for irreversible impacts (e.g. cutting down a species rich forest). Non-use values include the values people may attach to the environment because they want their children or fellow citizens to be able to enjoy unspoilt nature, or because the care about the existence of environmental goods.

For example, using the air over a city as a receptor for industrial emissions entails environmental costs in the form of increased frequency of respiratory diseases etc. Clean air for people to breath has a high use value, and polluting the air therefore entails an important cost to society. Likewise, building a road through a sensitive ecosystem or draining a wetland area may mean foregoing ecological benefits (often both use and non-use values) that such natural systems can provide to the local villages, or to the country at large.

Since most of the environmental goods, such as clean air and water and unspoilt forests, have no price that reflects how popular or scarce they are, as for other goods bought and sold in markets, they tend to be overused and degraded. This can be seen all over the world for a wide range of environmental goods.

The main concern of environmental economics is to try to determine the true value of the environmental costs and benefits from environmental goods, and to design public mechanisms that make consumers, producers and the government take the values into account in their decisions. In that way the production and use of both man-made goods and the environmental goods can be made more efficient, i.e. better for society as a whole. In this report, the mechanism is to incorporate the value of the environmental impacts of public construction projects into EIAs to better inform decision-makers and project developers.

Environmental costs = Willingness to Pay to avoid impacts

In this report we focus on how to measure the *environmental* costs (and benefits) of a proposed construction project. In most cases, the economic value of such impacts is negative, but some projects we can call environmental improvement projects will also have positive impacts. The one and the same project may also have some positive and some negative impacts for different people affected by the project.

The economic value of all man-made and environmental goods is based on peoples' preferences. More precisely, the value of negative environmental impacts can be represented by two measures:

- Willingness to pay (WTP) to avoid that certain negative impacts from a project materialise, or
- Willingness to accept (WTA) compensation for the negative environmental impacts[7]

These measures do not necessarily yield the same estimates in practice, and the most commonly used measure is WTP. The sum of all affected people's WTP values for example to avoid emissions of sulphur from a proposed factory is the environmental cost. Similarly, the environmental cost for a project that has ecosystem impacts and reduces biodiversity, is the WTP sum by all people who may want to avoid this impact happening. In practice, it is common to limit the WTP summation to national residents of the country where the valuation is carried out. If a project has impacts in other countries (such as global warming and acid rain), or impacts that are valued by other countries (for example biodiversity loss), the scope may be expanded (see Bateman et al 2002). If the project has *positive* environmental impacts, the correct measure would be peoples' WTP for the improvements.

The goal of economic evaluation of environmental impacts is to find the WTP figure for different impacts of a proposed project. In other words, the purpose is to

[7] More on this in the section on methods.

uncover the WTP to avoid loss of environmental use and non-use values from a project[8].

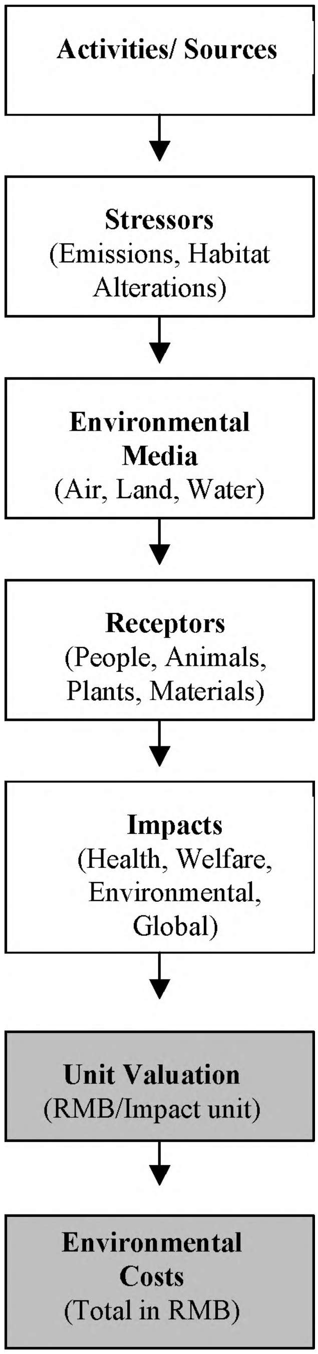
In many cases the true WTP figure is difficult or costly to estimate, so a whole range of methods has been developed to approximate the true WTP figure. Section 3.3 provides an overview of some of these methods, while the separate chapters on air, water and land will discuss more specifically types of method or approach to value the particular impact in question. But before going into the methodologies we present the key steps in economic evaluation.

3.2 Steps in economic evaluation

The figure below illustrates the traditional EIA steps of identifying and predicting environmental impacts of a project in physical terms (marked in white), and economic terms (marked in grey).

[8] In practice it is neither possible nor desirable to break down the value components into the subcategories under use and non-use values. Since non-use values often are substantially higher than use values, and more controversial, it is sometimes recommended to estimate and report them separately.

Figure 3.1 The steps of identifying and predicting environmental impacts in physical (white) and economic terms (grey)



Source: Adapted from ADB (1996)

Project activities (or sources) in the figure refer to the development project in any sector, which may have significant positive or negative environmental impacts and therefore is subject to an EIA. These projects can take place in any sector, and the impacts they generate can occur during the construction and/or operation phase of the project.

Stressors is a term used to denote the chemical and/or biological changes in the environment, e.g. emissions or habitat alterations associated with the project activities. A development project can have either negative or positive effects on stressor levels. For instance, a power plant may increase physical stressors by reducing the amount of natural habitat, but at the same time replacing an older facility reducing chemical stressor levels (lower emissions than the old plant).

The concept of *mitigation*, which refers to avoiding or minimizing increases in environmental stressor levels, is relevant for both the activity and stressor levels of project design – for instance choice of fuel type for a power plant (activity) or fitting of abatement technology, given a choice of fuel (stressor).

The stressors affect *receptors* (people, animals, plants, materials, and ecosystems) by going through *environmental media* (i.e. air, land, and water). When for example emissions from a stack travel through the air they are transported (dispersed) and/or chemically transformed before being deposited a considerable distance downwind.

The exposure of the receptors in time and space by different types of stressors determine the *environmental impacts*. These impacts refer to the good or bad chemical and biophysical consequences expected in a receptor after a change in exposure to stressors. Changes in impacts are typically quantified through dose or exposure-response relationships (both terms are sometimes used). The dose is the exposure to a stressor (e.g. particle emission), while the response is the physical impact (e.g. increased risk of respiratory decease).

The impacts can be categorized in terms of human health or welfare, environmental resources, or global systems, as depicted in the table below:

Table 3.1 Impact categories for stressors to air, water and land including examples (bullet points)

Human health	**Human welfare**	**Environmental Resources**	**Global systems**
Mortality: • Increased risk of death	*Materials:* • Damage to buildings, bicycles etc	*Coastal & Marine ecosystems:* • Thermal alteration • Mangrove reduction • Fishery loss	*Direct:* • Global warming • Acid rain • Ozone depletion
Morbidity: • Increased risk of diseases such as cancer, respiratory diseases etc	*Aesthetics:* • Reduced visibility • Traffic congestion • Landscape changes • Noise/odour	*Ground water:* • Lower water table	• Change in weather patterns • Wide range hazardous chemicals • Radiation from nuclear accidents
	Resource use: • Reduced fishery, forestry & crop yields • Reduced wildlife & recreation	*Freshwater ecosystems:* • Reduced biological productivity in wetlands, watersheds, rivers/lakes •	*Indirect:* • Desertification • Biodiversity loss
	Social/cultural: • Impacts on cultural/religi ous lands • Relocation of people	*Biodiversity/Endan-gered species:* • Loss of diversity of flora and fauna	
		Terrestrial ecosystems: • Reduced flora and fauna • Soil nutrient loss • Mineral loss	

Source: Based on ADB (1996)

A slightly different version of this table will be used for the identification of stressors and potential impacts in the case study projects (see Chapters 5-7, Part II of the report).

Economic evaluation builds on the physical impacts predicted by the EIA report and assigns economic values to these impacts. This is illustrated as the last two steps in figure 3.1. First the economic value (or price) for the different impacts per physical unit (for example RMB/case of respiratory illness) is estimated. Then the prices are multiplied with the extent of the physical impacts (for example number of illness cases). This is done to the extent possible for all impact categories to obtain the total sum of *environmental costs* measured in RMB.

In some cases, it may be possible to assign rough damage values per stressor, for example X RMB per tonne SO_2 emitted. In theory this is only correct when the stressor has the same impact regardless of location (such as for greenhouse gases), but as an approximation some stressors may have similar impact values depending on the size of the city where a pollutant is emitted, the height of the stack etc. This is the approach followed in the European research project ExternE (see chapter 4 for a discussion).

Not all projects and impacts should undergo a full economic evaluation. As suggested later in this report category A projects have significant environmental impacts and could be made subject to economic analysis of impacts[9]. For category A projects, the analyst will need to assess and screen which impacts are significant and also suitable for economic evaluation judged on the basis of scientific uncertainty, data availability etc. Such an assessment should include the following steps:

1a) Is the physical impact relatively small? If yes, drop the impact from quantitative assessment.

1b) Is the impact too uncertain from a scientific point of view? If yes, drop the impact from quantitative assessment.

2 If the answer is no to 1a &b; is there sufficient data/information easily available to assess the impacts in physical and economic terms? If yes, continue with a comprehensive EEEI of the impact.

3 If the answer to question 2 is no, consider the potential significance of the impact and the resources available for the assessment, and decide whether additional data collection and analysis should be carried out (e.g. CVM analysis).

If there are resources available and the impact is potentially large, additional local data collection/survey should be carried out and a comprehensive EEEI completed. The extra data could include both physical and economic data (for example costs of illness). If there are no resources available for more data collection, a simplified EEEI based on the existing impact information/data should be conducted. In the latter case, the analyst could choose a DR/ER function from the list of functions for air and water presented in the annex to this report, and draw on benefit transfer estimates from other parts of China or abroad.

The results of the screening and why some impacts were analysed and others left out, should be clearly documented in the EEEI.

We have made suggestions for key elements of a SEPA Guideline in Chapter 9 of this report, which pull together some of the issues discussed in this section.

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[9] Also plans and programmes may be well suited for economic evaluation.

3.3 Methods

3.3.1 Overview of methods

The amounts that people are willing to pay for goods, including environmental and health benefits, can be estimated in three main ways:

- by observing the prices that people pay for goods in various markets;
- by observing individual or household expenditures of money and time to obtain goods, or to avoid their loss, and inferring WTP amounts; and
- by asking people about their WTP for goods.

The former two are so-called market methods, while the latter is based on people's WTP in a *hypothetical* market situation. The market methods are either based on observations of people's behaviour (so-called revealed preferences), or estimate WTP indirectly through dose response functions or damage and resource costs (see table below). The hypothetical methods, such as contingent valuation, infer WTP directly through making people state their preferences. The choice of benefit valuation method depends on various factors, especially the availability of adequate data. The discussion of methods is mainly based on ADB (1996), ADB (1999), ECON (2000), ECON (2001) and World Bank (2000).

Table 3.2 Commonly used methods for economic evaluation

Market methods		**Hypothetical markets**
Revealed Preference	Dose-Response Damage & Resource costs	Stated Preferences
Hedonic pricing & Wage-risk Travel cost	Defensive and averting expenditures Cost of illness Property damage Vegetation damage	Contingent valuation e.g. of mortality risks Contingent ranking
Benefit transfer		

While both types of methods are suitable for identifying use-values, the hypothetical market method is the only one suitable for estimating non-use values.

Instead of estimating WTP based on primary research using market or hypothetical market methods, information about environmental benefits and costs can be transferred from another primary study (or set of studies) to the study site. This procedure is called *benefit transfer*, and indicated as an alternative in the table above. Benefit transfer is much used internationally, though the accuracy of this approach sometimes is questionable.

The remainder of section 3.3 first provides brief explanations of the methods mentioned in the table above, and then discusses more thoroughly how to value morbidity and mortality impacts which, often are a substantial part of the total environmental costs of a construction project.

3.3.2 Examples of evaluation methods

The costs of the various damages caused by pollutants can many times be observed directly in the market or derived from observable prices or costs. The table below presents some examples of how this could be done for some damages.

Table 3.3 Some examples of damages from pollution and how they could be priced.

Receptors	End point damages	Price (remark)
Materials (air)	Shorter length of life, various materials	Prices of purchasing and installing replacement material
Plants and animals (air, water, land)	Reduced agricultural output and quality	Prices of crops, price of husbandry, price of other outputs
	Reduced output from forestry/ forests	Price of timber etc.
	Other vegetation, parks etc.	Price/cost of replacement
	Reduced fish catches and fish quality	Prices of fish
Manufacturing industry	Reduced manufacturing industry output	Prices of manufacturing industry output

Defensive and averting expenditures

Environmental preferences can also be deduced from *defensive expenditures*. Averting expenditures are expenditures designed to prevent or mitigate environmental degradation *before* it occurs. Corrective expenditures abate or reduce the impacts of pollution *after* it occurs. They may include the replacement or restoration of damaged assets. Actual defensive expenditures reveal the minimum amounts that producers and households are willing to pay to prevent environmental degradation.

If emissions are taxed, the tax level could indicate how the authorities value the marginal reduction of the pollutant, and hence the tax level could be used as a price. However, it should be considered in each case whether the levy actually represents the value that society puts on the damages from the emissions, or if the size of the levy is decided for other purposes. A benchmark of typical abatement or mitigation costs for power plants or other industries can be used as an indication of the value of environmental costs from a specific construction project within the same sector[10].

[10] The abatement costs should generally be used with caution as an indication of WTP, as it contains elements of circularity. The purpose of environmental impact valuation is often to determine the optimal level of pollution control from a situation where the existing level is too low (which is particularly the case in developing countries). Using current mitigation costs to represent the value of (avoided) environmental impacts could therefore reinforce existing, sub-optimal control levels.

Hedonic pricing

Many assets are made up of several attributes. For example, houses have numerous attributes such as view, distance to shops and public transport, environmental quality etc. Among other things, they provide access to environmental services, because people can choose between living in polluted and less polluted areas. It turns out that these attributes usually have *implicit* prices that make up the total price. The method for estimating implicit prices is known as hedonic price analysis and implicit prices are sometimes called hedonic prices. These implicit prices provide much evidence on willingness to pay values for environmental quality.

Job occupations also have many attributes, including various degrees of amenity and risk. When people choose between safe and risky jobs, there is usually an implicit price for safety (a lower wage). Hedonic wage-risk studies are an important source of value of statistical life estimates (see section 3.3.3).

Although product, property and labour markets provide useful WTP data, they cannot provide data for non-marketed public goods, some externalities, or existence values. Other sources are needed in these cases.

Travel cost method

Households reveal their WTP for environmental quality when they travel to obtain access to environmental resources or when they pay to avert or correct environmental degradation. The *travel cost method* of valuation is based on the common observation that the use of environmental services varies inversely with the costs of access to them. In effect, travel costs act as implicit prices for access to non-priced services. From variations in travel costs and use, we can deduce what individuals would be willing to pay for the services.

Stated preference methods

This approach to estimating demand for environmental services draws on responses to surveys. Using the *contingent valuation* method, respondents are asked, among other questions, what they would be willing to pay for an environmental attribute such as cleaner water, unspoiled wilderness area, or reduced risk of respiratory disease or death from air pollution etc. This provides a direct way to elicit user values. Contingent valuation studies are used in China when assessing impacts of several projects.

Using *contingent ranking* respondents are asked to rank a series of choices involving hypothetical money transactions and various goods. WTP values are deduced from the ranking responses. Stated preference surveys are the main method for determining WTA (compensation) values and the only method for determining non-use or existence values.

However, the stated preference approach is based on asking hypothetical questions. This means that stated responses are not backed up by real economic commitments. In an attempt to make surveys more realistic, some studies in the United States have constructed markets in which payments actually take place. The technical literature commonly treats such constructed markets as an extension to the concept of contingent markets. However, constructed markets may be considered closer in spirit to the revealed preference approach than to the stated preference approach.

Valuation should mostly try to use market methods

The valuation approaches described above are mostly market methods, based on observed prices and costs in various markets. The only exception is the approach where people are asked how they evaluate various damages or improvements in environmental quality. Such surveys may have some weaknesses compared to observations of real behaviour in markets. Besides, the surveys are costly and time consuming to carry out. Therefore, this approach should only be used when observations of real preferences are not available or are inadequate, or if the project is large and is likely to have substantial non-use values. However, it should be kept in mind that the accuracy of the market methods also depends on the quality of price and quantity data that they use to derive environmental unit prices. If the data are poor, the result will inevitably also be poor.

3.3.3 Mortality impacts

Mortality often constitutes a significant share of overall environmental costs. We therefore take a closer look at the estimation of value of statistical life below.

Revealing risk reduction through observed prices

Pollution to air, water and soil carry a risk of excess death. Other things equal, all of us would like the risk of excess death to be as small as possible. But we would also like other goods and services that society can produce. In reality we have to limit our spending on reducing the risk of death in order to afford other goods and services. If risk reduction is expensive we might decide against investing in it. In general, the price of a good indicates what people are willing to give up at the margin in terms of other goods and services to buy a unit of that particular good. Similarly, the price of risk reduction indicates what people are willing to give up at the margin in terms of other goods and services in order to buy a unit of risk reduction.

Thus, in principle there is no difference between purchasing risk reduction and purchasing other goods and services. However, the price of risk reduction is more difficult to measure than the prices of most other goods and services.

The price of risk reduction shows up in labour market decisions. In many poor countries, for example, some people take comparatively well paid but dangerous jobs in mining, construction or industry instead of comparatively more safe, but less well paid work in agriculture. Had the wages been the same, people would have stayed with the safe jobs. The excess payment to the dangerous jobs therefore includes a compensation for excess risk. Those that stay in the safe jobs indirectly pay this compensation in order to decrease their risk, just as some people pay for risk-reducing equipment. A problem with this approach is that people usually do not have a good impression of how large the excess risk is.

Valuation of a statistical life (VOSL)

In the evaluation literature different approaches can be found for estimating the cost of mortality risk, among them the WTP approach, the market approach, and the human capital approach. The latter considers only the productivity side and estimates the risk from the present value of net foregone earnings (given death), which provides a relatively low estimate. This approach has been common in China, but is not much in use internationally.

The market approach estimates the price of reducing the death risk through market mechanisms, e.g. by observing the prices of insurance, deriving the risk premium in pay to some occupations, what authorities and others spend to reduce different risks of fatality etc. These are sometimes called wage-risk studies, as indicated in table 3.2.

It is important to be aware that the price of reducing the risk of death (VOSL) is associated with small changes in statistical risk. It has very little to do with sure life or death. For instance, it does not intend to measure the compensation that would be required by or should be paid to an average person who dies in a road accident or a plane crash. Nor does it imply how much a fatally ill person would agree to pay for a miracle of recovery, given such a choice.

The price of risk reduction depends on the income level of a country. In our view, a lower price on risk reduction is a reasonable consequence of the fact that a developing country is less rich than a developed country. A developing country has by definition less money to spend on everything, including risk reduction. It would be surprising if it were willing to spend the same on risk reduction as a developed country, and a whole lot less on other things. That does not mean that people in developing countries are less important than people in developed countries. People in developing countries buy fewer cars and smaller apartments as well, without that making them less important. If they move to a rich country, they are able to purchase more risk reducing equipment and more cars, without that making them more important.

International VOSL estimates

Some VOSL estimates from studies in China and developing countries are presented below.

Table 3.4 Value of statistical life estimates, developing and medium income countries and regions (USD)

Study reference, country	Region/City	USD Value	Type of study
Zhang (2002?), China	Beijing	(30 000, 200 000)	CV, air pollution
Wang Hong et al. (2001), China	Chongqing	(36 000, 150 000)	CV, air pollution
Liu et al. (1999), China	Taiwan	(413 000, 461 000)	
Shanmugam (2000), India		400 000	Hedonic, job fatality
Simon et al. (1999), India		(153 000, 358 000)	Hedonic, fatality risk
Kim (1999), South Korea		(530 000)	Hedonic, fatality risk
Fu, Liu and Hammit (1999), China	Taiwan	(600 000, 1 300 000)	CV, cancer risks, pesticide in food
Hammit and Liu (2004), China	Taiwan	(500 000, 2 200 000)	CV, air/water diseases
Hammitt and Ibarraran (2002), Mexico	Mexico City	(150 000, 500 000)	Hedonic, air pollution
Liu and Hammit (1999), China	Taiwan	(600 000, 1 200 000)	Hedonic, job fatality
Liu and Hammit (2003), China	Taiwan	(3 000 000, 12 000 000)	CV, SARS risk
Madheswaran et al (2003), India		(100 000, 400 000)	Hedonic, job fatality
Ortiz et al. (2004), Brazil	Sao Paolo	(1 100 000, 1 900 000)	CV, air pollution
*Sobian, A. (2001), Malaysia	Kuala Lumpur	(300 000, 700 000)	CV, air pollution
Shanmugam (2000), India		(1 000 000, 1 400 000)	Hedonic, job fatality
Shanmugam (2001), India		4 100 000	Hedonic, job fatality
Siebert and Wei (1998), China	Hong Kong	1 700 000	Hedonic, job fatality

Key: * Unpublished Master Thesis. CV= Contingent Valuation

Most of the VOSL studies in developed countries are from the US, though the EU has done some studies in recent years. For economic evaluation of policies USEPA has decided to use USD 6,2 million, while the EU uses an estimate of €1 million for VOSL. Other countries also use estimates in this range. The results in the table and the range of policy estimates show that the price of risk is very uncertain.

An ongoing project in China called the Environmental Cost Model (ECM) is currently working to finalise its economic evaluation of the environmental and health impacts of air and water pollution in the country[11]. A part of this work is a study of WTP for reduction in mortality risks in the cities of Shanghai and Chongqing. The idea is that the derived VOSL estimates can be used for the evaluation of mortality from air and water pollution on a province level in China.

Due to the large variation in VOSL estimates from primary studies it is difficult to recommend a specific VOSL estimate that should be used to evaluate mortality risks from construction projects in China. As a principle, the same VOSL estimate should be used to evaluate all projects in the same country. This is for ethical reasons.

[11] Expected to be finished during the summer of 2005.

Previous studies based on benefit transfer, e.g ECON (2000), have recommended that a reasonably conservative VOSL estimate for China could be between USD 95,000 and 125,000. The ECM work in China would be a reliable revision of this range when it is finished.

3.3.4 Morbidity impacts

Various emissions also affect human morbidity, and the valuation of illness and disability is important for assessing the full social costs of pollution. An internationally recognised method and the method we recommend to value morbidity costs is the cost-of-illness (COI) approach. The COI method estimates the change in explicit market costs resulting from a change in the incidence of a certain illness. COI simply measures ex post costs and does not attempt to measure utility loss due to e.g. pain and suffering, or defensive expenditures (i.e. costs of averting behaviours to avoid the illness). The COI is often considered a lower bound estimate of the true WTP[12].

Two types of costs measured in a typical COI study are direct costs (such as diagnosis, treatment, rehabilitation, and accommodation) and indirect costs (including loss of work time). A person's earnings (often approximated with GDP/capita) are often used to reflect the value of lost work days.

Since the amount of resources spent will vary between regions, local cost estimates should be used to the extent possible. If the construction project under scrutiny is large, the COI for the project should be estimated based on the collection of local data on treatment and costs.

If local health and economic data are not available or the construction project being assessed is small, COI estimates could be transferred from other parts of China. A range of international studies have been carried out to estimate COI for different diseases. It is not immediately appropriate to transfer these estimates to China as the costs of treatment may vary considerably between countries.

However, in recent years some studies of COI have been conducted in China, one of which is presented in the table below. The Environmental Cost Model project, mentioned in the previous section, is also in the process of estimating COI for important air and water pollution related diseases.

[12] This is not derived from theory, but in practice the COI-estimate usually tends to be low compared to the full WTP estimate.

Table 3.5 Cost of illness estimates from the Lianoning study (RMB per case), 2002

End points	Cost per case (RMB)	Methodology
Particles		
Acute respiratory hospital admissions	3399	Average of treatment costs for six respiratory diseases weighted with proportion of admissions
Acute asthma	133	Average cost per visit for two typical outpatient visits for examination (95x1), treatment (2x2) and drugs (83x2)
Acute upper respiratory inflammation	130	Methodology not specified in Zhaoyi et al (2004)
Acute lower respiratory inflammation	136	Valued as outpatient treatment for pneumonia (calculated in the same way as for acute asthma above)
Bronchitis (chronic/long-term effects)	1950	The cost of outpatient treatment (195) multiplied by the number of incidents per year (assumed to be equal to the lost working days of 10)
Emphysema (chronic/long-term effects)	2400	RMB 200 x 12. Methodology not specified in Zhaoyi et al (2004)
SO_2		
Acute respiratory hospital admissions	3399	Assumed same as for particles above
Acute asthma	133	Assumed same as for particles above
Work day loss	95	Based on working year of 260 days, and the production per worker in Fushan city (RMB 24790) from provincial statistical yearbook

Source: Zhaoyi et al (2004), Zhaoyi (2002), Holland (2004)

3.4 Issues in deriving economic values

This section explains some important cross cutting issues in deriving economic values for different environmental impacts, and related to the current Chinese EIA process. We recommend how to deal with each issue.

Project Boundaries

The most severe environmental impacts usually affect the immediate project area. In the EIA process this is defined as the area in the vicinity of the project. However, many types of stressors, especially emissions to air, can travel over long distances and inflict serious environmental impacts in other areas/regions, countries or indeed, globally. In principle economic evaluation should cover all environmental impacts caused by a particular project regardless of the location of the impacts. However, in practice it may be difficult to cover all impacts. We recommend that the economic evaluation as a minimum should adhere to the standard project boundary recommended in the general EIA guideline, unless there are important factors for a specific case to do otherwise. Such situations may be acid rain caused by SO_2 emissions from a plant, or water pollution far downstream from an emission source.

Time Horizon

A construction project has an economic or technical life span, which is used in the project economic analysis. These life spans may not be similar to the horizon for environmental impacts from the project. If possible, the time horizon for the economic valuation of environmental impacts should coincide with the economic and technical life span of the project. However, where the positive or negative impacts are expected to persist beyond the project's life span, the time horizon of the analysis should be extended accordingly (ADB 1999).

Defining the appropriate baseline

A critical aspect of any economic evaluation is the proper definition of the baseline, i.e. the scenario without the project. The environmental impact of a project is the difference between the environmental impacts over the project period compared to the likely scenario if the project was not carried out. The with- and without-project scenario is generally different from the before- and after-project scenario.

The without-project scenario is of course not known and an estimated most likely scenario will have to be chosen for the analysis. We recommend as a general rule to assume a baseline that is equal to the status quo situation without the project for the whole project period, unless there are strong arguments suggesting otherwise. This approach means that the economic evaluation assesses the *incremental* or extra impacts caused by the project as compared to today's situation.

In some cases, there may be good reasons for using a different baseline to assess impacts. If the project, for example a new an efficient coal plant, to some extent displaces other activities, for example an old and inefficient plant, the economic evaluation of the impacts should calculate the net contribution of pollutants to the environment.

Qualitative assessment procedures

Many impacts cannot be valued either because of lack of data, uncertainty etc. A qualitative assessment should at the minimum include a description of important impacts that cannot be quantified and/or monetized. These impacts should also be listed in the evaluation summary that includes the monetized benefits and costs. The direction of the impact using ++/-- could be telling. Ranking of impacts in order of importance is an alternative.

Who is affected by the environmental impacts, and who gets the benefits could also be described verbally, as could the issue of compensation for negative effects etc.

Use of discount rate

Environmental impacts of a project will happen during the construction and through the whole operating phase of the project. When comparing benefits and costs that accrue over different time periods, the cost and benefit elements must be discounted to present value. The way to do this is to use a discount factor, typically in the order of 1-10% per year. The difficulty is to choose a suitable discount rate. We recommend using the currently recommended discount rate for public investment projects in China. If a range of discount rates is in use for example depending on the level of risk, we generally recommend using the middle rate, unless the project has particularly high or low risk, in which case the high and the low rates should be used. For very large projects there may be reasons to assess the risk and the corresponding discount rate specifically.

Stressor and impact interactions

Environmental stressors through the different media interact since separate ecosystems are inherently interlinked and pieces of one big ecosystem. No impacts manifest themselves and can be assessed in complete isolation. EIA guidelines often state that such interactions, for example in the form of cumulative and indirect impacts or impact interactions[13], should be assessed. For some types of impacts, the interaction or overlap between impacts may be strong. The costs of air and water pollution for instance could be related, since both air and water pollution affect human health. It could be that a person that is weakened by air pollution is more susceptible to the dangers of water pollution. Similarly for damage on agricultural output, an agricultural plot that is weakened from being exposed to water pollution may be more susceptible to air pollution impacts. Through this mechanism, the impacts of air and water pollution could strengthen one another. However, if water pollution affects weak individuals (or crops, or forests) for instance, the effect of adding air pollution could be small. Through that mechanism the impacts could weaken one another. There are numerous ways through which different stressors can interact with each other, which can make the total impact more or less serious than the two stressors assessed in isolation. Whether joint stressors strengthens or weakens the partial impact of pollution therefore has to be determined empirically.

Unfortunately, none of the research that we know of has produced estimates of the joint effects of typical stressors for air and water. One reason could be that pollution is only one of several background factors that potentially affect the estimates. Hence, at the current level of knowledge the economic valuation can only approximate the total impact by summing the impacts of individual stressors.

[13] *Cumulative impacts:* Impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project. *Indirect impacts:* Impacts on the environment, which are not a direct result of the project, often produced away from or as a result of a complex pathway. *Impact interactions:* The reaction between impacts whether between impacts of just one project or the impacts of other projects in the area.

4 International experience

4.1 Overview

This chapter reviews some experiences from the use of economic evaluation of environmental impacts for practical purposes in other countries. While there is a vast amount of studies evaluating various environmental damages in many countries, few if any country uses economic evaluations systematically in their EIAs or requires that project developers include valuation of environmental damages in their reports. However, economic evaluation is increasingly being used for various purposes in many countries. Many countries use economic evaluation in cost benefit analysis of policies, plans and larger infrastructure projects etc. An increasing number of governments are recommending that economic evaluation be used in EIAs.

Most valuation studies of environmental damages have been carried out by research institutions in the US, and the results from these studies have been extensively used for many purposes around the world. However, an increasing number of studies have also been carried out in Europe, especially in Western Europe through the ExternE research project (see below). During the 1990s an increasing number of valuation studies have been conducted also in Eastern Europe. The number of studies from developing countries is fewer, but the number is increasing.

Below we present some interesting examples of the use of the results from the ExternE project within the European Union. We also briefly describe the use of environmental cost evaluations in the Unites States Environmental Protection Agency (USEPA) guidelines for preparing economic analysis in support of regulatory actions, and the use of economic estimates of the damages caused by the Exxon Valdez accident for damage compensation payments are described as some interesting or promising ways of utilising monetary estimates of environmental costs.

Economic evaluation of environmental impacts is increasingly being used in cost benefit analysis of larger, new projects of various kinds. However, as far as we know no country has so far made such use mandatory. Since the EU and US are in the forefront on this, our examples focus on the use in these countries.

4.2 The ExternE project

4.2.1 Methodology

The scope of the ExternE project has been to value the external costs, i.e. the monetary quantification of the socio-environmental damages from the production and consumption in Europe (European Commission, 2003). The main focus of the work has been on environmental costs related to power production and transportation.

The project applies a so-called bottom-up approach, i.e. focussing on emissions from single sources to cover site-specific effects. The dispersion of the emissions from the single sources is calculated, using an atmospheric dispersion model. From this the increase in concentration at the receptor sites in all affected regions are derived. Through dose-response functions the various impacts are quantified, and finally the monetary values of the damages are estimated. The dose-response models have been compiled and critically reviewed in ExternE by expert groups. Basically these are the same steps as described in chapter 3 (figure 3.1).

To perform the calculations, a software package called EcoSense has been developed. EcoSense provides harmonised air quality and impact assessment models together with a database containing the relevant input data for the whole of Europe. Two emissions scenarios are needed for each calculation, one reference scenario and one case scenario. The background concentration of pollutants in the reference scenario is a significant factor for pollutants with non-linear dose-response functions. This information is used to derive differences in physical impacts on public health, crops and building materials. It is important to note that not only local damages are considered. Air pollutants are transformed and transported and cause considerable damage hundreds of kilometres away from the source. So both local and European wide modelling is required.

Not only atmospheric pollution is analysed, but also pollution in water and soil. Human exposure to heavy metals and some important organic substances (e.g. dioxins) that accumulate through the food chain are represented in the calculations.

In the monetary evaluation of the damages market prices are used for impacts on crops and materials. For non-market goods, especially damages to human health, WTP or WTA approach is used. The monetary values recommended in ExternE by the economic expert group have been derived on the basis of informal meta-analysis (in the case of mortality values and the most recent robust estimates).

The ExternE methodology has been applied for a large number of European and national studies to give advice for environmental, energy and transport policies. A decade of research has resulted in a detailed set of data for impacts from a wide range of fuels, technologies and locations. The model has also been adopted to other territories in the world.

4.2.2 Example of use: the Benefits Table (BeTa) database

The BeTa database has been developed to provide a simple and easy way to estimate of the external costs of air pollution. The database provides default estimates of environmental costs, and allows the user to put in their own data based on local conditions to calculate their own environmental costs.

Pollutants (stressors) addressed in BeTa are:

- *Sulphur Dioxide (SO_2)*: through effects of SO_2 and sulphate aerosols on health, and SO_2 and acidity on materials.
- *Nitrogen oxides (NOx)*: through effects of nitrate aerosols on health and ozone on health and crop production
- *Volatile organic compounds (VOC)*: through effects of ozone on health and crop production.
- *Particulate matter ($PM_{2.5}$)*: through effects on health.

The following sources and locations are covered:

- *Emissions from all sources in rural locations in each country of the 15 EU member countries (i.e. the members before 1. May 2004) except Luxembourg*. Results reflect the impacts of emissions up to a range of typically 1000 km from the emission source. Modelling work undertaken has suggested that this is sufficient to capture 95 percent of the damages. The precise distance over which impacts are calculated is a function of the position of the modelled sources within each country, within the modelling domain. The main reasons for variation in figures between countries are differences in national population density, differences in distance from each country to the major population centres in Europe, and prevailing wind direction.
- *Emission at ground level (e.g. from traffic) in cities of different sizes*. A base case of a city with a population of 100,000 is selected. Factors are then provided for multiplying the results up to account for larger cities. Results for rural areas should be added to the urban results to reflect impacts outside the city boundaries.
- *Emissions from shipping*. These are based on data for urban areas of various sizes in the case of ports and on data for rural areas for coastal regions of each country, and on the weighted average of rural data from countries surrounding some specified sea areas.

External costs of air pollution vary according to a variety of environmental factors, including overall levels of pollution, geographic location of emission sources, stack height, local and regional population density, meteorology etc. This database taxes these issues into account only to a certain degree. It is envisaged that this will provide an acceptable quality of data for a variety of purposes, though not all. Exceptions would include very detailed local assessments, for example investigation of the costs and benefits of meeting air quality standards in a particular city. Or at the other extreme, analysis of options for reducing exposure to ozone, for which relationship between emissions of precursors (NOx and VOC) and concentration is complex.

Most of the effects considered are referred to as "acute" effects, those linked to short-term exposure to air pollution. Analysis to support these functions is typically based around estimation of annual mean concentrations. The effect of release of a tonne of pollutant from any facility can simply be assessed by dividing the concentration field arising from total emissions from the plant in a year, by the annual emissions in tonnes. Linearity of dose-response functions is assumed across the full range of concentrations likely to be encountered in Europe. Following the trends in emissions of the last 10 years this is not an unreasonable assumption.

A few effects arise from chronic, long-term exposures to air pollution. Given that chronic conditions typically take some time to develop, and then persist for a number of years, a discount rate is applied in describing the externalities. A rate of 4 percent is used.

Effects included in the analysis are:

- Acute (short-term) effects of PM_{10}, SO_2, ozone on mortality and morbidity.
- Chronic (long-term) effects of PM10 on mortality and morbidity.
- Effects of SO_2 and acidity on materials used in buildings and other structures of no significant cultural value.
- Effects of ozone on arable crop yield.

It is considered that the externalities taken into account in the database are likely to dominate the full damage costs. Health impacts dominate the damage cost figures.

Default estimates

The default damage costs estimates are based on a value of statistical life of 1 million Euro, recommended by the European Commission Directorate General for Environment. The following default values are included:

Table 4.1 Marginal damage costs of emissions in rural areas. Euro/tonne, year 2000 prices.

	SO_2	NOx	$PM_{2,5}$	VOC
Austria	7,200	6,800	14,000	1,400
Belgium	7,900	4,700	22,000	3,000
Denmark	3,300	3,300	5,400	7,200
Finland	970	1,500	1,400	490
France	7,400	8,200	15,000	2,000
Germany	6,100	4,100	16,000	2,800
Greece	4,100	6,000	7,800	930
Ireland	2,600	2,800	4,100	1,300
Italy	5,000	7,100	12,000	2,800
Netherlands	7,000	4,000	18,000	2,400
Portugal	3,000	4,100	5,800	1,500
Spain	3,700	4,700	7,900	880
Sweden	1,700	2,600	1,700	680
UK	4,500	2,600	9,700	1,900
EU-15 average	5,200	4,200	14,000	2,100

Source: Netcen (2004)

The EU-15 average is the weighted average of the costs in each country, using the country's emissions as weights. It can be seen from table 4.1 that the damage costs varies considerably between countries.

Urban damage costs for NOx and VOC are taken to be the same as the rural costs, given that quantified impacts are linked to formation of secondary pollutants in the atmosphere (ozone, nitrate aerosols). Given that these take time to be generated in the atmosphere, local variation in population density has little effect on the results.

Urban externalities for $PM_{2,5}$ and SO_2 for cities of different sizes are calculated by multiplying results for a city of 100,000 people by the factors in table 4.2. For a city of 100,000 people, the marginal external costs are:

- $PM_{2,5}$: 33,000 Euro/tonne
- SO_2: 6,000 Euro/tonne

Results scale linearly to 500,000 people but not beyond, as can be seen from table 4.2. These results are independent of the country where the city is located. Once results in the cities are calculated, nationally specific rural externalities should be added to account for impacts of long-range transport of pollutants.

Table 4.2 Scaling of marginal damage costs of emissions in cities compared with a city of 100,000 people.

Population	PM2.5	SO2
500,000 people	5	5
1 million people	7.5	7.5
Several million people	15	15

Source: Netcen (2004)

For shipping the estimates of marginal external costs distinguishes between emissions in the following locations:

- *In port*: urban results for city of the same size as the port city are used, and the rural externality figure for the country inn question should be added.
- *Close to shore*: use national rural results
- *Offshore*: based on rural results for countries surrounding sea areas, weighted by straight-line length of coast of bordering countries. Some estimates for various European sea areas (Eastern Atlantic, Baltic Sea, English Channel, Northern Mediterranean and the North Sea) are presented.

Health effects

The database presents recommended dose response functions for $PM_{2.5}$, sulphate aerosols, nitrate aerosols, SO_2 and ozone. Below functions for damages from $PM_{2.5}$ and SO_2 are presented for the EU average. The number of events in table 4.3 is calculated from dose response functions for the various effects, and is scaled up to an emission of 1000 tonnes of the primary pollutant simply to make them easier to read. These damage figures are different for different countries.

Table 4.3 Number of events of a health effect in rural areas per 1000 tonne emissions. EU 15 average case.

	SO_2	$PM_{2.5}$
Congestive heart failure	0.30	1.3
Restricted activity days	2,367	10,471
Bronchodilator usage – adults	536	2,373
Cough – adults	552	2,443
Lower respiratory symptoms – adults	199	881
Bronchodilator usage – children	64	281
Cough – children	110	486
Lower respiratory symptoms – children	85	375
Respiratory hospital admissions	0.79	1.1
Cerebrovascular hospital admission	0.59	2.6
Chronic mortality – deaths	4.8	21
Chronic bronchitis – adults	2.2	10
Chronic coughs – children	49	216
Acute mortality – deaths	1.90	216

Source: Netcen (2004)

The events in table 4.3 can then be multiplied with the prices for the various incidents, to get the marginal external costs for each event per 1000 tonne of emissions (or scale this to the actual emissions that are to be valuated).

Table 4.4 Valuation data. 2000 price level

End points	Euro/event
Congestive heart failure	3,260
Restricted activity days	110
Bronchodilator usage – adults	40
Cough – adults	45
Lower respiratory symptoms – adults	8
Bronchodilator usage – children	40
Cough – children	45
Lower respiratory symptoms – children	8
Respiratory hospital admissions	4,320
Cerebrovascular hospital admission	16,730
Chronic mortality – deaths	490,000
Chronic bronchitis – adults	169,330
Chronic coughs – children	240
Acute mortality – deaths	1,000,000

Source: Netcen (2004)

Note that the economic values in table 4.3 are based on the same figure of 1 million euro to value short-term (acute) effects of exposure on mortality. Recognising that the effects of emissions will be spread over a number of years (this is the long-term effect) this figure has been discounted at a rate of 4 percent, giving a value of 490,000 euro per death.

Default values for damages to materials and crops

Similarly, the economic values of damages to materials and crops are calculated for emissions of NOx, VOC and SO_2. Below unit damage costs for emissions of SO_2 are shown.

Table 4.5 Default damages costs to materials and crops from SO_2 emissions. Year 2000 price level.

Country	Euro/tonne emission
Austria	321
Belgium	287
Denmark	121
Finland	35
France	270
Germany	224
Greece	150
Ireland	94
Italy	185
Netherlands	256
Portugal	110
Spain	136
Sweden	62
UK	164
EU-15 average	189

Source: Netcen (2004)

Something to learn for China?

The way the Benefits Database is organised and constructed could serve as an illustration of how China could develop a system for damages assessment and economic evaluation of the various damages. As we see from the presentation, the damages from the same type and amount of emissions vary considerably between the European countries, but the variation between Chinese provinces and cities could perhaps be even larger.

However, China could build a similar system for economic evaluation of damages, emphasising simplicity and user-friendliness without making it too rough and jeopardising the meaning of the exercise. One could start with SO_2 and PM_{10}/TSP, since these pollutants are regularly measured and their damages are rather well understood. Some sets of dose response functions for SO2 and PM_{10}/TSP for various events could be selected, based on experience from China and elsewhere. These could for instance cover some of the same health effects as in tables 4.3 and 4.4, or one could start with fewer effects and gradually expand the system when more knowledge and experience are gained.

Differences in damages between geographical areas in China, perhaps in particular between urban and rural areas should be taken care of. One could for instance imagine that a set of dose response relations, for instance translated into number of events like in table 4.3 could be established for each province, or for several provinces together to start with. This would be a parallel to the European approach. Within each province some differences between rural and urban areas could be established in a simple way like in Europe. The damage evaluation of urban areas could also be made more sophisticated that in Europe, for instance by recommending different dose response relations for various emissions sources depending on stack heights and the population in the exposed area.

Prices on damages could be similar in all provinces like for health damages in Europe, based on the same value of a statistical life or the value of life years lost. The value of damages to materials and crops could vary between provinces based on local prices, or some averages could be used to simplify this also.

This approach seems to be a fruitful one that should be elaborated further. The results from the case studies presented later in this report could be used for such an elaboration, building a system step by step.

5 Air

5.1 Introduction

Purpose and main contents

The purpose of this chapter is to guide EIA experts and practitioners in the economic evaluation of projects' environmental impacts through the media of air by quantitative and/or qualitative indicators. The chapter applies in a practical way the methods described in Chapter 3. A detailed case study of the environmental impacts from the extension of a power plant in Datong is included in Part II of this report.

It also points out the barriers to be overcome, the pre-conditions to be met, in order to do economic evaluation of environmental impacts of air pollution. This chapter mainly covers the major air pollutants of SO_2, NOx, TSP/PM_{10}, and only to some extent O_3, CO, Pb, F, and noise based on China's Environmental Quality Standards. Further, the chapter includes some stressors that have been proven important by scientific studies but not included in the standards, e.g. VOC and ground level O_3, as well as GHGs. The impacts can be divided into two categories:

- Impacts through ambient air quality change: mainly referred to as air pollution caused by chemical pollutants
- Other impacts through the media of air: heat and temperature changes, radiation, noise, etc.

Basis of existing guidelines, regulations

The chapter is mainly based on the following current laws, regulations, standards and relevant research:

- Environment Impact Assessment Law (2002)
- Management Regulation for Environmental Protection of Construction Projects (1998)
- Management Methods for Environmental Protection of Construction Project (1986)
- Management Category Inventory for Environmental Protection of Construction Projects (2003)
- HJ/T2.1-93: Technical Guideline for Environmental Impact Assessment: General (SEPA)

- HJ/T2.2-93: Technical Guideline for Environmental Impacts Assessment: Atmosphere Environment (SEPA)
- GB3095-96: Standard for Air Quality (SEPA)
- GB3096-93: Municipal Noise Standard (SEPA)
- GB16297-1996: Integrated emission standard for air pollutants
- Industrial emission standard for air pollutants[14]:
- TJ36-79: Sanitary Standard for Industrial Enterprises Design
- ADB (1996)

Structure of chapter

The logic structure of this chapter is as follows:

SOURCE → STRESSORS → CONCENTRATION CHANGES BY EMISSION → EXPOSURE OF RECIPIENTS → IMPACT SCREENING → HEALTH AND OTHER IMPACTS → IMPACTS QUANTIFICATION → INTEGRATION OF IMPACTS → ECONOMIC EVALUATION

Each of these steps is described as follows:

- ***Analysing sources:*** to analyse the characteristics of sources which emit air pollutants, including production processes, major pollutants, location of sources, time and path of pollutant emissions, etc.
- ***Identifying stressors:*** according to existing regulations, standards and research, to identify the impact stressors from the air pollutants emitted by the target project.
- ***Predicting ambient air quality change:*** to predict the concentration changes of air quality due to the change of the stressor emissions.
- ***Identifying exposure recipients and impacts:*** to identify potential impacts on recipients through marginal change of air quality.
- ***Screening impacts:*** according to the significance and ease of impact quantification of impacts, to sort out impacts for quantification.
- ***Quantifying impacts:*** Choosing suitable E-R functions to quantify the impacts.
- ***Integrating impacts:*** to integrate all the impacts from different pollutants or stressors, and to decide on the indicators and end-points that will be used for evaluation.
- ***Evaluating impacts:*** using evaluation methods and instruments, to calculate monetary value of all impacts.

[14]GB13271-91\GB9078-1996\GB13223-1996\GB16171-1996\GB4915-1996\GB14554-93\GB14761.1, 4761.7-93\ GB14621-93

5.2 Identification of major stressors and impacts

5.2.1 Identification of major stressors

This section explains how to identify major stressors of air pollution

Criteria for identifying major stressors

- The stressors are due to project activities in its whole lifecycle, including the construction, operation as well as demolishment of the project. When we carry out economic evaluation of a construction project, we should list out all stressors according to the project's characteristics of pollutant emission.
- The stressors should make significant impacts through air media, including SO_2, NOx, TSP/PM_{10}/$PM_{2.5}$, O_3, VOC, CO, Pb, B[a]P, F, GHGs, and noise.
- The stressors should be pollutants that cause air pollution according to environmental standards, emission standards and guidelines.
- According to the Technical Guideline for Environmental Impacts Assessment, when we identify major stressors we should consider two aspects. First, we should choose the pollutants with high equivalent emission amount as main stressors; second, we should consider pollutants that have been identified as major pollution factors in assessed area. For the requirement of economic evaluation, the stressors should also be important from the point of view of impacts on receptors, rather than impacts on environmental quality, because detailed evaluation methods require the calculation of the value change for receptors.
- The stressors should be assessed in the EIA report to ensure sufficient information for economic evaluation. Hence, the stressors should be identified during the stage of EIA outline approval.
- Some stressors that have been proven important by scientific research but not required by the standards yet, e.g. VOC, ground level O_3 and GHGs are recommended for inclusion if potentially large.
- Some stressors could be primary pollutants as well as secondary pollutants from a certain project. All these stressors should be listed respectively, and try to avoid overlapping or missing any important impacts. For example, SO_2 emitted from high stack may produce another stressor, acid sedimentation.

Major stressors from different types of construction projects

According to Management Category Inventory on Environmental Protection of Construction Projects (2003), typical stressors of main projects are listed in Table 5.1.

Table 5.1 Major Stressors from different types of construction projects

Industry \ Stressors		SO_2	NOx	TSP/ PM10/	O3	VOC	CO	Pb	B[a]P	F	GHGs	Noise	Electro-magnetis	Nuclear radiation
Electricity	Coal	√ √	√ √	√ √		√	√ √			√		√		
	Fuel Oil	√	√	√		√	√							
	NG						√				√			
	MSW								√ √					
Hydro-electricity												√		
Renewable Energy	Wind											√		
	Solar													
	Bio										√			
	Geothermal	√					√				√			
Power Transfer													√	
Petrol, NG Exploitation		√ √	√				√ √							
Coal Gas Exploitation							√ √							
Coal Exploitation				√ √			√ √							
Ferrous and non-ferrous metal ore selection				√ √				√						
Non-metal ore selection				√ √				√						
Metal processing and production												√		
Black ferrous metal smelting		√	√	√			√	√		√				
Non-ferrous metal smelting		√	√	√			√	√ √		√				

Food processing							√			√			
Drinks manufacture						√							
Tobacco					√								
Spinning					√						√		
Costume manufacture											√		
Leather and its products					√								
Paper pulp and paper making					√								
Petroleum processing	√	√			√	√	√	√	√	√			
Medical materials/ medical products manufacture				√	√			√	√	√			
Medicine manufacture					√			√	√	√			
Medical fiber manufacture					√								
Rubber products	√				√								
Plastic products					√								
Nonmetal ore products such as cement	√	√	√ √								√		

Notes: 1. This table refers to “Title catalogue of environment protection of construction projects” and is not exhaustive.

2. “ √ ”means slight/medium emission load; “ √ √ ”means heavy emission load.

5.2.2 Definition of receptors and major impacts

Receptors for air pollution are mainly human beings (health and human welfare), ecosystems, global system, etc, as described in Chapter 3. Impacts for each receptor are listed as following:

- Human health
  - Mortality: death rate or probability of increase of death rate from air pollution related diseases
  - Morbidity: Rate of diseases, including cancer, respiratory system disease, cardiovascular disease, etc.
- Human welfare
  - Material: damage to construction material e.g. corrosion due to acid rain
  - Amenity, aesthetics and ethnics: visibility reduction due to particle emissions, noise from traffic, etc
  - Natural Resources: changes of productivity or commercial value of natural resources, e.g. crops, plants from dust deposition on leaves etc.
  - Society/culture: impacts on indigenous people, impacts on religion or cultural customs, forced migration, loss of homestead.
- Natural ecosystem
  - Ocean and freshwater ecosystems, biological diversity, land ecosystems to the extent that these directly or indirectly are affected by air pollution (e.g. acid rain, particle deposition, bird impacts, forest impacts).
- Global system: change of weather pattern and global climate from GHG emissions, ozone layer depletion.

5.2.3 Identification of major impacts for each stressor

Based on environmental science, ecology and medical science, the linkages between pollutants, receptors and impacts are listed in table 5.2.

Table 5.2 Summary of Impacts from Air Pollution

Pollutant/ stressors	Receptor Affected	Nature of Effect (damage)
SO_2	Human health	Increased morbidity and mortality; through inhalation
	Plants and Crops	Reduced plant productivity, through acid deposition
	Surface waters	Acidification of surface waters, leading to loss of fish stocks, damage to aquatic wildlife caused by acid deposition
	Buildings and built structures	Acid deposition causes erosion and corrosion. Impact varies by type of material, e.g. soft limestone is very vulnerable to acid attack.
Particulate Matter (PM) (less than 10 microns)	Human health	Inhalation of small particles causes increased respiratory disease, increased morbidity Note that there is a synergistic effect between PM_{10} and SO_2
	Human well-being	Poor visibility
NO_x	Human health	Direct impact on human mortality Indirect effect through interaction with VOCs to produce tropospheric ozone
VOCs	Human health	Some hydrocarbons are carcinogenic (e.g. benzene). Others have indirect effect on human health through interaction to form ozone
Ground level ozone	Human health	Increased incidence of respiratory diseases, increase in mortality and morbidity
	Crops	Reductions in some crop yields, loss of biodiversity
	Buildings and materials	Damage to materials, e.g. rubber, paints
Greenhouse gases (CO_2, CH_4)	Global warming	Sea level rise, change in vegetation patterns, change in water resources, possible losses in biodiversity
Lead	Human health	Increases coronary disease and hypertension; some linkage with premature mortality, and decreased intelligence in children at low to moderate exposures.

Table 5.3 is based on the framework offered by the ADB (1996), which has covered most key impacts of air pollutants, and can serve as a worktable for EIA practitioners in identifying the relation between stressors and impacts. IN addition, this chapter will add more types of impacts that are potentially important according to the most recent progress in scientific research.

Table 5.3 Main stressors and impacts

	Human health		**Human welfare**				**Ecological system**					**Global system**
	Mortality	**Morbidity**	**Material Damage (e.g. buildings)**	**Aesthetics**	**Plants and crops**	**Society/culture**	**Ocean eco-system**	**Groundwater**	**Freshwater ecological system**	**Biological diversity**	**Land eco-system**	
1. SO2		√	√	√	√				√		√	
2. Nox		√		√					√		√	
3. TSP/ PM_{10}/PM	√	√	√	√								
4. O3	√	√	√	√	√					√		
5. VOC	√	√		√							√	√
6. CO		√										
7. Pb	√	√			√				√	√	√	
8. B[a]P	√	√										
9. F		√			√							
10. GHGs												√
11.Noise		√		√		√				√		
…												

Source: ADB (1996)

Below we analyse what we should consider when identifying important stressors.

SO_2

SO_2 in the air emitted by mankind come from combustion of fuels which contain sulphur such as coal and oil; smelting of ore which contain sulphur, especially non-ferrous metal ore which contains much sulphur; production processes of chemical plants, refinery plants etc. SO_2 has impacts on human health, crops, forests, material, visibility, etc. When we assess impacts of SO_2, we should consider:

1. SO_2 from different sources may have different impacts on different receptors in different ways. For example, the characteristics of emission sources in different industries differ much. These differences include volume of pollutants emitted, emission mode, emission intensity, emission height, emission temperature, emission time, etc. These differences make SO_2 diffuse, transfer, and transform with different modes and as a result,

have different impacts and occurrence. Hence, we should identify impacts of SO_2 according to emission characteristics of certain projects.

2. Secondary pollution of SO_2. After SO_2 is emitted it may have impacts on the environment as "primary pollutant", as well as "secondary pollutant". When we carry out the assessment, we should identify the types of impacts according to weather condition and existence of other pollutants. In the electricity plant project of the ADB report, impacts of SO_2 (primary impacts) produce secondary impacts by producing secondary pollutants such as PM_{10} and acid deposition.
3. To a great degree, impacts of SO_2 on human health are relative to the existence of other pollutants, e.g. PM_{10}. When we identify the impacts of SO_2 and the degree of impacts, we should examine the existence of other pollutants, which tend to interact with SO_2.
4. Impacts through other media and off-site impacts by SO_2. SO_2 will not only impact receptors directly through the air medium but also impact water body and soil ecosystem by transferring to water, soil and other media. In the latter situation, SO_2 is not a stressor of air but a stressor of water body and soil — acid precipitation. These impacts are counted into impacts on water and soil and we only discuss impacts through air medium in this chapter[15].

NOx

NOx in the air emitted by human activities is caused by burning of all kinds of fuel and the emission of exhaust gas when producing nitric acid, nitrogenous fertilizer, dynamite, and dyestuff. Of all the sources, burning of fuel causes the most pollution. Of all kinds of burning, industrial burning and vehicle emissions account for the most.

NOx mainly impacts human health and welfare (material, crops, and visibility).

We should consider the following aspects when identifying impacts of NOx:

1. NOx can form several kinds of oxides. Types and degrees of these oxides' impacts differ much. So the composition of NOx in certain conditions should be considered.
2. Damage of secondary pollutants caused by the reaction of NOx may be greater. We should pay much attention to these secondary pollutants such as O_3

TSP/PM_{10}/$PM_{2.5}$

Industries such as coal fired electricity production, steel, coking, non-ferrous metal processes, chemical fibre, machining, paper making, cements are main sources of solid and liquid particles in air. Particles mainly impact human health and welfare (smudge, visibility). To identify impacts of particles, we should consider:

[15] Considering a receptor such as a plant which is influenced by SO_2, it is hard to judge acidification of which media causes the impact. Maybe the impact is caused by direct precipitation, maybe it is caused by soil acidification. So overlapping should be avoided. One feasible way is to measure impacts in term of receptors, not in term of type of impact.

1. Coexistence of other pollutants. Particles in the air (aerosol) coexist with other pollutants such as SO_2, NOx, and CO. They react easily with each other. Many E-R functions supplied by present researches have not excluded impacts of non-TSP.
2. Chemical components of particles and aerodynamic radius. Chemical components of PM_{10} in different regions may have great difference. It causes problems of applicability of E-R functions derived from different regions. Moreover, the objects of sequent monitoring are TSP and soot. In the course of calculation, PM_{10} is generally considered to account for 55% of TSP. But in fact, the ratio of TSP in different places of China differs much. So when we quantify the impacts, we should try our best to use the results of research from regions where the background is similar to the region we assess.

O_3

Generally, **ground level** ozone (O_3) is always a secondary pollutant. O_3 is mainly caused by reactions of VOC and NOx. So the main sources of O_3 are sources of VOC and NOx. These sources include industrial burning, vehicle emissions, and production and usage of VOC. O_3 mainly impacts human health, natural ecosystems (biological diversity and species), and welfare (material, taste and crops). The identification of O_3 needs to establish the relationship between O_3 and the precursor (NOx and VOC).

VOC

VOCs are the floorboard of organic compounds with low boiling point. It mainly refers to organic compounds of which saturated steams pressure exceeds 70.91Pa or boiling point is under 260 degrees. VOCs include volatile hydrocarbons and low boiling point heterogeneous chain compounds. VOCs mainly impact human health, natural ecosystems (land ecosystem), and the global system. VOCs are a kind of organic compound. It has many categories and has complex components. When we identify the impact, we should analyse the components and when we select E-R function, we should confirm for which component E-R function is to be used.

Fluoride (F)

The Pollutant fluoride comes mainly from aluminium smelting, rock phosphate processing, phosphate fertilizer production, steel smelting, and coal burning. Some industries such as pottery, glass, plastic, pesticide, chemical fertilizer, and uranium separation also emit compounds containing fluoride. Fluoride mainly impacts human health and welfare (crops). Impacts of fluoride come not only from air but also from other media such as land and soil. When we identify impacts, we should consider all the media.

5.2.4 Procedure and steps of impacts screening

We should use proper screening procedure to identify impacts that should be quantified or described only quantitatively. Chapter 3 of this report also provides a general procedure for screening. A possible procedure for air is:

- Whether these impacts be internalised or mitigated

    - Does the impact represent the internal cost or benefit of the project? For example, is the receptor the one who causes the impacts? (If yes, we do not need to assess.)
    - Can the impact be totally restrained or mostly restrained? For example, does the one who causes the impact do something to eliminate the impact on others or minimize the impact? (If yes, we do not need to assess.)
- Are these impacts important or not?
    - Does the concentration meet national or local standards? (If not, it cannot pass EIA and we should assess)
    - Does the air quality after diffusion meet function zone's quality standard and environment target? (If not, it cannot pass EIA and we should assess)
    - Is the impact stressor effective stressor? For example, does the stressor exceed marginal value? Is there any sensitive receptor in impact area? (If yes, we should assess in order to supply policy-making basis.)
    - Is the impact important or not compared with other impact?
- Are impacts too uncertain or too sensitive to achieve an objective assessment?
    - Is the scientific understanding regarding the impact uncertain so that the impact cannot be assessed?
    - Is the impact too sensitive to make the assessment result useless? The sensitivity may be due to law, cultural value, political consideration, religion, and social reasons.
- Can the quantitative analysis be done?
    - Are there proper E-R functions to express physical the impact?
    - Can the region and receptors be defined and quantified?
    - Are data available?

5.2.5 Results of impacts screening

The result of screening should tell us what we should do with each impact. There are three types of actions to be taken: what to be quantified; what to be described qualitatively; and what to be excluded.

Table 5.4 is a table for practitioners. The last two columns, results of impacts screening and actions to be taken, should be will be filled in for each specific project after identification of impacts.

Table 5.4 Results of identification and screening of main stressors

Impacts stressors	Impacts	Results of impacts screening	Actions to be taken (quantification, describe qualiftatively, exclusion)
1. SO2	Human health (mortality, rate of disease) Materials, crops and plants		
2. Nox	Human health		
3. TSP/PM10/PM2.5	Human health		
4. O3			
5. VOC			
6. CO	Human health, comfort, biological diversity		
7. Pb	Human health		
8. B[a]P	Human health		
9. F	Plants		
10. GHGs	Global impacts		
11. Noise			

Source: ADB (1996)

5.3 Methods and steps of quantifying the physical impacts

The impacts that have been identified for quantification should be quantified according to certain methods. The impacts that cannot be quantified should be analysed and described qualitatively to increase the information content of the EIA report for policy-makers. The quantification should be carried out in the following steps:

To define the scope for impacts evaluation

The following principles of defining the scope for impacts evaluation should be followed

- As a minimum, the scope for impact evaluation should cover the scope assessed in EIA report.
- The scope should be extended to cover most of the affected area
- Special attention should be paid to trans-boundary environmental issues

To decide the endpoints for quantification

The existing literature often analyses specific kinds of impacts on health of air pollution. If all the impacts are calculated separately and summed, the actual impacts will be overrated. In order to facilitate economic evaluation, we suggest endpoints, which can easily be expressed in monetary terms (see table 5.5). Even so, the Disease incidence rate is hard to deal with, for it involves many kinds of stressors and each stressor may induce many diseases. The selection of diseases should be considered combining with the selection of E-R function.

Table 5.5 Impacts, endpoints and economic prices

Impacts	Quantification of impacts	Price
Health	Outpatient rate Hospital rate	Medical expense
	Mortality	VSL
	Working day loss	Wages
Material	Decrease of lifespan and quality	Expense to purchase or substitute the material
Plants and animals	Decrease of quantity and quality of outputs	Price of the outputs or substitutes
Enterprises	Decrease of quantity of products	Price for products

Source: ECON (2000)

To decide whether or not to evaluate the endpoints according to critical value

The critical value of pollution means the lowest level of pollution that will induce impacts. Some literature does not agree to use marginal value and some considers that at least PM_{10} (sometimes also O_3) does not have a critical value. After some consideration, World Health Organisation (WHO) concluded that all the pollutants except particles should adopt critical values. We recommend WHO's opinion. The critical values of major stressors are listed in Part II of this report.

The method to integrate impacts is to sort out the most prominent diseases as endpoints from all the diseases, then pick out the most prominent stressors as indicators from all the stressors that will induce these diseases, and finally to calculate extent of impacts with the E-R function.

To choose the exposure-response function

Exposure-response functions are used to calculate the degree of impacts, and are usually expressed in terms of *exposures to ambient concentrations* of each pollutant. Available E-R functions are listed in Part II of this report. There are different ways to express E-R functions. The most typical and the easiest way to calculate is expressed as the changing rate of impacts due to per unit concentration change of pollution. One example is the increased number of patients per million when the concentration increases one unit.

The principles for the selection of E-R functions are:

- They should be simple and applicable. E-R functions that are expressed in the form of "increased impacts on the end points due to marginal increment of concentrations of pollutants" are prioritised.

- Research results from China should have higher priority;
- The researchers in the field of E-R functions should have high authority or reputation.
- Public health data and environmental data should be available for the chosen E-R functions

To measure the exposure of receptors

The measurement includes exposure time, distribution of recipients (especially sensitive recipients) and exposure concentration in different geographic locations. The measurement should use reliable environmental monitoring equipment, social data of receptors, ecological monitoring data. GIS could be a very useful tool to do calculation.

To calculate the physical magnitude of impact

For health impacts, if only simply considering linear relationships, the following formula could be used:

The increase of number of patients induced by a certain project =

Change of pollutant's concentration × rate of increase of patients' number per unit of population per unit of change of concentration × exposed population

5.4 Economic evaluation of Impacts

5.4.1 Principles for evaluation and approaches

When calculating the economic evaluation of impacts, the following principles should be followed:

- Economic evaluation of environmental impacts tries to measure social welfare. Most of measurable parts are actual damage costs, which are only a part of the total social welfare costs.
- By different valuation techniques, there could be different results of the evaluation, though usually the results will cluster around the true value
- The choice of prices for end points may also contribute to variation in the results.

There are three main methods to do economic evaluation: market approach, revealed preference approach, contingent valuation (CV). Each of the three approaches has its advantages and shortcomings. See Chapter 3 for details on general economic valuation methodologies.

We recommend the following techniques to evaluate impacts of air pollution (see table 5.6)

Table 5.6 Evaluation techniques: recommended approaches

Impacts	**Main stressors**	**Information basis**	**Recommended method**	**Main parameters**
Human health	$TSP/PM_{10}/PM_{2.5}$ SO_2, O_3, Lead	E-R available	(E-R)+(cost of illness, human capital)	Exposed region, exposed population, sensitive crowd, background data of disease and death, average medical cost, salary loss
	NOx, VOC, CO, B[a]P, F, noise	E-R not available/E-R not mature enough	Preventive expenditure, CV	
Welfare				
Materials & construction	SO_2	E-R available	Direct market valuation	Category and quantity of exposed materials, corrosion rate and lifespan of materials, market price of products of substitutes
		E-R not available	Hedonic property pricing, preventive expenditure, reset cost	Quantity and price of preventive materials
Resources (plants, animals, forests)	SO_2	E-R available	Changes in productivity, opportunity cost	Category and quantity of exposed sources, changes in productivity, changes of market value
		E-R not available	Preventive expenditure, reset cost	
Smell, visibility, noise	TSP, SO_2, Nox, VOC	E-R not available	Hedonic property pricing, travel cost, CV	Demand curve of travel
Natural ecosystem				
Ecosystem (forests)		E-R not available	Opportunity cost, CV	
Biological diversity		E-R not available	CV, production reference	
Global system		E-R not available	Trade price, production reference	

Details of E-R functions for air pollution can be found in Part II of the report.

5.4.2 Specific evaluation techniques

Evaluation of mortality costs

The formula to calculate death loss of respiratory system disease, cardiovascular disease, and respiratory system cancer is:

$$L = \sum VSL \times P \times \Delta c \times M \times DR$$

Of which:

VSL = value of statistical life

Pi = population of exposure

△Ci = ambient quality (concentration) change

M = mortality

DR (ER) = Dose/Exposure-response function for mortality rate

Evaluation of disease costs

Disease costs include costs of being hospitalised, outpatient service, work delay, and costs of having family accompanying the ill person to hospital. The costs of outpatient service of different diseases are calculated together; the costs of other diseases are calculated separately. The calculation formulas are:

Outpatient visit costs: $L = E \times R \times P \times \Delta c \times ER$

E = average expenditure on outpatient service,

R = Outpatient visit rate

P = population of exposure

△C = ambient quality (concentration) change

Hospital admission costs: $L = E \times T \times R \times P \times \Delta c \times ER$

E = average expenditure on outpatient service,

T = average days of hospital admission

R = hospital admission rate,

P = population of exposure

△C = ambient quality (concentration) change

ER = Exposure-response function for hospital admission

Workday loss due to disease: $L = T \times P \times GDP \times \Delta c \times ER$

T = average workdays delayed (equal to average days of hospital admission),

P = number of hospital admission,

GDP = average GDP per capita,

$\triangle C$ = ambient quality (concentration) change

ER = Exposure-response function for hospital admission

Workday for accompanying relatives: $L = T \times P \times GDP \times \Delta c \times ER$

T = average attendance days (equal to average days of hospital admission)

P = number of people accompanying the ill (proportion is assumed to be 1:1),

GDP = average GDP per capita

$\triangle C$ = ambient quality (concentration) change

ER = Exposure-response function for hospital admission

Evaluation of other, non-health costs

Mortality and disease costs typically constitute the largest and most important part of total environmental costs from air pollution. But there are also other impacts, which may be important. We refer to the chapters on land (and water) for a demonstration of valuation methodologies related e.g. to reduced agricultural production and other resource impacts.

5.5 Summary of case study

5.5.1 Introduction

Datong No.2 power plant, located in the southern suburb of Datong city, Shanxi Province, is one of the most important power plants in northern China. The power plant has six sets of 200MW power generation facilities now and another two sets of 600MW air-cooling facilities will be constructed in the second phase of the project. A full case study report is included in Part II of the report.

The EIA was carried out by China North Power Engineering Co. Ltd, which is a company with a class-A EIA certification (see Chapter 2 for explanation). The area for the EIA should be a quadrangle of 20*20 km with the power plant at the centre. However, two important sites, the Yungang grotto and Dangliuzhuang ash field, are outside this area, so the assessment area was expanded to 456km^2 to include these. In this area, they monitored and forecasted the air quality in 10 concerned spots. The results are:

(1) The current air quality: pollutants concentration of most spots can meet standards;

(2) Air Quality Prediction: pollutants concentration of 3 spots will increase after the construction of new power facilities;

(3) Contribution of stressors: NO_2>SO_2> PM_{10}>TSP>F.

5.5.2 Evaluation process and results

According to the demand of the project, the economic evaluation is based on the present EIA report. So, first we choose proper E-R function to calculate physical impacts, then we use direct market approach to calculate the damage in monetary terms.

Based on the framework and procedure provided by ADB (1996), we analysed the information from the EIA and accessibility of data and chose SO_2 and PM_{10} as impacts stressors. The major impact is loss of human health. The specified endpoints and necessary parameters for calculation are listed in table 5.7.

Table 5.7 Parameters for evaluating loss of human health

<table>
<tr><th>Stressors</th><th>End-points</th><th>Types of Loss</th><th colspan="5">Parameters</th></tr>
<tr><td rowspan="5">SO_2
PM_{10}</td><td rowspan="5">Respiratory system disease

Cardiovascular disease

Respiratory system cancer</td><td>Mortality</td><td>Mortality of a certain disease</td><td>E-R correlation of mortality and exposure</td><td>Population of each unit in the evaluated area</td><td>Statistical value of life</td><td>Concentration change</td></tr>
<tr><td>Hospital Admission</td><td>Number of Hospital Admission</td><td>E-R correlation of HA rate and exposure</td><td>Average expenditure per day</td><td>Days in hospital</td><td>Concentration change</td></tr>
<tr><td>Out-patient Visit</td><td>Number of outpatient visit</td><td>E-R correlation of outpatient visit and exposure</td><td>Average expenditure of outpatient service</td><td></td><td>Concentration change</td></tr>
<tr><td>Work day loss</td><td>Number of Hospital Admission</td><td>E-R correlation of HA and exposure</td><td>average GDP per capita in evaluation area</td><td></td><td>Concentration change</td></tr>
<tr><td>Attendance</td><td>Number of Attendance</td><td>E-R correlation of HA and exposure</td><td>average GDP per capita in evaluation area</td><td>Days in hospital</td><td>Concentration change</td></tr>
</table>

The process of quantifying each step in table 5.7 is explained in detail in the case study report in Part II of this report. The total calculated environmental costs are given in table 5.8 below.

Table 5.8 Damage costs. RMB

Damage cost	**SO_2 (1)**	**SO_2 (2)**	**PM_{10}**
RMB/year	20695635	2676458	569141
RMB/ton	1449.477	187.4533	427.6041
RMB/kWh	0.003136	0.000406	8.62E-05

Note: Costs of SO_2 are calculated using two alternative E-R functions.

The results show annual air pollution costs related to increased mortality and disease of between 2,3 and 20,1 million RMB for SO_2, and 0,6 million RMB for particulates.

5.5.3 Discussion of results

We can see from the results that:

- First, the impact results calculated using different E-R functions are very different
- Second, these results are small compared with results from other research, one of the most important reasons is that some impacts are not calculated due to data availability.

The results of this case are based on plenty of other projects and the most accurate data at present. Two important problems were encountered during the economic valuation:

The incomplete calculation

The results cannot completely represent the economic loss of the electricity plant's environmental impact. In fact, the actual loss may be much greater than the results we worked out. The limited information support from EIA and the quality of data restricted the extension of the results.

- ***Restriction from existing EIA law and guidelines.*** The contents of current EIA law limit the opportunities for economic valuation. The restriction includes:
  - the EIA only assessed impacts in a limited area and ignored impacts of pollutants on other places;
  - the EIA applied an atmospheric dispersion model and ignored other types of pollution such as acid deposition;
  - the EIA only identified SO_2, NO_2, PM_{10}, and fluoride as impacts stressors and ignored other pollutants such as O_3 and NOx;
  - the EIA did not identify the recipients and endpoints.
- ***Lack of solid scientific data and problems with accessibility of data.*** Due to lack of solid scientific research work in the field of medical science in China, there is a big information gap. Some data are hard to get, which restricted the results. For example, we only considered losses of health because of inaccessibility of necessary data in other areas. Even so, some kind of health losses still cannot be calculated due to data reason. Another problem is that the present medical statistical data do not match parameters of E-R function exactly.
- ***Limitation of economics.*** When calculating the damage costs, some of them are real costs and some of them are potential costs with probabilities. However, environmental valuation techniques have progressed to a stage where they are very useful in estimating a large part of total environmental costs.

Stability of results

There is still a lot of room to improve the calculation results. The calculation results are not robust enough due to data limitations and evaluation techniques.

- ***Uncertainty of information***. The uncertainty includes disunion of statistical data, differences of E-R functions, loss of basic information such as medical information and agricultural information, etc. For example, we use two different E-R functions in the case study, and we get two different calculation results. When different results are obtained, an average can be used with an indication of uncertainty range.

- ***Restriction of techniques.*** In the process of evaluation, there is still some uncertainty. For example, should we use market price or shadow price? Using the market price will often approximate the shadow price well
- ***E-R functions are uncertain.*** For some impacts, there are several E-R functions to describe the relations. When using different E-R functions, there are different calculating results. Assessment can be made of which E-R functions are the most reliable, or an average of results from different E-R functions can be used.

5.5.4 Conclusions from the case study

This case study has used the data with available quality we could find so far to do the calculation, and the result itself is therefore the most reliable given the circumstances. The result only covers a part of the true cost of air pollution from the power plant.

- Area and components of assessment are related to economic evaluation results. For this case study acid rain, CO_2 and other GHGs have not been considered. So, the evaluation results have not covered potentially large impacts. This results in an underestimation of actual impacts.
- Distribution of exposed population is related to economic evaluation results. For different assumptions of exposed population, the assessment and evaluation results will be different. In this case study, due to lack of data, for all of the exposed population, it has been simplified as average even distribution.
- Lack of Chinese E-R functions. Although there are several E-R functions, none of them are directly from China, based on a real survey in China. For example, hospital admission rate is not only affected by pollution but affected by several social conditions as well. For many people, they are not able to afford hospital admission fees, they only stay at home to treat by themselves. The E-R of hospital admission from western countries is not able to cover such differences.

6 Water

6.1 Introduction

Purpose and main contents

The EIA standards provided by the existing technical guideline for environmental impact assessment of China are based on the pollutants discharge standards and environment quality standards. Based on these standards, many projects actually produce more costs than benefits, if taking environmental costs into consideration. At present, the way to decide whether a project is acceptable is: if the pollutants discharged by the project comply with the corresponding pollutants discharge standards, and taking environmental impacts caused by the project into consideration after it is put into production, and the local environmental quality still complies with the environmental quality standards, the environmental impacts of the project are considered acceptable.

This chapter describes procedures for quantifying the impacts of different water related stressors through the media of surface water and ground water in economic terms, based on the EIA system for the water projects. The chapter covers the following parts:

- Identification of stressors of water environmental impacts;
- Summary of the types of impacts;
- Screening the impacts;
- Quantifying the impacts (Dose-response relationships);
- Methods of economic evaluation of environmental impacts;
- Estimate economic values of water environmental impacts;
- Case study: Wanxinzhuang wastewater treatment plant (WWTP)

Supporting laws and regulations

The most important laws, regulations and guidelines related to water are given below:

- Law of Environmental Impacts Assessment (2002.10.28)
- Decree of Environmental Management on Construction Project
- Technical Guideline for Environmental Impacts Assessment: general outline (HJ/T2.1-93)

- Technical Guideline for Environmental Impacts Assessment: Surface Water Environment (HJ/T2.3-93)
- Environmental Quality Standard for Surface Water (GB3838-2002)
- Seawater Quality Standard (GB3092-1997)
- Underground Water Quality Standard (GB/T14848-93)
- Water Quality Standard for Drinking-Water (CJ3020-93)
- Sanitation Standard for Drinking-Water (GB5749-85)
- Water Quality Standard for fisheries (GB11607-89)
- Water Quality Standard for Scenery and Recreation Area (GB12941-91)
- Water Quality Standard for farmland irrigation (GB5084-92)
- ADB (1996)

Some Concepts

Water environment here includes the river (including estuary), the lake and the reservoir on the surface of land, sea (including bay and seashore area) and groundwater. It lies between the changes of stressors related with the project activity and the recipients affected by these changes. Stressors of water environmental impacts operate through the water environmental media.

"Water environmental quality parameters" are defined as all kinds of physical, chemical and biological parameters that account for the water quality status.

"Stressors of water environmental impacts" are factors that bring about the change of human health, human welfare, environmental resources and global systems due to the change of water environmental media caused by human activities.

"Water environmental impacts" are the chemical, biological or physical effects caused by the changes of stressors of water environmental impacts through water environmental media.

6.2 Main water stressors

The first step of economic evaluation of water impacts is to identify and list all actual and potential stressors of water environmental impacts related with construction projects.

Based on the water quality parameters listed in the Environmental Quality Standard for Surface Water (GB3838-2002), and according to the practical conditions of the project and the circumstance where it is located, parameters of other related environmental quality standard on water environment will be used for reference in order to identify the basic range of stressors of water environmental impacts for further selection.

The EIA generally lists all stressors of the project that may bring about water environmental impacts in an engineering analysis. According to this, the range of stressors of water environmental impacts for selection can be identified further, which means that only the stressors related with the project will be selected.

Referring to ADB (1996) and according to the practical demand of the economic evaluation of water environmental impacts of the project, the range for selecting can be supplemented.

Under the guidance of these principles, we provide a table of major water environmental stressors for different industries. Adjustments may be made in the economic evaluation of environmental impacts (EEEI) practices according to specific conditions of the projects. See table 6.1.

Stressors \ Sectors	Production area and living, recreation establishment	Urban construction and infrastructures	Ferrous Metal land mine	Nonferrous metal and mine	Fire power electricity/ thermo electricity	Coking and coal gas making	colliery	Petroleum development and refining	Chemical mining	Nonorganic material	Fertilizer /pesticide	Synthetic detergent	Sugar refining	Water-electricity and water conservancy project	Agriculture development project	Ecological construction project
Water Temperature	√	√			√	√	√	√			√	√	√		√	
PH	√	√	√	√	√		√	√	√	√	√	√	√		√	
DO	√	√				√	√	√			√	√				
Index of permanganate											√					
COD	√	√		√		√	√	√		√		√	√		√	
BOD	√	√				√	√	√				√	√		√	
Ammoniac nitrogen	√	√				√					√				√	
TP	√	√									√				√	
TN															√	
Metals: Cu, Zn		√	√	√	√				√	√						
Metals: Hg, Cd, Cr^{6+}, Pb		√	√	√	√				√	√						
Fluoride				√	√				√	√	√					
Nonmetal: Se, As				√	√	√	√			√	√					
Total cyanide				√		√		√			√					
Volatile hydroxybenzene				√	√	√		√			√					
Petroleum		√		√	√	√		√				√				
Anionic surface activated detergents	√	√										√				
Sulphide			√	√	√	√	√	√	√	√	√		√			
Coliform													√		√	
Disease/Pathogens																
Salinization										√	√				√	
Water diversion/withdrawal					√		√	√						√	√	√
Channelization/Impoundment														√	√	√
Odour						√										
Suspended substance	√	√	√	√	√	√	√	√	√	√	√	√	√		√	
Sedimentation					√		√		√						√	
Chrome						√										

Table 6.1 Main Stressors of Water Environmental Impacts for Different Industries

Sectors / Stressors	Production area and living, recreation establishment	Urban construction and infrastructures	Ferrous Metallogyand mine	Nonferrous metallogy and mine	Firepower-electricity/ thermoelectricity	Coking and coal gas making	colliery	Petroleum development and refining	Chemical mining	Nonorganic material	Fertilizer/ pesticide	synthetic detergent	Sugar refining	Water-electricity and water conservancy project	Agriculture develop-ment project	Ecological construction project
Water Temperature	√	√			√	√	√	√			√	√	√		√	
PH	√	√	√	√	√		√	√	√	√	√	√	√		√	
DO	√	√				√	√	√			√	√				
Index of permanganate											√					
COD	√	√		√		√	√	√		√		√	√		√	
BOD	√	√				√	√	√				√	√		√	
Ammoniac nitrogen	√	√				√					√				√	
TP	√	√									√				√	
TN															√	
Metals: Cu, Zn		√	√	√	√				√	√						
Metals: Hg, Cd, Cr^{6+}, Pb		√	√	√	√				√	√						
Fluoride				√	√				√	√	√					
Nonmetals: Se, As				√	√	√	√			√	√					
Total cyanide				√		√		√			√					
Volatile hydroxybenzene				√	√	√		√			√					
Petroleum		√		√	√	√		√				√				
Anionic surface activated detergents	√	√										√				
Sulphide			√	√	√	√	√	√	√	√	√		√			
Coliform													√		√	
Disease/Pathogens																
Salinization										√	√				√	
Water diversion/withdrawal					√		√	√						√	√	√
Channelization/Impoundment														√	√	√
Odour						√										
Suspended substance	√	√	√	√	√	√	√	√	√	√	√	√	√		√	
Sedimentation					√		√		√						√	
Chrome						√										

Table 6.1 Main Stressors of Water Environmental Impacts for Different Industries (continued)

6.3 Main water impacts

6.3.1 Types of water impacts

EIA of the water environment generally lists the object, type, range and degree of water environmental impacts according to the engineering conditions of the project and the environmental characteristics of the project location. But because of the difference in method, means and evaluation purpose between EIA and EEEI, during the actual economic evaluation on water environment based on the EIA, the object, type and range of impacts need to be reconsidered according to the practice.

When identifying water environmental impacts, several aspects should be taken into account specifically:

- ***Positive and negative impacts.*** The construction project may cause positive or negative impacts through the water medium. When estimating the economic value of environmental impacts of the project, the negative impacts will bring about loss and increase the cost while the positive impacts will bring about benefit and decrease the cost. Both kinds of impacts should be taken into account.
- ***Local and trans-boundary impacts.*** Water environmental impacts may occur locally or regionally. Both kinds of impacts should be taken into account. Many regional impacts have a trans-boundary nature. For example, the impact of the upstream on the downstream, and the impact of the terrestrial water body on the sea, especially the seashore area, should not be ignored.
- ***Surface and underground impacts.*** The project activities not only affect the surface water, but also affect the groundwater directly or through surface water.
- ***Material impacts, social and economic impacts and mental impacts.*** Material impacts on humans and the environment include the physical, chemical and biological impacts on human health and environment. Social and economic impacts may consist of income loss, change of the cultural structure, human migration, and the change of skill demand at the local labour market. Mental impacts include the stress increase caused by the project activities.
- ***Short-term and long-term impacts.*** Environmental impacts may occur during the construction and operation period, and may also occur after the project is expired. So the entire process of the project should be analysed.
- ***Actual and potential impacts***. Some impacts are not distinct, which are long-term cumulative impacts, or cumulative impacts of different projects, or impacts from interactions between several factors, or indirect or secondary impacts (see also chapter 3). Therefore, when identifying the impacts, the potential impacts and interactions should be analysed carefully.
- ***Normal and accidental impacts.*** During the construction and production period of the project, the accidental pollutant discharge sometimes can produce severe environmental impacts and loss. The EIA generally includes

the special analysis evaluation on the risk of pollution accidents. So the economic evaluation should put the same emphasis on this with the environmental impacts of normal production.

6.3.2 List of impacts

After finding out all stressors related with the project, these stressors should be associated with their impacts, that is, the list of water environmental impacts should be set up.

The impact in the traditional EIA on water environment mainly means the direct or indirect impacts of the stressors on the quality of water environmental media, including a few impacts on such recipients as humans and ecosystems. The impact in EEEI on water environment mainly means the ultimate chemical, biological or physical effect on recipients caused by the change of stressors through water environmental media. According to ADB (1996) the impacts can be classified as human health, human welfare, environmental resources and global system.

Each aspect can be further divided into several sub-aspects in term of the practical conditions of the project and the need of economic evaluation. The impacts on global system here mainly mean the international environmental impacts caused by the stressors of the project through the trans-boundary water bodies such as rivers, lakes and seas. Table 6-2 list the impacts of the main stressors on human health, human welfare, environmental resources and global ecological system.

Stressor \ Sector	Human Health			Human Welfare				Environmental Resources					Global System
	Mortality	Morbidity	Impact on pregnant woman and enfant growth	Materials	Aesthetics	Resources use	Social/ Cultural	Coastal and Marine Ecosystems	Ground water	Fresh-water Eco-system	Biodiversity/ Endangered Specicies	Terrestrial Ecosystem	
Water temperature						√		√		√	√	√	
PH				√		√				√	√	√	
DO						√				√	√	√	
COD_{mn}													
BOD						√				√	√		
Ammoniac nitrogen		√	√		√	√		√	√	√	√		
TP		√	√		√	√		√	√	√	√		
TN		√	√		√	√		√	√	√	√		
Metal (Cu, Zn)		√	√			√		√	√	√	√	√	
Metal (Hg, Cd, Cr^{6+}, Pb)	√	√	√			√		√	√	√	√	√	
Fluoride		√	√			√				√	√	√	
Nonmetal (Se, As)	√	√	√			√		√	√	√	√	√	
Total cyanide	√	√	√			√		√	√	√	√	√	
Volatile hydroxybenzene	√	√	√			√		√	√	√	√	√	
Petroleum		√	√		√	√		√	√	√	√	√	
Anionic surface activated detergents													
Sulfide													
Coliform		√	√			√					√		
Disease/Pathogens	√	√	√			√					√		
Salt				√		√				√	√	√	
Water diversion/withdrawal		√	√		√	√	√	√	√	√	√	√	
Channelization/Impoundment		√	√	√	√	√	√	√		√	√	√	
Odour					√	√	√						
Suspended substance				√	√	√				√	√	√	
sediment				√	√	√		√		√	√	√	
Chrome					√	√	√						

Table 6.2 The impacts of the main stressors on human health, human welfare, environmental resources and global ecological system

6.3.3 Description of key impacts

Water Temperature

With regard to the ability to stand very high or very low temperature, aquatic organisms are way behind land organisms. The increase of water temperature will significantly increase the toxicity of the pollutants and reduce the dissolved oxygen. Therefore, heat discharged into water bodies by project practices will increase water temperature and threaten the normal life and living of the ecological environment and aquatic creatures, which will further affect human being's life.

PH

A too high or too low PH value will erode water pipes and other facilities, and also affect the industrial and agricultural activities. Moreover, it has a great impact on aquatic creatures. Most fish species live when PH value is between 5-10, and if PH value falls out of this range, fish will die. Further, the change of PH value will change the existing forms of other pollutants, for example, the decrease of PH value makes it easier for metal ion to separate out and increase the toxicity.

COD/BOD and DO

Organic materials will be decomposed after it enters the water body, consuming a lot of dissolved oxygen. This will disturb the physiological functions of the aquatic organisms and destroy the ecological system.

N & P

Eutrophication of water bodies is a phenomenon caused by the over-breeding of planktons, especially phycophyta. The major reason is the excess amount of nutritive matters, like N and P, the main sources of which are chemical fertilizers and pesticides. Eutrophication will change the plankton community, and phycophyta will become the dominant species to form water flowers, which will sharply reduce the amount of dissolved oxygen in the water and causes large scale death of fish. In a serious situation, it will speed up the aging of the water bodies until the whole water ecosystem disappears. When it happens to oceans, red water bloom will appear, and affect fishing and tourism industries.

Heavy Metal

Because heavy metals like Hg, Ca, and Pb have great toxicity and cannot be degraded in the environment, they have a large impact on human health and ecological environment, even if the concentration in the discharge is quite low. Sewage irrigation with high concentration of metals and/or pesticides will pollute the agricultural products, thereby affecting human beings, animals, soils and water bodies (see also Chapter 7 on land). Table 6.3 lists the major impacts of poisonous heavy metals on human health and the ecological environment.

Table 6.3 Major impacts of poisonous heavy metals on human health and ecological environment

Stressors	Impacts on Human Health	Impacts on Ecological Environment
Hg and its Compounds	Nonreversible damage on brain tissues, nervous system and kidney; methyl mercury may cause minamata disease.	Hg is a relatively high poisonous heavy metal pollutant in water. It's impact on water ecological environment and even the whole ecological environment mainly comes from methylation and biological magnification.
Ca	Destroy blood vessels; change activity of enzymes; reduce functions of kidney; disturb normal process of ossification and cause pathologic change of skeleton; affect the absorption of Fe in intestinal canal.	Might accumulate in fish bodies and damage gill tissues, intestinal villus and canaliculus in kidney duct, affect activity of enzyme in liver and functions and blood, and also may cause pathological changes of fish bodies.
Cr_6^+	High concentration of is highly poisonous to human bodies, e.g. annoy skin; cause mutation and canceration.	Influence the respiratory function of water aquatic organisms.
Pb	Although lead is absorbed by respiratory tract not as much as by human bodies, it is also poisonous to skeleton hematopoiesis and nervous system; a potential carcinogen; affect child development.	Influence respiratory function of water aquatic organisms.
Cu, Zn		Influence respiratory function of water aquatic organisms.

Fluoride, Arsenic(As), Cyanide, Volatile Phenol, Oils, Sulphide etc.

Poisonous matters like fluoride, arsenic(As), cyanide, volatile phenol, oils, sulphide, etc. have a large impact on human health and ecological environment even in very small doses (see table 6.4 below)

Table 6.4 Impacts Poisonous Matters on Human Health and Ecological Environment.

Stressors	Impacts on Human Health	Impacts on Ecological Environment	Other Impacts
Fluoride	The mechanism of the toxicity of fluoride is mainly affecting the normal metabolism of Ca and Pb, and often cause fluorosis, like dental fluorosis.		
As	Compounds of arsenic are mostly poisonous (e.g. white arsenic) and threaten human bodies: low level ingestion will attack human bodies after a long time, and cause nerve inflammation, muscular atrophy, skin cancer and habitual abortion, etc.		
Cyanide	Highly poisonous; acute poisoning will cause asphyxiation immediately; chronic toxication may take antidotal action in human bodies; its toxicity is dependent on PH value, concentration of DO and other metal ions.	Poisonous to aquatic creatures, affecting respiratory process of fishes, seashells and phycophyta.	Affecting the growth of wheat and paddy rice.
Volatile Phenol	Medium toxic matters; entering human bodies in many ways; causing anemia, nervous system and damage of cells and tissues.	Inhibit weight building of fish and development of fish eggs; reducing DO in water; disturb multiplication of phytoplankton.	Affect fishing industry; high concentration of phenol will inhibit the growth of crops.
Oils		Leakage events on oceans cause greatly damage to ocean ecological environment; disturb living and reproduction of aquatic organisms; damage aquatic ecological system.	Affect fishing industry and tourism industry; highly affect growth of crops, especially paddy rice.

Other stressors

Table 6.5 below lists the impacts of other stressors, like coliform, salts, odours, suspended matters, sediments, chrominance, etc.

Table 6.5 Impacts of other stressors

Stressors	Impacts on Human Health	Impacts on Ecological Environment	Other Impacts
Coliform	Cause intestinal diseases and other disease.		
Other Pathegons	Cause many types of disease.		
Salts			
Variation of Water Sources			
Water Canals, Water Storage			Influence scene of water bodies.
Odors			Influence scene of water bodies.
Suspended Matters			Influence scene of water bodies.
Sediments			Influence scene of water bodies.
Chrominance			Influence scene of water bodies.

6.4 Screening impacts

Chapter 3 describes a general screening procedure. The following procedure can be used to screen water environmental impacts:

Step 1: List the pollutants discharged from the project

Generally speaking, each project will discharge several pollutants listed in table 6.2. Based on the information provided by the EIA report, we can easily rank the pollutants in terms of quantity discharged. In the water case, the pollutants discharged from Wanxinzhuang wastewater treatment plant (WWTP) is shown in table 6.6:

Impacts / Stressors	Human Health			Human Welfare				Environmental Resources				
	Mortality	**Morbidity**	**Impacts on Pregnant Women and Infants**	**Materials**	**Aesthetics**	**Resources Utilization**	**Social Culture**	**Aquatic Ecologic System**	**Underground Water**	**Fresh Ecological System**	**Biological Diversity**	**Terricolous Ecological System**
COD	√					√				√	√	
BOD	√					√				√	√	
TN		√	√		√	√		√	√	√	√	
TP		√	√		√	√		√	√	√	√	
SS				√	√	√				√	√	√
Heavy Metals	√	√	√			√		√	√	√	√	√

Table 6.6 Screening water environmental impacts from WWTP of Wangxinzhuang

Step 2: List the main receptors based on step 1 and environmental information from the EIA report

The main work is to combine the main pollutants, impacts and environmental functions of the water body for scoping.

Step 3: Scoping the main area which covers most impacts taken place to most receptors

This work should be done by the EIA report. The ideal situation is that the EIA scope covers most parts of impacts' evaluation needed by the EEEI. If the EIA scope is smaller than needed by EEEI, the researchers have to extend the scope to cover most of the impacts.

According to the list of water environmental impacts and the practical situation of this project, we can identify the receptors of water environmental impacts caused by the project. At this stage, the most important thing is to find out the water body functions of each segment of River Jialu and River Shaying, two rivers affected by the case study project.

Based on the investigation, the main function of River Jialu and its branches is to receive urban wastewater of the Zhengzhou city zone, flood discharge and irrigation sewage. And there is no other function in the Jialu river basin. Besides some water for industry, the water body function of River Shaying is generally similar to that of River Jialu. Therefore, we can analyse all potential receptors according to the practical situation of the basin.

Human health

Review all receptors to be considered including the mortality and morbidity of all related diseases in the basin, such as the mortality of liver cancer caused by COD and BOD. In this part, the objective population is the people who directly or indirectly use the water discharged by the WWTP and people who will be influenced by the water discharged by the WWTP. Therefore, we should collect the data of society and economy, population density etc along River Jialu, its branches and the River Shaying basin. This will be introduced in the section on the situation of society and economy.

Human welfare

Human welfare consists of materials, aesthetics, resources utilization and social culture shown in table 6.2. In this case, according to the importance of each sector, we should consider the impact on resources first, which include industry, agriculture, livestock and fishery.

As for the River Jialu basin, agriculture is the most significant receptor. The improvement of water quality of River Jialu will have three kinds of positive effects on sewage irrigation. The first kind of effect is to increase the production and quality of primary products. The second is to increase the area of farmland irrigated by sewage. The last is to decrease the consumption of clean water during the irrigation.

In addition, as for aesthetics, the operation of WWTP will improve the appearance of the downstream water body. Furthermore, because the living wastewater will mostly enter the WWTP through civil pipelines and do not flow into the River

Xiong'er in the city zone, the aesthetic value of River Xiong'er can be increased. The CV method can be used to evaluate this benefit.

Environmental resources

In this part, we should consider the impact on groundwater of this project. The improvement of water quality of the basin may affect the quality of nearby groundwater.

Scoping the area of evaluation

The affected areas of many construction projects are actually beyond the EIA area provided in the guideline. The consequence is that the environmental impacts are underestimated, and naturally cannot provide enough information for EEEI.

In the Wangxinzhuang case, the EIA area which complied with the EIA Guideline, with an annual capacity of removing 50-60 thousands of COD, is 41.5 km along Jialu River which is located within Zhengzhou administrative boundary. Total length of Jialu river is about 230 km from Zhengzhou to Shaying River.

After several field investigations, we found there are no receptors within the EIA zone. The water quality of Jialu river has not been meeting class 5 of national surface water quality standard before or after the operation of WWTP. Then we extend our scope to whole Jialu river basin to find receptors. Because the water quality in whole Jialu river does not change after operation (the forecast is the same in the EIA report), the only receptor is some agricultural irrigation downstream of Jialu river.

For human health, the possible receptor would be villagers along the bank of Jialu River who drink underground water using the well in their home. The Zhengzhou municipal health bureau is responsible for monitoring the potable water quality in most villages. However, it is often difficult to get hold of such information for economic valuation.

6.5 Quantification of impacts

Quantification of water impacts is to find the relationship between water environmental stressors and receptors, and calculate the water environmental impacts. It is a necessary early step in EEEI.

Important points to consider in quantifying impacts

Usually DR relationships are used to quantify impacts to water. However, not all economic evaluation methods require the quantification of impacts, such as the "pollution cost of emission method", which is directly based on emission to make an evaluation.

Impact evaluation generally quantifies and analyses the environmental quality (ambient medium), but does not quantify the impacts on receptors.

A screening procedure should be followed to decide the impacts to be quantified, for which to find available functions that connect environmental changes and receptors' impacts.

In our research project, we have reviewed all relevant literature both in Chinese and in English we know of especially focusing on China. The list of papers and D-R functions for water are provided in Part II of this report.

We classified the D-R functions into four categories as is shown in table 6.7 below.

Table 6.7 Classification of D-R Functions

D-R category	Sub-category	Number of studies
D-R on human health	sewage irrigation	26
	drinking water pollution	50
	drinking water pollution by toxic substances	10
	D-R with general water pollution index	1
D-R on crops	sewage irrigation	18
	D-R with general water pollution index on crops	1
D-R on fishery and livestock	water body pollution	15
	water body pollution in form of water pollution index	1
D-R on ecological impacts		5

As shown in table 6.7, there are many D-R functions involving the same impacts. Because each D-R function focuses on a different geographical location and different environment, it is difficult to recommend how to choose suitable D-R functions.

Based on the literature on D-R functions, we can estimate water pollution damage partly in terms of value if the related information is available. In fact, based on our research, most information and data needed for EEEI exist in different institutions.

Steps of quantification

Step 1: Calculate the value of the water environmental stressors, including discharges of relevant pollutants and quantitative analysis of water environmental quality changes. Usually, the EIA report provides this information.

Step 2: Identify the receptors. We have described how to do this in a previous section.

Step 3: Analyse the relative sensitivity of the receptors.

Step 4: Estimate the seriousness of the impacts.

Step 5: Quantification of the impacts.

The aim of the last three steps is to find the DR functions and quantify the impacts.

6.6 Economic valuation of impacts

To estimate environmental costs from water pollution is to transform the physical loss into monetary loss. Several methods exist as described in chapter 3 of this report. The sections below apply these general methods specifically to impacts of relevance to water.

6.6.1 Health costs

Below is listed two human capital approaches, while we in Chapter 5 on air pollution demonstrated the use of value of statistical life for mortality valuation.

(1) Human Capital Method: including direct and indirect losses

Direct medical costs = Population suffered from diseases or death × increased percent caused by pollution × medical costs

Indirect costs include:

Work day loss for staying in hospital = population suffering from diseases or death (e.g. 50% of patients expected to get well) × days in hospital × production (productivity × domestic income coefficient 0.5);

Costs of relatives accompanying ill people are estimated as 50% of the costs of above patients or people who died;

Early death costs = working day losses due to early death × net GDP output value per capita

(2) Modified Human Capital Method

$S = [P\sum Ti\ (Li\text{-}Loi) + \sum Yi\ (Li\text{-}Loi) + P\sum\ (Li\text{-}Loi)Hi]\ M$

S = Health losses due to environmental pollution;

P = Human capital (net GDP output per capita);

M = Population in polluted area;

Ti = Average working day time losses of people suffering from disease i;

Hi = Working day time losses of accompanying people due to disease i;

Yi = Average medical costs due to disease i;

Li = Incidence of disease i polluted areas;

Loi = Incidence of disease in clean areas;

Example of modified human capital method

For example, assume water pollution condition is very serious in a region, where we identify major increases in the morbidity of cancer and hepatomegaly. Through investigation we find that the morbidity of cancer is 0.1‰ higher in polluted areas than in clean areas ($L_1\text{-}Lo_2$= 0.1‰), while hepatomegaly is 70‰ higher ($L_2\text{-}Lo_2$=70‰). Average working time losses means that average days or years that people cannot work due to the disease, and here we assume that it is 12 years for cancer (T_1=12 year) and 1 year for hepatomegaly (T_2=1 year). And since Chinese like to accompany relatives or friends when they are in hospital, these people cannot work for a certain period of time. Here we assume the average number for cancer is 36 days (H_1=36/360 year), and hepatomegaly 25 days (H_2=25/360). The average medical cost in this area for cancer and hepatomegaly is 9000 yuan (Y_1=9000 yuan) and 400 yuan (Y_2=400 yuan) respectively. Further, assume that the population in this area is 1 million. As for the output per capita, we can use the net income of local people, as it is easier to find in statistical yearbooks, here, we say it is 1000 yuan per year (P=1000yuan).

Now we can make the calculation:

S=[1000*(12*0.1‰+1*70‰)+(9000*0.1‰+400*70‰)+1000*(36/360*0.1‰+25/360*70‰)] *1,000,000

=[71.2+28.9+4.86]*1,000,000=104,960,000 yuan

(3) Combination of human capital method and protection costs

This method estimates not only the economic losses of the patients but also the social costs to prevent diseases. The formula is as follows:

Ch = Lh+Ph

Ch = Economic value of human health losses due water pollution;

Lh = Health damage cost caused by water pollution, or the economic losses due to water pollution caused diseases;

Ph = Protection costs, or social costs for preventing water pollution related diseases.

Lh = Lc+LW+Ld+Li+Oc

Lc = Medical costs of water pollution related diseases

Lc = ∑lciSiαi

lci = Average medical costs for disease i;

Si = Population that suffer from disease i;

αi = Proportion in population suffer from disease i that get the disease due to water pollution;

LW = Economic losses for working day losses due to water pollution related losses;

Lc = ∑GaNiSiαi

Ga = Domestic income per capita

Ni = Working day losses of patients and accompanying people;

Ld = Economic losses due to water pollution related diseases;

Li = Economic losses from cancelled or postponed social and economic activities due to the breaking out of infectious diseases;

Oc = Economic development opportunity losses due to expenses on medical care;

Ph= Po+Pw+Pt+Pv+Op

Po = Public costs for preventing hydrophytic diseases;

Pw = Construction costs of water supply factory due to water pollution;

Pt = Increases of municipal water treatment costs;

Pv = Water supply reform costs in rural areas;

Op = Investment opportunity losses for expenditure on disease prevention.

Example of applying the formulas

Let us continue the above cancer and hepatomegaly example. We find that besides the costs of the patients (Lh), here we also should include the losses that the society suffers because of the money it has put into the prevention of water pollution related diseases (Ph).

Let's first calculate Lh: Lh=Lc+Lw+Ld+Li+Oc. It's easy to find that Lc+Lw is what we got in the previous method.
(Lc=(9000*0.1‰+400*70‰)*1,000,000=28,900,000,

Lw=[1000*(12*0.1‰+1*70‰)+1000*(36/360*0.1‰+25/360*70‰)] *1,000,000=76,060,000)

Besides the direct losses like medical costs and losses of incomes for taking off to cure disease or to accompany people, we now also take into account the indirect losses. If the patient die from the disease, the society loses the value that he would be able to make if he did not die, and the patient loses the income after he dies. Assuming the average local life-span is 70 years, and that average cancer patients die at 40, while hepatomegaly at 50, and the local net output per capita is 1000 yuan per year, as we've mentioned.

Therefore, Ld=(70-40)*1000+(70-50)*1000=50,000 yuan (Here, we neglect interest, which should be taken into consideration in real calculation)

Assume that an infectious disease spread in the whole region and many social activities were called off or delayed because of it. This data is probably difficult to get, but possible to estimate, say, to compare the outputs in the disease season and the same season last year. Here, we assume it is 200,000 yuan (Li=200,000 yuan).

We know that the patients spent Lc=28,900,000 yuan on medical costs, which, if put into investment, might create an economic return. But whether and how to invest the money often depends on the incomes, jobs, and even characters of the patients, therefore it is difficult to estimate, if it involved a large group of people. You may ask the patients or people who know them how they would invest the money one by one to get the loss, but that's definitely not realistic. One conservative way is to put the money in the bank use the return as an estimate of the economic loss due to losing investment opportunities. Here, we assume the interest is 1%. Since people who died of cancers would have 30 years to invest, and people who died of hepatomegaly 20 years, $Oc=(1+1\%)^{(70-40)}*(9000*0.1‰)*1,000,000+(1+1\%)^{(70-50)}*(400*70‰)*1,000,000-28,900,000=1,213,064+34,165,321-28,900,000=6478385$ yuan

Therefore,

$Lh=Lc+Lw+Ld+Li+Oc$
$=28,900,000+76,060,000+50,000+200,000+6478385=11,688.385$ yuan

As for Ph, the social expenses on prevention of water pollution related diseases, can be obtained from the government agencies and other relevant institutions, except for Op, which can be calculated based on the total prevention investment in the same way that we've calculated Oc.

6.6.2 Agricultural costs

Three methods for calculating agricultural impacts of water pollution are mentioned below:

(1) Market Value Method

$E = \sum Pi\Delta Ri$

E = Economic value of agricultural impact by water pollution

Pi = Market value of agricultural product i

Δri = Production decrease of agricultural product i due to water pollution.

Agricultural production losses due to sewage irrigation

E = Sewage Irrigation area × Productivity decline factor × Price

Quality losses of agricultural products due to sewage irrigation

E = Sewage irrigation area × Production of unit area × Price decline factor

Costs for soil alkalization and increased use of chemical fertilizers

E = Sewage irrigation × increased use of chemical fertilizers factor × price of chemical fertilizer

(2) Productivity method

Economic losses due to agricultural productivity decline caused by temperature decline

(3) Market Value Method and Prevention and Protection Method

LA = DP+DQ+DA

LA = Economic losses of agriculture due to water pollution

DP = Production losses caused by water pollution

DQ = Quality decline of agricultural products due to water pollution

DA = Economic losses of agriculture due to water pollution accidents.

6.6.3 Prevention cost of water pollution

Prevention costs can be used as an estimate of the environmental costs. Assume that the lowest cost of water pollution is to eliminate the pollution. In our case study we calculate the total cost of removing pollutant by WWTP. The cost of WWT can be measured by three indexes:

- treatment cost per ton sewage,
- disposal cost per ton COD,
- annual wastewater treatment cost per capita in the service area of WWT.

The calculating formula is as follows.

Treatment cost per ton sewage (yuan/t) = yearly total cost of WWT/yearly amount of wastewater disposed

Disposal cost per ton COD (yuan/t) = treatment cost per ton sewage / amount of COD disposed per ton sewage = total cost of WWT/yearly amount of COD disposed of WWT,

Annual wastewater treatment cost per capita (yuan/person·year) = annual wastewater treatment cost of WWT/population served by this plant.

Because the WWTP also treats a little industry sewage, the yearly living wastewater treatment cost needs more calculation, namely, yearly living wastewater treatment cost=yearly total cost of WWT×yearly amount of living wastewater treatment/yearly amount of wastewater treatment.

Doing this calculation[16] for the WWTP in our case gives an estimate of prevention costs (see table below):

Table 6.8 Forecast and Actual Waste Water Treatment Costs

	Treatment cost per ton sewage	Disposal cost per ton COD	Annual municipal wastewater treatment cost per capita
Forecasting	0.42	1986	41.2
Actual	0.579	1264	32.7

6.6.4 Other environmental costs

Animal husbandry costs

(1) Market Value Method

[16] Details are provided in the case study report included in Part II of this report.

$E = \sum Qi (\Delta Fi \times mi + \Delta Si \times ni)$

Qi = Number of animal i in polluted area

ΔFi = Increase of morbidity of disease i due to pollution

ΔSi = Mortality increase of animal i due to pollution:

mi = Average medical care costs of animal i

ni = Average market price of animal i

(2) Market value method and protection and prevention method

LA = DP+DQ+DA

LA = Economic losses of animal husbandry due to water pollution

DP = Animal production volume losses due to water pollution

DQ = Economic value of quality decline of animals due to water pollution

DA = Economic losses of animal husbandry caused by water pollution accidents.

Water pollution might reduce the volume of production from a to b, and the loss due to production output losses is (a-b)*P, assuming the price is P. Pollution may also affect the quality of the animal, which should be reflected in the price but unfortunately in most cases not. One way to estimate the price of the animal with decreased quality is to assume that the price drops at the same rate as the quality, that is to say, if the quality declines s%, the price also drops the same proportion. And the value due to quality decline is b*P*s%. Besides, water pollution accidents might happen and cause great economic losses, which we can often get in relevant reports.

Fishery costs

(1) Market Value Method

$E = \sum(Si \times \Delta Li \times ni)$

Si = Farming area of fish or other aqua product i

Δli = Loss factor of farming fish or other aqua product i

Ni = Average price of fish or other aqua product i

(2) Divide pollution zones according to comprehensive water quality pollution indicator, and determine the economic loss rate of fishery by consulting fishery experts and investigating samples.

(3) Productivity method and protection and prevention method

Impacts on fishery, including the increase and decline of fishery production

(4) Market Value Method and Protection and Prevention Method

LF = DFR+DFA+AF

LF = Economic losses suffered by fishing industry due to water pollution

DFR = Fishery resources losses caused by water pollution

DFA = Economic losses due to water pollution caused by fishery pollution accidents

AF = Expenditure on preventing water pollution in fishing industry.

Industry costs

Market Value Method, Protection and prevention Method, and Opportunity Cost Method can be used:

LI = DIS+DIF+ DIQ+AIT

LI = Economic losses suffered by industry due to water pollution

DIS = Economic losses suffered by industry due to water shortage caused by water pollution

DIF = Economic losses due to quality decline of industrial products

AIT = Increase of water treatment costs due to water pollution.

Drinking water costs

(1) Opportunity Cost Method

Losses due to pollution of drinking water sources in urban areas are calculated as the net productivity of water resources.

(2) Shadow Project Method

Loss from underground drinking water losses in rural areas: Multiply increased costs for increased difficulty to obtain water and the damage costs of water supply equipments with the pollution factor to get the economic losses caused by drinking water sources pollution in rural areas

Currently, in most rural areas of China, farmers use ground water resources, however, in many places, farmers have to transfer water from other places, because the ground water is polluted. So they spend extra money on construction of the transferring facilities, etc. This can be regarded as the loss value of the ground water pollution.

(3) Protection and prevention costs method

Costs due to drinking water sources pollution in reservoirs. Increased drinking water treatment costs due to water pollution is regarded as the economic losses of reservoir pollution

This method calculates the extra money it should cost to treat the polluted ground water. It is appropriate to use if we know the quality level and amount of the ground water.

Recreation costs

(1) Recover and Protection Costs

Aesthetic loss of rivers: annual investment on treating river pollution is regarded as the minimum value of the loss

(2) Investigation methods

Loss of seashore swimming sites: investigate people's WTP for current seashore swimming sites and for those with improved environment and find the difference between them

(3) Travel costs method

Method can for example be used for the economic evaluation of dams on recreational activities

Ecological costs

Recover costs method and rehabilitation cost method can be used: Economic evaluation of dam's impact on wild animals, including the increase and decline of wild animal species.

6.7 Summary of case study

6.7.1 Introduction

We chose Wangxinzhuang Waste Water Treatment Plant (WWTP) as the case. It is located in the southeast part of Zhengzhou City, and mainly treats the municipal wastewater (also the industrial waste water discharged into the sewer system) of the South Eastern area of the city and new district of Zhengzhou city and discharges treated water into Jialu River, a branch of Huai River. Jialu River joins Shaying River in Zhoukou City, Henan province.

Jialu River is the most important river running through Zhengzhou. As the upper stream was blocked, Jialu River is actually receiving no clean water. As Jialu River receives municipal sewage from Nanyang Dam, and receives the seasonal returning water from agricultural irrigation in the suburb area, it has effectively become the drainage of municipal wastewater of Zhengzhou City, with the water quality inferior to level 5.

As both the biggest WWTW and one of the key projects in Huai River Basin, the plant not only effectively improved the water quality by decreasing the BOD, COD and SS content in municipal wastewater discharges of Zhengzhou, but will also contribute to the improvement of the water quality of the downstream Shaying and Huai Rivers. In addition to the municipal wastewater, the plant also treats part of the industrial sewage in the downtown area.

6.7.2 Evaluation process and results

The environmental benefits of the WWTP are mainly obtained by the downstream area. We chose Jialu River Basin and the downstream Shaying River as the area to be evaluated.

In selecting stressors, we chose COD, BOD, SS and TP, which are the main pollutants eliminated by the plant.

Health benefits

In selecting environmental impacts, we put the emphasis of the economic evaluation on the impacts on human health, agriculture and aesthetics. In evaluating the impacts on human health, the problems or difficulties that we face include the applicability of DR relations and the absence of data, and the fact that local residents do not use the water in the river for drinking, instead, they take underground water or the upstream water. But, the underground water quality is also very bad, and about 15% percent of the total farmers in Zhengzhou City drink seriously polluted water. We can also assume that around the same 15% of farmers in Jialu River Basin drink bad quality water, which is a conservative estimate as the area is the most seriously polluted in Zhengzhou City.

By summarizing the population of local farmers, we estimated the involved number of farmers to be 99353. Then we used Modified Human Capital Method to calculate the benefit, that is 26.9 million, and we further multiplied it with the contribution percentage of the waste treatment plant, 0,33, and got the economic value of the impact on human health, which is **8.84 million RMB**

Agricultural and other benefits

In the calculation of the impacts on agriculture, we calculated the economic benefits from the increase of agricultural production and from quality improvement. We first calculated the concentration of the WWTP with two methods.

The first method is to calculate the contribution of the WWTP in disposing of the COD if water quality is improved from two levels, and got the result of 69%, which means that if the treatment capacity doubles, water quality in the down stream of Jialu River in Zhongmou County Area would reach Class III. That seems unlikely.

The other way is to divide the population that the WWTP serves by the whole population of the city, and we got 41% contribution to the increase of agricultural production. The first method neglects the impact of natural purification, which would have over-estimated the percentage of contribution of the WWTP. Besides, the second data seems more realistic. We choose 41% as the contribution of the WWTP.

Then we calculated the outputs from sewage irrigation farmland in 2000, 6369 tons of paddy and 6868 tons of wheat. With DR functions, we got that the output of paddy and wheat increases 1592 ton and 763 ton respectively when irrigation water quality increases from standard III to standard V and multiplied them with the contribution percentage of the WWTP to get $1592\times0.41=653$ tons of paddy production increase and $763\times0.41=313$ tons of wheat production increase.

Based on these data, we calculated the benefits from quality enhancement and quantity increase by multiplying the prices of the crops, and we got **1,020,000 yuan** from quantity increase and **180,000 yuan** from quality enhancement, the total of which is **1,200,000 yuan**. This is the economic value of the impact on agriculture by the WWTP.

We also roughly estimated the impact on underground water resources. We used increased water treatment cost as the benefit. Our calculation is based on the fact that the water quality of all rivers in urban area of Zhengzhou is at level V, and the underground water, most at shallow level and some deep level, has been seriously polluted. Therefore, we assume that the water infiltrated from surface water into ground water is all at level V. The amount of underground water resources in urban area of Zhengzhou City was 127,280 thousand m^3, of which 19,840 thousand m^3 is recharged by surface water, including water infiltrated from rivers, pools, reservoirs, ditch irrigation systems, etc.

Since Jialu River is the major river in Zhengzhou, and the water used in ditch irrigation is mostly from Jialu River, we assume that the water is filtrated from Jialu River, including it's four branch rivers, and assume that the water quality is at level V. The treatment cost would be $0.42*19840*10^3$=8,332,800 yuan for secondary treatment (assuming the cost to be 0.42yuan/ton). Although, soil and its ecosystem may have absorbed or removed some pollutants when the water is passing through, the water that finally arrives in ground water reserves may have been treated to a certain extent. Nevertheless, soil ecosystems also belong to environmental resources, therefore, the value we have got may be considered as the benefits both on underground water, soil and soil ecosystems. Further, we multiply this value with the contribution percentage of the WWTW 0.41, that is 8,332,800*0.41=**3,416,448 yuan**.

Total benefits of the WWTP

In conclusion, what we have calculated include health benefits, which is 8.84 million, human welfare benefit, which is 1.02 million (quality benefit of 0.18 million excluded), and environmental resources benefits, which is 3.4 million, the total economic value is **13.26 million RMB.** And in calculating the three values, we tend to be conservative; therefore, the value is likely to be much smaller than the actual one.

What we have not been able to calculate include benefits of industry, saving of agricultural water use, aesthetic value and on water ecosystem, among which, as we have argued, benefits of industry is small, and the other three would be very large, especially that of water ecosystem.

Please refer to Part II for detailed information of the case study.

6.7.3 Findings and Analysis

In this study, our objective has been to make an EEEI based on the EIA report of a large wastewater treatment plant. We have calculated the economic value of three very important impacts, but there are many more we have not been to calculate due to many reasons. Our calculations were all based on assumptions that the water quality is improved from level V to III, and we calculated the contribution of the WWTP. With this method, we find that we can calculate many impacts of the project, if we have data. However, lack of data is sometimes a problem.

We sum up some of the challenges we encountered and key lessons in conducting an EEEI based on EIA below:

(1) Insufficient data and Information in EIA Report

What the EIA report provides are the emission data of the pollution sources and the concentrations of pollutants in the environmental media before and after the construction of the project, while information concerning the final receptors (e.g. human health, agricultural products) is rarely given.

In the WWTP case, the EIA report estimated the changes of surface water, ambient atmosphere, groundwater, soil, agricultural products and sound environment etc that the project are expected to bring, while it provided no information concerning the population and the agricultural products exposed to these water bodies, and naturally no evaluation of impacts on them.

Even with regard to the evaluated items, the EIA did not make a comprehensive estimate, only a simple description of the future condition is given. Another example is the agricultural products, where the EIA report only describes the structure of agricultural products and the total products in general terms. There is no attempt to give an indication of agricultural benefits.

In addition, the EIA report does not provide economic data.

The absence of the information described above largely increases the difficulty of EEEI only based on the EIA report.

(2) EIA area is generally too small

The affected areas of many construction projects are actually beyond the EIA area provided in the guideline. The consequence is that the environmental impacts are underestimated, and naturally cannot provide enough information for EEEI.

In this case, according to the EIA Guideline, the EIA area for the WWTP, with an annual capacity of removing 50-60 thousand of COD, is within the Jialu River Basin, when the affected area should be much larger (at least the downstream Shaying Watershed should be included).

(3) Insufficient DR functions

As far as what we have found, there is only one study carried out by the World Bank that sets a scale of five levels for environmental quality, while most DR relations only distinguish clean areas and polluted areas. Generally speaking, a single project cannot be expected to move the water quality to a different level of the water quality standard. For example, as a water treatment project, Wangxinzhuang WWTP is quite a big project, and the EIA report estimates that the water quality is still below grade V after the plant is brought into operation. Therefore, we doubt if there are appropriate DR relations for individual projects.

Beside, as literature on DR relations provides little background information, the applicability of them becomes a problem.

(4) Economic data are available

In the process of calculation, we found that economic data, for example, prices, salaries and GDPs are basically available.

(5) The case demonstrated that benefit estimation beyond the EIA report can be very useful

Despite the general lack of information in the EIA report, some additional data collection can be combined with the EIA report to provide very useful estimations of health and agricultural benefits of water treatment projects. It is likely that such calculations will be more useful the larger the area under consideration, and the more projects are considered together.

7 Land

7.1 Introduction

Purpose and main contents

This chapter discusses the impact on receptors and their valuations via the media of land, by social economic activities.

Land is a more broad term than soil. Land as a resource has two features: area and quality. The EIA should not only focus on the quality of soil by pollution, but also on the land quality and area changes due to the changes of land use, as those activities may result in the decrease of land productivity either directly or indirectly, and further impose impacts on human health, human welfare, environmental resources and global system, and therefore influence the cost effectiveness or cost benefit analysis of the project be assessed.

However, due to the heterogeneity of land/soil, the variety of special allocation, and different objectives of the quality standards (for example, to protect the normal function of land, protect the environment for plants to grow, and human health), uncertainty and lack of dose response functions[17], and the diversity of the valuation and assessment approaches and methods, it is not straightforward to conduct EEEI of pollution and use changes on land. Furthermore, there is limited information and data available in the EIA reports, and it may also be hard to judge its reliability.

Given this situation, this chapter is not only based on single project EIAs, but has a broader focus on activities with regional impact. The chapter provides procedures and related valuation methodologies for impacts on land use and land quality, and demonstrates the use of those methodologies in the case studies.

The basis logic follows the overall methodology of this report, that is emission sources → stressors → changes of environmental quality → determination of impacts → screening of impacts → quantification of environmental impacts → economic valuation of impacts

The key contents of this chapter cover:

[17] Especially hard to find the direct relationships on the human health)

- Identification and definition of stressors. Stressors will be identified according to the pattern of the impacts on land degradation by projects and activities, including, soil quality, land productivity, land use, etc. They will also be identified and defined according to guidelines on environmental impact assessment, environmental standards, emission standards, as well as the up to date literature and studies.
- Identification and analysis of the environmental impact and impact on the final receptors via land as a media, for example, crops, livestock, underground water
- Procedures and quantification of environmental impact and economic evaluation on land and soil
- Economic valuation approaches and methods
- Case studies and issues need to address

Existing guidelines and regulations

Below is a list of relevant laws, regulations and guidelines:

- NPC: environmental impact assessment law
- Decree of Environmental Management on Construction Project
- HJ/T2.1-93）SEPA: Technical Guideline for Environmental Impacts Assessment
- SEPA: Technical Guideline for Environmental Impacts Assessment for surface water（HJ/T2.3-93）
- SEPA: Technical Guidelines for Environmental Impact Assessment: Ecological Environment of Nature Resource Development
- GB15618－1995 SEPA:environmental quality standards for soil
- GB3838-2002）SEPA: Environmental quality standards for surface water (GHZB1-1999)
- GB/T14848-93）SEPA: Environmental quality standards for underground water SEPA:
- Environmental Quality Standards for Domestic Drinking Water（CJ3020-93）
- Emission standards for sewage water
- Standard for pollution control on the security landfill site for hazardous wastes
- Sanitation Standards for Domestic Drinking Water（GB5749-85）
- Water Quality Standards for Fishery（GB11607-89）
- Water Quality for Landscape and Recreation（GB12941-91）
- GB5084-92）Standards for irrigation water quality
- HJ/T 80-2001 Technical norm on organic food
- Standards for Safe Use of Pesticides (GB4285－89)

- P.R. C Industrial Standards: Technical Standards for Road Engineering (JTJ001－97)

7.2 Identification of stressors and definition of impacts

In order to assess the impacts on land by a construction project or social economic activities on land and further impacts on final receptors, the first step needs to identify those factors influencing the land quality and land uses, and specific impacts on the soil quality, human health and welfare, and environmental resources as well as the global system. Secondly, one needs to estimate the scope of those impacts, identify the dose-response functions, and further to give a monetary assessment of those impacts based on certain economic evaluation methods, which could serve as the basis for the overall evaluation of the feasibility of a project or activities (e.g. in a cost benefit analysis, as discussed in Chapter 1).

7.2.1 Criteria for identifying and screening key stressors

(1) Identify the path of the impact on land by project or social economic activities

To identify and describe how the projects/activities impact on land, via pollutants emissions, construction, operation, etc on soil quality, land productivity, land use pattern, etc, and which in turn impacts on land media, and impacts on receptors, which will represent social and economic losses. Therefore, the first step of this chapter is to find out whether a certain project, activity, or production process imposes impacts on land. The driving force for producing those impacts is the stressor to be addressed in this chapter.

(2) Define the key stressors based on existing environmental impact guidelines and standards

The Technical Guidelines for Environmental Impact Assessment, Technical Guidelines for Environmental Impact Assessment: Ecological Environment of Nature Resource Development and others state that:

- The EIA must be objective, transparent, fair, and give a comprehensive consideration to various environmental factor and its impacts on ecosystem during the planning process and operation after the completion of the construction project.[18]
- The major ecological impacts on land as a media, include: biome (reduction of biomass, reduction of the degree of heterogeneity, biodiversity reduction, loss of endangered species); regional environment (reduction of green land, uneven distribution of green land, poorer accessibility of the land); water

[18] NPC, EIA Law, 2002

and land degradation (desertification, physicochemical property/degradation), sensitive areas[19]

(3) Cover key pollutants and activities listed in existing environmental standards

According to the various standards listed in 7.1, the key pollutant which impacts on the physical and chemical features of the soil includes:

- cadmium, mercury, arsenic, copper, lead, chrome, zinc, nickel, 666, DDT[20]
- Technical Guidelines for Environmental Impact Assessment: Ecological Environment of Nature Resource Development requires the assessment of typical natural resource development projects, which requires the EIA of natural resources development projects, hydro projects, mining resources projects, transportation projects, land development and utilization projects, forest harvesting projects, and tourist resources development projects

(4) Existing studies and findings

As there are no concrete guidelines available, the land is different from the chapters on air and water. Therefore, to introduce the up to date findings from literature and studies is very much necessary

7.2.2 Identification of stressors

Based on the literature review and consultation, the key influencing stressors for land includes the following:

- inorganic, 8 is stated in standards, Cd, Hg, As, Cu, Pb, Cr, Zn, Ni
- toxic organic, in which pesticide is the most importance
- organic: Benzo(a)pyrene, PCB, Dioxin
- fertilizer
- sanitization
- soil erosion
- hazardous microbes
- radiation
- invasive species
- over use
- land use

[19] Technical Guidelines for Environmental Impact Assessment: Ecological Environment of Nature Resource Development HJ/T 19-1997

[20] Environmental Quality Standards for Soil.GB15618-1995

7.2.3 Definition of receptors and impacts

Receptors

Receptors can be divided into direct and indirect receptors:

- *Direct receptors:* human beings, plants, forests, animals, underground water, soil
- *Indirect receptors:* refers to those receptors not directly affected by land media changes, but by affected through the food chain due to the quantity and quality changes of land media

Table 7.1 Receptors of major stressors

Stressors	Receptors
Heavy metal	Crops, plants, animals, human
Inorganic (As)	Crops, human
organic Benzo(a)pyrene, PCB, dioxin	Human, fish, plants, crops
Pesticide	Crops, plants, animals, human
Fertilizer	Forests, crops, fishery, underground water, soil
Stalinization	Land resources, crops, plants
Soil erosion	Land resources, fertility, crops, forest, amenity

Impacts

As for the other chapters in the report, this chapter uses the ADB (1996) impact categories below. Some sub categories are developed based on the real situation and needs for economic evaluation

- human health: morbidity, mortality, sensitive population
- human welfare: material, amenity, uses of resources, social and culture
- natural ecosystem: ocean, underground water, freshwater ecosystem, biodiversity, territory ecosystem,
- global system

The following are dimensions of impacts that should be kept in mind:

- short-term impacts/long term impacts
- surface and underground impacts
- positive impacts/negative impacts
- internalised/external impacts
- some questions should be noticed when discussing the impacts on land: cumulative effects, joint effects between pollutants; the joint effects between different media (water, air)

7.2.4 Table of stressors and impacts

After defining the stressors, it is necessary to link those stressors with impacts on receptors, that is to establish the list and table of the stressors and impacts.

It is needed to state here, that the impacts discussed are not only focussing on the impact stressors (pollutant stressors) on the land media either directly or indirectly, but also the impacts on the receptors, for example, human, ecosystem, etc. It mainly refers to the final impacts by the changes on soil/land due to the stressors' changes and their chemical and physical biological results on receptors. According to ADB (1996), the impacts are divided as human health, human welfare, environmental resources, and global system. Table 7.2 summarises the stressors and impacts.

Table 7.2 Potential stressors/impacts on land

		Human health		Welfare				Ecological system					Global impacts
		Mortality	Morbidity	Quantity of crops	Quality of crops	Quantity of livestock	Quality of livestock	Fertility of land	Underground water	Types of land resources	Biodiversity	Terrene eco-system	
Inorganic	Cd	√	√	√	√	√	√	√	√	√	√	√	
	Hg	√	√	√	√	√	√	√	√	√	√	√	√
	Cr	√	√	√	√	√	√	√	√	√	√	√	
	Pb	√	√	√	√	√	√	√	√	√	√	√	
	Copper	√	√	√	√	√	√	√	√	√	√	√	
	Zn	√	√	√	√	√	√	√	√	√	√	√	
	Sn	√	√	√	√	√	√	√	√	√	√	√	
	Ni	√	√	√	√	√	√	√	√	√	√	√	
Organic	Benz□	√	√	√	√	√	√	√	√	√	√	√	√
	PCB	√	√	√	√	√	√	√	√	√	√	√	√
	dioxine	√	√	√	√	√	√	√	√	√	√	√	√
Pesticide	666	√	√	√	√	√	√	√	√	√	√	√	√
	DDT	√	√	√	√	√	√	√	√	√	√	√	√
Fertilizer				√	√			√	√	√	√	√	
Soil pH value				√	√			√	√	√	√	√	
Acid deposition				√	√			√	√	√	√	√	
Erosion and Salinization				√	√	√	√	√		√	√	√	
Desertification				√	√	√	√	√	√	√	√	√	√
Land use				√	√	√	√			√	√	√	√
Sewage irrigation		√	√	√	√	√	√	√	√	√	√	√	

7.3 Quantification of environmental impacts and economic analysis

The applicable valuation techniques vary with impact pattern and scope on the final receptors from different pollutants, their transformation and cumulative impacts as well as the joint impacts and effects among pollutants in a certain environmental media. But generally speaking, three major steps are required:

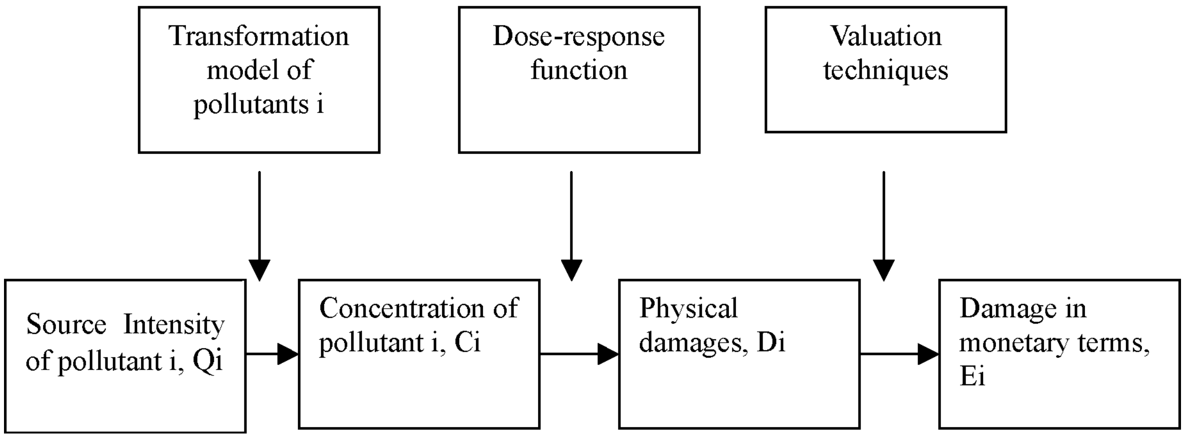
(1) Identify the changes of the ambient environmental quality and their receptors, to determine the items that need to be estimated;

(2) Determine the physical quantities or changes of the receptors and choose the applicable valuation methodologies;

(3) To choose the right price to estimate the monetary value of the impacts.

The steps involved in this process of EEEI are summarised below[21] and illustrated in Figure 7.1.

Figure 7.1 Process of economic valuation for estimation of environmental impacts



Step 1: Determine the pollutants and emissions, and identify the type and size of associated environmental impacts.

In this step, the pollution sources and emission intensities are determined based on information either by EIA reports or related studies, or based on the direct investigations of emission discharges or the production processes etc. After bringing together this information, one can identify those potential stressors and impacts that should be quantitatively assessed.

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[21] Based on the approaches used by Zhang Shiqiu, Duan Yanxin.1999. Marginal Cost Pricing for Coal Fired Electricity in Coastal Cities of China: The Case of Mawan Electricity Plant in Shenzhen, Guangdong Province. EEPSEA Research Report Series. Singapore, April 1999

Step 2: Identify and assess the changes in environmental quality.

Based on literature review as well as pollution transformation models, the incremental changes of each pollutant in the land can be simulated and calculated. For land pollutants and pollution, the following methodology is introduced:

$$\Delta C_i = F(Q_i), \text{ and}$$
$$\Delta C_{i'} = F'(Q_i) \qquad [2]$$

In which,

ΔC_i	the concentration changes of pollutant i in land or soil studied
$\Delta C_{i'}$	concentration changes of secondary pollutant i' of pollutant i
Q_i	intensity of pollutant i

Once the pollutants and pollution transformation models are established, the pollutants distribution emitted by certain sources can be estimated. Typically, receptor cells will be defined for the effected regions. The concentration at the central point of each receptor cell can be calculated using the model and this central point value will serve as a proxy for the concentration of the whole receptor cell.

The concentration of pollutant *i* in each receptor cell *k* is thus approximated by formula [3]:

$$\Delta C_{ik} = A_{ik} \times Q_i \qquad [3]$$

In which,

ΔC_{ik}	incremental concentration of pollutant i in receptor cell k
A_{ik}	transformation coefficient of pollutant i in receptor cell k
Q_i	intensity of pollutant i

A_{ik} is a parameter determined by the pollutants' transformation models. Its value is dependent on the type of pollutant i as well as the location, topographic features, and geographic conditions of receptor cell k.

Step 3: Calculate the physical damages caused by pollutants by establishing dose-response relationships.

Using a dose-response relation and ΔC_i, the physical damages caused by each pollutant can be calculated. Each pollutant will affect several receptors within a receptor cell. The degree of damage, D_{ijk}, in each receptor cell is the function of C_i and the number of receptors. Previous studies show that the dose-response relations of pollutants have different shaped curves. Although most of the D_{ijk} functions are non-linear, to simplify calculation, a linear function can be used for simulating the real D_{ijk} at certain levels of concentration.

The linear dose-response function used in this study is shown in formula [4].

$$D_{ij} = D(\Delta C_i)$$
$$D_{ijk} = B_{ij} \times \Delta C_{ik} \times T_{ijk} \qquad C_{ik} \geq C_{i0} \qquad [4]$$
$$D_{ijk} = 0 \qquad C_{ik} \langle C_{i0}$$

In which,

D_{ij} physical damage j caused by pollutant i

D_{ijk} physical damage j in receptor cell k caused by pollutant i

ΔC_{ik} concentration changes of pollutant i in receptor cell k

C_{i0} threshold for damage caused by pollutant i

B_{ij} coefficient of dose-response of pollutant i and impact j

T_{ijk} number of receptors in cell k for impact j caused by pollutant i

Step 4: Economic Valuation of physical damage in receptor cells identified above

The valuation methodology for the various types of physical damages will vary depending on the characteristics of the damage. There are many valuation techniques that have been developed, which have been described in Chapter 3. However, due to the limited information and data currently available, the "benefit transfer technology" technique can also be used. This can be expressed in the following way[22]

Formula [5] is used to calculate the monetary value of the physical damages.

$$E_{ijk} = P_{ij} \times D_{ijk} \qquad [5]$$

In which,

E_{ijk} monetary value of the impact j in receptor cell k produced by pollutant i

P_{ij} monetary value of impact j in one year produced by pollutant i

D_{ijk} physical damage j in receptor cell k caused by pollutant i

Step 5: Summary and analysis of the computational results.

The following formula [6] summarises the computation of damage effects:

$$E = \sum_i \sum_j \sum_k [P_{ij} \times (A_{ik} \times Q_i) \times B_{ij} \times T_{ijk})] \qquad [6]$$

In which, E represents the annual value of total environmental damages caused by certain pollutants.

7.4 Selection of valuation approaches

General way for choosing the methodologies

Environmental resources are assets that provide services for productivity, health, amenity, and existence values. For valuing the different functions, different valuation techniques can be used (see table 7.3). Further explanation of these methodologies is give in Chapter 3.

[22] The other methodologies being used is further explained in the following section 7.5

Table 7.3 Valuation techniques based on the services provided

Impact	Valuation
Productivities	Direct market valuation, prevent and defensive approach, reallocation approach, substitute market
Health	Human capital, VSL, COI, CV, defensive and prevent. approach
Amenity	CV, Travel cost, hedonic pricing
Existence value	CV

Criteria for economic analysis on land

In addition to the general criteria, the following factors should be given consideration:

- Importance of the impacts and the size of the project/problem: Only those impacts with significant effects and large projects should be given thorough evaluation Therefore, the features of the key impacts are the most influencing factor for the choice of to methodology
- Availability of data and information
- Funding available and timing requirements.

7.5 Specific valuation methodologies

We can evaluate the impacts on land through three sets of approaches, which are described in table 7.4 below:

(1) Examine the impacts on the final receptors, and value those directly;

(2) Estimate the cost of compliance, pollution control or mitigation, to use this cost as a proxy of the impact value. It should be noticed here that due to the cumulative effects, activities that meet the policy requirements may still generate impacts on the final receptors. Therefore, the cost estimated here is a conservative estimate of the value of the damages;

(3) Estimate the cost of prevention and defensive expenditures, to estimate the WTP to avoid possible damages. It should be noticed here that people would generally value the prevention or defensive cost lower than the predicted damages (otherwise they would not pay for prevention and accept the impacts). Therefore the cost estimate here would also be conservative and lower than the impact valuation based on the final receptors. However, for various reasons people may be able to judge the situation and spend too much on prevention etc. Therefore, in practice, it is necessary to clarify what are rational defensive behaviours.[23]

[23] Please refer to Zhang Shiqiu, Chap 8 economic valuation approach, in the text book of "Environmental Economics" by Ma Zhong, Zhang Shiqiu, etl. 1999

Each main type of methodology is described in detail after the table below, starting with methods assessing impacts on final receptors.

Table 7.4 The methodologies recommended for evaluating the impacts on receptors and behavioural choices

Impacts	**Evaluation based on the impacts on final receptors**	**Behavioural choices**	
		Compliance or pollution control/mitigation	Prevention, defensive restoration, averting behaviours
Changes in the output of agricultural products; which can also apply to livestock	Conventional economic valuation can be introduced Productivity Approach CV	Cost of investment and operation and maintenance for compliance of water (sewage irrigation) Pre treatment cost for reaching the irrigation water standards Cost of facilities and behaviours to meet the effluent standards	Defensive cost Replacement cost Alternative cost Shadow engineering Opportunity cost
Changes in the agricultural quality, which can also apply to livestock			
Impact on human health	COI Human capital VOSL CV Regional comparison		
Changes in soil quality and fertility (productivity)	As changes of land productivity and land use will serve as media, to further produce impacts on the final receptors: agricultural products, therefore, need not to be calculated here to avoid double counting	Compliance cost (as above)	Cost of alternatives: for example, land use changes, to use clean water for irrigation Cost of Restoration of the soil's function or the fertility of soil
Pollution on underground water	Same for underground water, as it may serves as the sources of drinking water sources for human being or livestock, therefore should value the health impacts on human or livestock, here need not to calculate	Pre treatment cost before using the underground water	Cost of changes of drinking water
Changes of land use			Opportunity cost

Valuation based on the impacts on final receptors

Changes in output and quality of agricultural products

The general procedures to value the changes in quantity and quality of crops or livestock can be summarized as follows:

1) Use dose response or other available information, for example, by regional comparison, to estimate the changes in degree and scope of the output and quality of agricultural products through changes in soil or land quality, to estimate the impacts on the production cost and output, or;

2) Estimate the market value of the changes of outputs or costs. Assume that "E" in the following formula refers to the economic value due to overall changes of productivities and qualities caused by pollution or pollutants in land or soil:

$$E = \left(\sum_{i=1}^{k} p_i q_i - \sum_{j=1}^{k} c_j q_j \right)_x - \left(\sum_{i=1}^{k} p_i q_i - \sum_{j=1}^{k} c_j q_j \right)_y$$

In which,

P refers to price of crops or livestock, "i";

q refers to quantity of output or input being studied

c refers to the price or cost of the unit input of "j"

i=1, 2,…,k , refers to the types of products;

j=1,2,…,k , refers to the types of input for producing products (crops, or livestock) "i".

x, y denote the land or soil with and without change respectively.

This formula is generally applicable to most of the situations. Three complications should be noted:

- *All* changes in net output, direct and indirect, associated with the environmental change should be valued. For example, deforestation may open up agricultural land, but also cause soil erosion and increase sedimentation of waterways.
- To value output changes, we generally need to forecast both the impacts of the proposed action on the environment and the relationship between this environmental change and output.
- Producers may respond to environmental changes by altering their output or their method of production, for example by changing their crop or their mix of inputs.

Human health impacts

Six steps to carry out the valuation of human health impacts:

(1) Identify the driving factors for a certain disease in the environment
(2) Identify the relationship between that driving factor or stressors with morbidity and mortality (via dose response or regional comparison approach)
(3) Assess population under risk
(4) Calculate income losses and medical costs related to the working day loss due to certain disease, which can be used to estimate the economic value of time and resources wasted (see also the Chapters on Air and Water). To use the COI

$$I_c = \sum_{i=1}^{k} (L_i + M_i)$$

I_c, economic losses due to environmental quality changes

L_i, average wages losses of type i in the population due to the disease

M_i, medical costs of type i in the population

If the real medical costs suffer from price distortion, we should use shadow price or wages to adjust

(5) The human capital approach can be used to estimate premature death losses

$$Value = \sum_{i=1}^{T-t} \frac{\pi_{t+i} \bullet E_{t+i}}{(1+r)^i}$$

π_{t+i} = probability of the person in age t to survive to t+i

E_{t+i} = predicted income at the age t+i

r = discount rate

T = retirement age

Valuation based on compliance, control or mitigation costs

The general process can be summarised as follows:

(1) Identify the related information and data regarding investment costs (capital costs), I; then discount I to net present value, I_{NPV}, by using the following formula:

$$I_{NPV} = \sum_{t=1}^{n} \frac{I_t}{(1+r)^t}$$

Where I_t refers to the investment cost in year t, t = 1.... n; and r is the selected discount rate.

(2) To estimate the annual net present value of investment cost I_{NPV} use the following formula

$$AI_{NPV} = \frac{I_{NPV}}{T}$$

Where the AI_{NPV} refers to the annual cost per year, that is the annual investment cost; T refers to the period of study.

(3) Identify the annual operating and maintenance cost, and treatment amount for compliance, control or restoration activities, O_i. It should be noted here that the operating and maintenance cost also happen in various years. Here we use O to represent this cost as the present value in the base year.

(4) Estimate the present value of total annual cost of the activities being studied

$$AC = \sum_{i=1}^{k} AI_{NPV_i} + O_i$$

AC, refers to the annual cost for the activities of overall compliance/mitigation or restoration. i=1,2,3…k; refers to the activities studied (pollutant or pollution that meet the emission standards, compliance, or mitigation, or elimination, or restoration);

(5) Estimate the unit cost of compliance or mitigation, or restoration or elimination

$$UAC = \sum_{i=1}^{k} AC_i / Q_i$$

Qi refers to treatment amount or mitigation amount of pollutants via type i activities/facilities

It should be noted here that AC or UAC are both estimation results, which can be applied for different purposes, either annual cost (value) or unit value of the evaluation of environmental impacts.

Valuation based on the defensive expenditures and averting behaviours

For those preventive/defensive behaviours involving engineering projects or facilities, the same procedures and approaches listed in the above section (evaluation based on compliance activities) can be used. Here we only introduce those, which were not covered above or have specific features.

Restoration of the fertility of soil (which can also used for Cost of changes of drinking water[24])

(1) Identify the quantity and scope of soil fertility losses

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[24] Usually the alternative would be to buy bottles of water at the market

(2) Identify the type and amount of fertiliser that could be used as a substitute to restore fertility
(3) Use the market value of the substitute fertiliser to estimate the fertility losses

$$L_i = p_i \bullet Q_i$$

Li refers to the fertility losses due to certain activities, pi refers to the price of the fertilizer I, Qi refers to the quantity needed for fertilizer I to substitute the losses of the certain fertility.

Changes of land use pattern
(1) Understand and collect information regarding the existing uses and areas of the land to be assessed (k, m, S)
(2) Collect and process the output value of the land being used for various purposes
(3) Estimate the unit value of each types of land being used for various purposes (Pm)
(4) Estimate the opportunity cost of the land use by construction or development projects

$$Total = \sum_{m=1}^{k} p_m s_m$$

Total = total losses various types of existing land uses;

k = types of land, m＝1, 2, …, k;

Pm = unit value of m type of land;

Sm = areas affected of m type of land.

7.6 Summary of case studies

In order to discuss the impact on final receptors via the land medium by social and economic activities, the cases are selected based on the following principles.

- The impacts identified are on a regional level
- The subject to be studied, should be typical in China, and have a need for economic assessment, that can also generate policy implications.
- With a reasonable basis of studies, data and information

Unlike the air and water pollution studies, the existing EIA system give little attention to land, which makes it hard to provide the necessary basis for economic analysis. In addition, as the land is much more closely related with the air and water media, it is hard to separate single impacts from other media and activities. Furthermore, the existing EIA shows that the impacts on land are not significant measured by a single project.

As China has a long history for sewage irrigation, the impacts of irrigation become significant and attract attention. Based on the principles above, and many internal discussions and external consultation, this study decided to choose the four villages in Shijiazhuang Irrigation district to conduct the economic assessment for the soil quality changes, and to choose the Chongqing High Way project to conduct the economic assessment for land use changes. The features of the cases selected can be summarized as following:

- The sewage irrigation has a long history, and has potentially serious impacts on fertility and soil quality
- The Chongqing Highway network plan involves the land use issue, and it is at the proposal stage, and can work together with the EIA simultaneously
- Typical for soil quality and land uses changes

7.6.1 Description of the cases

Shijiazhuang sewage irrigation district

Geographical location.

It is mainly located in the Xiao River and Hutuo River Basin. And in the Luan Cheng County, Zhao County, Xinji, Zhengding, Luquan County. The irrigation practice has been dominant in this area for over 30 years, covering sewage irrigation of 225,000 Mu, in which 160,500 are located in Luancheng County.

Sources of sewage irrigation.

Due to the drying of the Hu Tuo River, since late 1970's, the sewage irrigation mainly uses the water from Xiao He River. However, Xiao He River is also the river to receive the wastewater discharge from industrial and domestic source in the urban areas of Shijiazhuang, Luan Cheng, and Zhao County.

Water quality of the irrigation.

The wastewater discharge to the Xiao He River is mainly from medical and medicine plants, chemical industry plants, beer and food processing, textile, and electricity generation. The wastewater treatment plant a the capacity of 1.6×10^5 in Shijiazhuang also discharges the treated water to Xiao He River. The water quality of Xiao He River was exceeding the grad V, categorised as the most polluted water. The water quality exceeds the standards about 4-7 times. (Hebei EPB 2003). For details see the case study in Part II of this report.

The ground water in Luanchen has also been polluted. The morbidity of disease related to water quality is higher than those who use clean water to irrigate.

Information of the four study villages is given in table below.

Table 7.5 Information about the 4 villages

County	Village	Irrigation	Proportion of the irrigated land to all cultivated land	Population
Luan Cheng	Xiahuzhaung	Sewage	92.3%	1400
	Wangjiatun	sewage	94.4%	1038
Zhao County	Fancun	sewage	71.2%	1577
	xinhecun	Clean + sewage	43.4%	830

Data sources: from survey and field investigation

Chongqing highway network plan

Chongqing is the newly established municipality directly under the jurisdiction of the central government, located in the areas that connect Central and Western China. These areas are important terminals for east-west and south-north transport. In order to improve the roads and conditions of the highway network and improve the transportation capacity, a more advanced and wide cover range highway network is proposed to be built with a planned timing of 2003-2030.

It is proposed that by year 2010; to finish the key highway parts for forming the network; by 2020, to form the highway networks; by 2030, all the urban areas, districts, cities, and counties have access or can be reached by a highway.

The proposed plan combines 18 roads with a road length of 4306 km, in which, about 3800km is devoted to new road construction.

7.6.2 Results from the irrigation case

Detailed results are given in Part II of this report. A short summary is provided below.

Evaluation based on final receptor

Evaluation based on final receptor: Loss of crop output

Information and data

Based on data collected from the local government, research institutes, and survey conducted at the household level, a comparison of the corn and wheat production in the four villages and one reference region was conducted. Results are shown in the table below.

The price of wheat is 1.04 RMB/kg, and for corn 0.84RMB/kg. The soil quality changes reduce the crop quality, for example because the heavy metals exceed standards. No price information on different qualities of products exists. Based on an estimate by Guo Xiaomin's, we assume that 10% less than the price can be applied.

Table 7.6 Corn and wheat production (kg/mu[25])

Village name	Overall cultivated land Mu	Irrigated land Mu	Output of wheat kg	Output of corn kg	% of irrigated land in total	Wheat kg/mu	Corn, kg/mu
Xiahuzhuang	1300	1200	400000	475000	92.3%	333.3	395.8
Wangjiatun	1038	980	340000	393500	94.4%	346.9	401.5
Fancun	3370	2400			71.2%	375.0	460.0
Xinhecun	1075	467	165000	280000	43.4%	353.3	599.6
Fujiazhuang	Clean water					541	570
Average output per mu						352.1	464.2

Basic calculation formula

Based on the approach and formula stated above,

$$E = \left(\sum_{i=1}^{k} p_i q_i - \sum_{j=1}^{k} c_j q_j \right)_X - \left(\sum_{i=1}^{k} p_i q_i - \sum_{j=1}^{k} c_j q_j \right)_y$$

As the data available is for unit output, and there is no crop production cost changes, we can use the output per Mu in clean areas referring to the situation without sewage irrigation (the situation of X). Then the same formula can be applied.

According to the dose response function to estimate the changes of output and quality

This study use the same dose response function being used in the water study, see table below.

Table 7.7 Dose response

Final receptor	Reduction of the output	Loss of the quality
Vegetable	-25%	-4.5%
Rice	-20%	-4%
Corn and wheat	-10%	-2%
Overall crops	-20%	-3.5%

Then the per mu losses can be summarized as

E = [570kg/Mu × 10% × 0.84RMB/kg + (570 - 570kg/Mu×10%) × 0.84RMB/kg ×10%) + 541kg/Mu × 10% ×1.04RMB/kg + (541 - 541 kg/Mu × 10%) × 1.04RMB/kg × 10%] = 197.87 RMB/mu

Where the output loss is 104.14 RMB/mu and quality loss is 93.73 RMB/mu

[25] mu is a standard Chinese unit of area

According to the regional comparison estimate of the changes of output and quality

Then per mu losses of output =

[wheat (541 - 352.1) × 1.04 + corn (570 - 464.2) × 0.84] = 285.3RMB/Mu

Per mu losses of quality=

352.1×1.04×10% + 464.2 ×0.84 ×10% = 75.6RMB/Mu

Hence, the total loss is 360.9 RMB/Mu

Evaluation based on final receptor: human health damages

According to our investigation, the morbidity rate of heart and brain disease is 8% for the age above 45, which account for about 38% of the total population in the case areas. The morbidity is calculated as 3.04% higher than the clean water irrigation areas. The morbidity of cancer is 2.7% at the age of 40-60, accounting for about 23% of the total population, is about 0.525 higher than the clean areas. The morbidity for mouth and teeth diseases is 4.49% higher, and digestive system disease is about 3.68% higher.

Based on the local investigation, the treatment cost for heart and brain disease for one year is about 3000 RMB, cancer is 20000 RMB, digestive system is 500 RMB, and mouth and teeth is 20 RMB.

Heart and brain cost = 4845 (total population) × 0.5% × 3000 = 72675 RMB

Cancer cost = 4845 ×0.525% × 20000 = 508725 RMB

Digestive system cost = 4845 × 3.68 × 500 = 89148 RMB

Mouth and teeth = 4845 × 4.49% × 20 = 4350.81 RMB

Recalculated to the medical cost being shared by per mu irrigated areas = (72675 + 508725 + 89148 + 4350.81 RMB)/5047Mu = 133.72 RMB/mu

Evaluation based on final receptor: summary of the total economic losses:

From 197.87 RMB/Mu (DR function) + 133.72RMB/Mu ≈ 331.6 RMB/Mu

To: 360.9RMB/Mu (regional comparison) + 133.72 RMB/Mu ≈ 494.6RMB/Mu

Evaluation based on compliance behaviours

The pretreatment cost of water can be summarised as follows:

1. Estimate the water quantity being polluted at various levels, W_i , $W_i = W \times b_i$, where W refers to the total water quantity being used, b_i refers to the polluted water proportion being used
2. Calculate the total amount of the pollutants that needs to be treated P, then $P = \Sigma [W_i \times (S_i - S_0)]$, where S_i refers to the indicator of various degrees of

pollution (includes grade IV, V, and worse than V) ; S_0 refers to grade III water quality level (that is the baseline water quality standard).

3. Estimate the pollutant treatment cost, that is $L = P \times C$, where C refers to the unit treatment cost for certain pollutants.

Due to the data availability, we assume that the water quality of Xiao River is worse than grade 5, and therefore needs to be treated to the grade 3 to satisfy the surface water and crop irrigation water standards, and the per mu irrigation water is 300 tons/mu per year.

According to the study conducted by China's Academy of Environmental Sciences (conduced in 1994-1997),[26] and Yang Jintian et al (1998), since co-effects exist for the mitigation of pollutants, the single pollutant treatment cost is usually higher than the combination. Therefore, if we choose the highest cost of single pollutant treatment to represent the overall treatment cost, it is a conservative estimate.

In this case study we chose 0.35RMB/ton to be the unit treatment cost of sewage water. Then the pretreatment cost of sewage water is 300 ton/mu × 0.35 RMB/ton = 105 RMB/mu

Evaluation based on preventive/defensive behaviours: alternative projects

In the Luancheng Irrigation district, irrigated areas are 457,350 Mu using wells driven by electricity. There is 100,000 Mu using sewage to irrigate. According to the field investigation, there are two reasons for using sewage to irrigate, 1) increase productivity of crops; 2) reduce the agricultural input, especially the use of fertiliser, electricity and water charges.

1. For electricity, the cost of irrigating using clean water is 15RMB/mu, while sewage is 1 RMB/mu, the average frequency of irrigation is 3 times a year. The opportunity cost of using sewage water is then 42 RMB/mu, or we can also define it as the defensive cost for using sewage water.
2. The changes in fertiliser use, if using the clean water, about 30kg of ureophil are needed, with price of 0.7 RMB/kg, then it is 21 RMB/mu
3. Assume the water sources fee is equal then the opportunity cost or defensive cost for using sewage irrigation is 63 RMB/mu

It needs to be noted here that due to the missing data, we do not consider the differences of the water charges for sewage water and clean water.

Summary of the sewage irrigation case study

Table 7.8 summarises the estimation results. The results show that:

[26] This study analyse about 800 facility samples for treating COD and was built after 1980, and they have established the relationship between the operating cost and the elimination amount of COD, then they further estimate the average cost for COD elimination

- The impact of sewage irrigation is huge, even we use a very conservative approach, and the economic losses can reach to **236-399 Yuan/Mu**, which is about **40-60% of the current output**.
- Even for such a conservative and simple analysis, the results itself can have strong policy implications
  - To introduce preventive actions will be cost effective.
  - The separation of the pollutant source, the practice of the sewage irrigation, and the final receptors, have significant income distribution effects.

Table 7.8 Summary of the economic evaluation for sewage irrigation

Methods		**Loss of per mu (Yuan)**
At the final receptor	Use dose responds function	331.6
	Use regional comparison approach	494.6
To use alternatives		63
Pre-treatment		105

7.6.3 Results from the Chongqing highway case

A short summary of the results from the highway case is given below. A detailed case report is provided in Part II of this report.

The estimation results and sensitivity analysis

We use the opportunity cost approach to estimate the cost of land utilisation by the road construction. The objective is to provide a basis for selecting the road location or to make decision among alternatives, by giving a rough but correct number (or ranking number). Therefore we use the following two formulas to calculate:

$$Total = \sum_{m=1}^{k} p_m s_m$$

Total = total losses to use various types of existing land;

k = types of land, m=1, 2, …, k;

Pm = unit value of m type of land;

Sm = areas affected of m type of land;

The Sm is estimated based on the joint mapping approach of land use map, and highway plan map to get the affected areas of various types of existing land. Pm is estimated by (1) estimate the existing land use and their areas, (2) based on the data collected from the statistics for each districts to estimate the average output value of each type of use of the land.

The total is then estimated: the annual cost for permanent land use is 0.683 billion RMB (see table 7-9). Taking into consideration that the land uses for the construction period is about half of those permanent ones, the annual loss is 0.342 billion RMB. We assume 30 years to estimate the permanent losses and 3 years for the temporary losses (construction), and then estimate the present value of the total losses.

$$NPV = \sum_{i=1}^{30} A(1-r)^{i-1}$$

The choice of discount rate will have impacts on the estimation as well as the decision. The discount rate also reflects the attitudes of the decision makers regarding risks, and attitudes to environmental and natural resources protection. We use r = 5%, 8%, and 10 to conduct sensitivity test (see table 7.10).

Table 7.9 Annual losses of the highway construction (10 thousand RMB)

Items	**Permanent land use**	**Land use only for construction**
Economic loss	68332.15	34166.075

Table 7.10 Estimation based on different discount rate (billion RMB)

	Permanente land use	**Land use for construction**	**Total**
r =5%	14.343	0.978	15.321
r=8%	9.221	0.949	10.170
r=10%	7.513	0.930	8.443

Comparison with alternative plan

According to the plan, there are two alternatives, that is a1 and a2 in Yunyang County. The land uses are summarised in table 7.11. Using the same methods above, we get the results summarised in tables 7.11. and 7.12.

It shows that alternative a2 has less losses compared with a1, although the difference is not that significant.

Table 7.11 Annual value of the economic loss

Land time	**Unit output value 10 thousands RMB**	**Land occupation for a1 Sm2**	**Annual loss 10 thousands RMB**	**Land occupation for a2 Sm2**	**Annual loss 10 thousands RMB**
Forest	0.039	1.05	1.02375	2.249	2.192775
Grass	27.676	9.847	6813.1393	9.426	6521.8495
Cultivated	0.769	16.079	309.118775	16.073	309.003425
Reservoir	0.171	0	0	0.041	0.175275
Total			**7123.281825**		**6833.220875**

Table 7.12 *Comparison with the different choice of discount rate (billion RMB)*

Discount rate/Alternatives	a1	a2
r=5%	1.592	1.527
r=8%	1.053	1.010
r=10%	0.872	0.837

7.7 Challenges for the use of economic evaluation for land

This section sums up some of the challenges encountered in using economic evaluation for land impacts.

Irrigation case

Feature of the case study

- It is a regional problem, has close relationship with regional assessment and regional management, and not a assessment for a single project
- Close relationship with other media, water, and air
- Has significant cumulative effects, hard to separate additional effects from others, and hard to separate the contribution of single projects
- Joint effects with other pollutants

Choice of price

As we are analysing a partial market, we take the local market price as a reference, however, shadow price are recommended to use

Findings and issues

- Poor EIA and information and data basis compared with air and water.
- Hard to find and determine the dose response relationships
- The dose response relationships are closely related to the accumulation of impacts. Therefore, the use of dose response relationships developed in other areas or at another time may not be applicable
- Multiple media effects and cumulative effects should be given full consideration.

For the soil project, if the project is not large enough, it is hard to give economic evaluation at an individual project level. It is better to apply economic evaluation on the regional level. In addition, the data and information provided by existing EIA are insufficient for a straightforward economic analysis of environmental impacts.

Highway case

Contribution of the economic assessment

If the economic evaluation goes simultaneously with the planning, then it can contribute to the optimal choice of route, which can be based on overall cost benefit analysis.

Economic evaluation techniques

There are many economic analysis tools available. However, the approaches that are used should based on the real situation. As for the Chongqing project, it has already avoided the ecological significant areas, and therefore it only needs to conduct the economic analysis for the general uses of land. In addition, other defensive activities have already been integrated into the projects cost analysis.

Regarding the accuracy of the economic assessment

If the economic analysis is conducted simultaneously with the EIA it can serve as an input to redesign of the road. Due to the uncertainty of the data and information we use a conservative approach, which is the lowest level, which has already had the policy or decision making implications. Therefore, the accuracy at a certain degree is enough.

Linkage between EIA and economic assessment

- EIA should be the basis
- EIA should based on the requirements of economic assessment to provide necessary data and information
- From a long run point of view, the economic assessment should be part of the EIA, and also should be integrated with the various stages of the EIA process

In this case, EIA should have some changes, which should be more focus on receptors, defensive and preventive measures, alternatives analysis, in addition to evaluation of the changes of environmental quality and resources changes

Timing and other issues for introducing the economic evaluation

- Economic analysis should be part of the EIA, that is, it should be introduced at the beginning not after the EIA is finished.
- Need not give too heavy focus on accuracy, but should pay more attention to the operational and practical issues
- Need not cover everything, but give weight to the key issues or problems
- For those activities that violate the laws and regulations, for example, the land law, and nature reserves regulation, there is no need to further conduct economic assessment. However, if everything follows the legal requirements, then the economic assessment can contribute to
  - Link the EIA results into an overall cost-benefit analysis of a project, which can provide basis for the dynamic adjustment of the plan or proposal

- Help to make choices among alternatives
- Help to make decisions whether some defensive or mitigation activities are needed

8 Gap analysis

This chapter sums up challenges and gaps in using economic evaluation of environmental impacts (EEEI) based on the current EIA system and EIA practice in China.

8.1 The role of EEEI

Requirements for EEEI by law and regulations

"Management for Environmental Protection for Construction Projects" issued in 1998 requires that the EIA report should include Economic Evaluation of Environmental Impacts (EEEI) of the construction project. The EIA Law issued in 2002 emphasises the same requirement. Although both the Law and Regulation require economic evaluation to be conducted in the EIA process, no clear objectives or implementation guidelines have been mentioned in any legislative or administrative documents.

Considerations for EEEI by the Environmental Authorities

Environmental authorities under the State Council have pointed out many times that there is need to quantify the economic value of the environmental impacts from construction projects. The department of EIA under SEPA also mentioned that it is necessary to develop a guide or guideline for economic evaluation in order to better implement the EIA law and the Management for Environmental Protection for Construction Projects.

Specifically, as discussed at the outset of the report in Chapter 1, EEEI can play four roles for single projects (but also for plans and programs that are suitable for analysis):

- To feed the environmental costs into the cost-benefit analysis..
- To motivate and priorities mitigation measures.
- Compare significance of different impacts.
- Analyse project alternatives.

Gaps

- Although the law and policy require EEEI, there is no specific requirements regarding what role that the EEEI could play
- SEPA should provide requirements for economic evaluation according the Chinese situation, under the basis of overall assessment of policy objectives,

functions and roles and specific needs of existing EIA, following the law and relevant polices of the State Council

- At the current stage, the law and policy makers and the administrative authorities lack understanding of the role of EEEI. There is a need to introduce how economic evaluation can play a role to the law and policy makers as well as the authorities responsible for EIA.

8.2 EEEI procedures and methodology

Basic procedures

The following procedures should be followed when conducting EEEI:

- Identify the possible sources of environmental stressors (stressors identification)
- Identify the impacts on environmental media
- Identify the affected receptors
- Understand the relationship between sources, environmental media, and receptors
- Identify the environmental impacts that can evaluated in economic terms (screening)
- Value the environmental impacts identified in monetary terms
- List and describe qualitatively those environmental impacts which cannot valued in economic terms, but may still be important

We give more details on the elements that could form part of a SEPA guideline on EEEI in Chapter 9.2 below.

Gaps

- Not all receptors are identified in EIA reports, for example, human health, building materials
- The relationship among sources (stressors), environmental media and receptors are not established or clearly understood
- The existing EIAs do not identify those environmental impacts which could be valued in economic terms
- The methodology and approaches to value the environmental impacts in monetary terms are still in process of development. However, at present the many methodologies exist that are good enough to make accurate estimation of environmental costs.
- Existing EIA did not list those environmental impacts which can not be valued in economic terms

8.3 Projects applicable for EEEI

Based on the lessons learned in this study, we think that EEEI may not applicable for all projects.

No legal statements on which types of projects are applicable for EEEI

Although both the *EIA Law* and the *Management Regulation on Environmental Protection of Construction Projects* require that economic evaluation of environmental impacts should be a component of the EIA report, neither has clarified what kind of projects are applicable for EEEI. Further, the *EIA Law* has required EIA for plans, but it does not specify whether plans should conduct EEEI.

Gaps

- Administrative authorities have no clear idea about the applicability of EEEI, especially regarding the existing gaps between the requirement of an ideal EEEI and the current EIA system and practice
- EEEI of plans could potentially have an impact on decision-making, but there is no legal or policy basis to justify EEEI on plans. It is the same situation for policies.
- No regulations or policies clarify that results from EEEI can be supplementary information for decision-making when environmental impacts cannot be assessed through the EIA process.

8.4 Institutional limitations for conducting EEEI

Some of the gaps in this area are related to the gaps in current EIA practice (geographical scope of EIA, insufficient information in EIA reports etc) and gaps related to the environmental management bureaucracy (lack of staff trained in EEEI, and EEEI manuals, difficulties in getting hold of information from relevant institutions etc).

- There are no (or few) implementation manuals for conducting EEEI, and none that we know of made especially for a Chinese audience. Therefore there is not a strong basis for developing the technical guidelines for conducting EEEI. Although the article 17 of EIA law requires that the EIA report for construction projects should include "the economic benefits and costs analysis for the environmental impacts by construction projects", there are no specific requirements and supporting implementing manual. There are also no specific requirements for how to implement the EEEI in regulations issued by the State Council.
- The geographical scope covered by existing EIAs is too small to apply economic evaluation. The existing EIA only assesses impacts for the immediate surrounding areas. However, for projects with long-range transportation and cross boundary features, the scope is too small to cover all the impacts. The limitation and inconsistency of the geographic scope requirements by existing EIA practice compared with their real impacts, may result in underrating of the extent of impacts in the EIAs.
- The data and information provided by existing EIA reports cannot satisfy the requirements for conducting EEEI. Specifically, the existing EIA did not provide sufficient information regarding receptors, for example, the

exposed population, morbidity and mortality, changes of the agricultural production in quantity and quality, and impacts on building materials.

- Lack of staff trained in economics among current EIA practitioners.
- The existing law and regulation do not enforce the project being evaluated, and the regions being affected must provide EIA (including EEEI) the necessary data and information. In the current situation it is very difficult to collect necessary information. For example, the data regarding human health, and drinking water quality are not publicly available and hard to get to hold of.
- The definition of significant projects by existing EIA guidelines cannot support EEEI. Adjustments are required.

8.5 Data and information availability for conducting EEEI

Data and information requirements of EEEI

- Data and information about sources or driving factors for environmental pollution, including characteristics and intensity of emission/resources exploitation, contribution of different environmental stressors, and impact pathways etc.
- Impact of each stressor on environmental media, and its distribution
- Exposure level and the response in receptors. Exposure-response relations are required, and other data are required from monitoring or observation to identify the impacts on receptors
- Technical and economic information and data about mitigation measures or options;
- Price data, including price data before and after the project, market situation of substitute goods and proxy prices etc.

Data deficiency of EIA reports

- Environmental impacts from the project on the final receptor are normally not identified. Only the impact on environmental media is assessed.
- The geographical scope of the EIA is too small to cover most of the impacts on receptors, based on which, the economic analysis cannot reveal the real impacts of the project.
- Exposure level and the impacts on receptors are not identified, which leaves a large gap for the economic analysis to overcome.

Exposure response relationships

Exposure response coefficients from different studies vary

E-R coefficients are critical for evaluating environmental impacts. As part of the case studies, our researchers collected hundreds of E-R coefficients from research conducted both in China and abroad (see Part II of this report). But it is clear that E-R coefficients from different studies vary quite a lot, and are closely related to the research objects and therefore not always easy to transfer.

The main methodology for E-R research is to collect data on a historical time span, with which to build up a statistical relationship between the pollution (exposure) and the impacts (response). But as these data are all distinguished by the characteristics of each individual research object, it means that this method is heavily influenced by the conditions of the research objective (response) and its environmental background (exposure status).

In order to improve the applicability of the research results, E-R researchers try to distinguish the impact from different local factors. Even so, the research results are only partly applicable. For instance, WHO put forward a unified function value for E-R after referring to large amounts of data from different research projects. But they only recommend the E-R functions applicable for developed countries, considering their environmental conditions, human health conditions and so on. They point out that the quoted data was obtained under a low pollution background environment (e.g. the average PM_{10} concentration below 10-100μg/m^3). These data are not directly applicable for environments with higher than 200μg/m^3. But PM_{10} in China is between 100-1000μg/m3, which is out of the WHO range. Aunan and Pan's research shows that we tend to have lower E-R coefficient's results in China, a higher one in Europe, and the highest in the US.

Few E-R functions are applicable for China

Problems arise if we simply refer to the research results from western countries as we have so many different background levels, including combustion of coals, and different composition of vehicles, different population health condition and age distribution. With a different research background, we have little to refer to. In this regard, we suggest that if we want to do evaluations of environmental impact in China, we should put more efforts in E-R functions. We may also take the second best choice to transfer the research conducted in countries with a similar environmental background as we have when research in China is absent.

But currently, we are still in a very preliminary stage in E-R function research, especially for water related endpoints, and we have limited research experience and research results. We lack a set of E-R functions applicable in our country and only very limited stressors and endpoints of impacts have been included in that research.

Furthermore, there is a lack of standardised formats for E-R functions, which also make them difficult to transfer. They also fail to use an index in accordance with that of the Health Departments, so the data are not applicable for further calculation.

Despite the shortcomings of some of the current E-R knowledge and research, there is still a large body of knowledge of the severity of air, water and land pollution on human health and other end points. Especially air pollution is a heavily researched area. So, even if research results are imperfect and always being revised it would be a large mistake not to conduct EEEI on the basis that the current knowledge is insufficient. One cannot and should not wait for the research to become perfect. It is much better to illustrate the potential severity of human health and other impacts in an EEEI, than to leave them out of the EEEI altogether, effectively assuming them equal to zero. Uncertainty can be accounted for by indicating a mean value and an uncertainty range around the mean.

Exposure data

Exposure and distribution of receptors can only be roughly identified

This is because the affected area is often not the same as the unit area from which the statistical data have been obtained. Take population distribution as an example. We know that the Chinese population statistical unit is the administrative unit, and the minimum unit is the village. But the distribution of pollutants and the affected areas are of course not in accordance with the administrative area. Consequently, we cannot correctly get the affected population distribution for a certain project. Ideally, a more applicable statistic foundation and a more complicated population database, assisted with GIS system, should be put in place in order to improve the accuracy of population distribution. However, despite this shortcoming, a useful estimate of the affected population can still be made for the EEEI based on the existing data.

Statistics for end-points for assessed groups

- Data for many diseases are absent. In our case analysis we discovered lack of sanitary statistic data. We still cannot get comprehensive data for mortality, morbidity, out patient visits, and hospital admissions . We can get these data through conducting surveys in individual hospitals, but not from statistical books. It is very resource consuming to collect such data for individual project EEEIs.
- E-R functions do not match the end-point parameters. There is no standard statistical index system for end-points. Under these circumstances an EIA practitioner without medical skills will find it hard to make judgment on the quality of data quality or choice of a better data source.

This also reminds us that during E-R function research, we should take the current statistic index into consideration.

Some indicators of endpoints are distorted by institutional issues

Due to institutional differences, it is hard to compare the medical data in developing countries and China with countries that have well-developed sanitary systems. Take HA as an example. (1) the number is not accurate, but usually limited by sanitarian conditions: a shortage of beds or doctors and nurses; (2) affected by income conditions: to most Chinese, the cost of hospital treatment is considerable, and it is not uncommon for people not to go to hospital despite of a serious disease; (3) affected by the sanitarian institution: a difference in payment by the public and by the people themselves. All these factors can make the calculation results disputable.

Economic data

First, statistical data of costs cannot fully meet the demands for economic evaluation. Take the evaluation of disease costs as an example again. According to the statistical reference material the outpatient expenses are calculated by diseases. But morbidity, if the data exists, is calculated by sections of hospital services. So, when we calculate monetary loss as endpoints by outpatient rates, we discover that there exists a difference between disease incidence and outpatient expense. E-R functions, objective number, endpoints, loss expenses and other data with different index limit the type of loss we can calculate and consequently limit the accuracy of it.

Secondly, economic data are also organised according to administrative area or sectors, which is not in accordance with the receptors. What is more, on a whole, administrative or sector wise macro economic data is relatively easy to get while the micro economic data is difficult. So, we have to neglect the difference within areas and use the average instead. Of course, to make it easier, it is possible to use the average in areas without significant economic differences.

How to choose discount rate is also important in EEEI. Different discount rates may impact significantly on calculations. In Chapter 3 we discuss this issue.

In conclusion, economic analysis cannot represent the real impact due to incomplete, non-standardised and inaccurate data. These shortcomings will make EEEI a challenge for EIA practitioners, but it is possible to give guidance, as we have done in this report, to make it easier for them to conduct the EEEI. For instance, the challenges can be overcome through using more simplified procedures that may still give useful estimates of environmental costs. When the data quality improves over time, the procedures can be gradually refined and the uncertainty in environmental cost estimates be reduced.

8.6 Issues raised by EEEI

Methods of EEEI

Normally it is acknowledged that methods used by EEEI should meet the following conditions:

- *Simplified techniques and easy operation.* The techniques should be simple so that they can be used by staff who have not been trained or have limited knowledge of environmental economics. For the EIA engineers, they can conduct EEEI after quick training.
- The rationality of the techniques has been acknowledged, especially in the country, regions, and to the parties, and the suitability of the methods has been accepted.

There are two types of methods for EEEI:

- *Basic methods,* which are based on the relevant data of environmental impacts. The staff evaluates the economic value of environmental impacts by using the collected social and economic data and the economic techniques. The social and economic data can be collected directly from the market or indirectly through survey and other information sources.
- *Benefit transfer*. Practitioners can use the data or results from other countries or regions, and transfer to the assessed area through proper adjustment.

Using basic methods to evaluate the environmental impacts involves much expertise, especially the procedure of economic evaluation. At the same time, it costs a lot, requires more implementation manuals with longer working time, which confines the implementation of the method. However, for types of projects mentioned above that may have substantial environmental impacts, it may clearly be justified and can be very useful.

Using benefit transfer to evaluate the environmental impacts require less funds and staff, as well as less working time than basic methods, but requires expertise in making proper adjustment when transferring the coefficients to China. With a different culture, economic, social and environmental backgrounds, we face a tough task to do the proper adjustment. As a consequence, the rationale of the evaluation results will be affected under this situation.

EEEI cannot in practice determine "optimal" level of environmental protection

In implementing EEEI, the decision-makers usually require information about:

- Economic benefits for protecting and improving environments (environmental benefits)
- Economic costs for not protecting the environments (environmental loss).
- Costs for protecting and improving environments (environmental protection costs).

Regarding these three points the following can be noted:

- Because of the limitation of the evaluation techniques and the information, environmental costs or environmental benefits can only be partly calculated, and the calculation is always relatively uncertain.
- The direct environmental protection costs are relatively easy to calculate with high certainty.
- This asymmetry of uncertainty between the two actually means that it is difficult to ensure the optimal environmental protecting costs for the environment. Or putting it another way, to ascertain environmental capacity based on environmental loss and environmental protection cost is only theoretically possible.
- In conclusion, it is often in practice unrealistic to find the so-called optimal level of environmental protection based on quantification of environmental costs and benefits. The realistic work should be to focus on reaching environmental targets at least cost (cost-effectiveness). However, over time the environmental targets should be made stricter, and for revising the targets information on environmental benefits and costs (even if they are uncertain) is absolutely essential.

We have to admit that the environmental protection targets should be a decision with an integrated consideration of current political, economic, social and technological conditions. Sufficient environmental protection funding is the central factor for achieving environmental protecting targets. In practice, the main factor in the failure in reaching our targets is the lack of environmental protection funds. Environmental protecting funds include governmental funds, enterprise funds and individual funds.

When we have established the environmental protection targets, we can improve the efficiency of environmental protecting funds in the following ways:

- *Technological progress:* to improve production efficiency and disposing efficiency;
- *Improvement policies:* property rights, compensation, price, and finance;
- *Improvement in management*: efficiency in the use of funds, reduction in management costs;
- *Reconciliation*: cooperation among agencies and regions.

The implementation of benefit transfer in China

Benefit transfer is common in China. However, a correct use of this method depends on the criterion to select suitable results and a suitable way to transfer the result and coefficients. If the selection of both is too flexible, the role of BT to decision making would be very weak because of uncertainty.

In the evaluation procedure, if we fail to get the appropriate standard for choosing the relevant successful results to refer to or if we fail to transfer the parameter, we may get totally different results for the same project. In this way, we cannot do much for the decision-making procedure.

However, if conducted carefully BT can still be very useful in EEEI, and in any case much better than not making an estimate at all due to lack of Chinese or local research results for the study area.

9 Conclusions and recommendations

This chapter first responds to some of the gaps identified in chapter 8 in the current EIA system for conducting economic evaluation of environmental impacts (EEEI). The second part of this concluding chapter offers our suggestions for core elements in a SEPA guideline for EEEI as part of EIA. The executive summary of this report offers are full conclusions, recommendations and summary of the report.

9.1 How to bridge the gap?

The purpose of the first part is to analyse how the gaps discussed in Chapter 8 can be bridged. Many of the gaps are related, but we go through them area by area: the role of EEEI, procedures and methodology, projects applicable for EEEI, institutions and data requirements.

The role of EEEI

The main gap here is that both the EIA law and the regulation[27] require some sort of EEEI as part of the EIA process, but there are no clear objectives of the role of EEEI or implementing guidelines. The main purpose of developing the approach for conducting EEEI is to strengthen the influence of EIA on decision-making, through:

- Strengthening the decision-making support by the Environmental Impact Report
- Strengthening the decision making support for national economic evaluation (cost-benefit analysis) of projects (and suitable plans and programs)

Therefore, we recommend that SEPA, as the executive body of the EIA law, should provide precise and detailed requirements for economic evaluation according to the Chinese situation, on the basis of an overall assessment of policy objectives, the role and specific needs of the existing EIA system, following the law and relevant polices of the State Council.

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27 "Management for Environmental Protection for Construction Projects"

These precise requirements should clarify the roles of EIA and EEEI in relation to the project level and the levels of plans and programmes. A result from this study is that EEEI in many cases would be more useful for a program or plan (e.g. assessing a plan to clean up a watershed) because projects assessed in isolation have marginal impacts and because the geographical scope in the EIA often is too narrow.

EEEI procedures and methodology

The first required steps of a good EEEI are identical to those of a good EIA report, i.e. understanding the physical relationships between stressors (pollutants) and impacts on receptors. A serious gap in the EIA practice in China is that the impacts are often not assessed at all, i.e. the EIA only reports the emission levels and not the impacts on receptors. As long as this shortcoming exists, the information provided is not very useful for decision-making regarding the project and it is hard utilise the advantages of EEEI to assess impact significance. Other gaps identified in chapter 8 are the lack of a detailed guideline for EEEI as part of EIA, and that D-R functions and economic valuation methodologies are under constant development and improvement.

- SEPA, as executive body of the EIA law, should also provide precise and detailed directives for improving the current EIA practice. The following items should be considered:
  - Require the EIA to assess impacts on receptors for the most important impacts, and not just report stressor levels (e.g. tonnes of emitted pollutants)
  - Extend the evaluation scope of environmental impacts including health, vegetation and material damage considerations
- To develop a proper practical economic evaluation guideline for large projects, and for plans and programmes that are suitable for EEEI. This report gives a good research basis for going ahead with designing this detailed guideline.

Projects applicable for EEEI

The environmental authorities seem not to realise the significant shortcomings of the current EIA practice for the use of EEEI. However, based on the lessons learned in this project, we have found that not all projects are applicable for EEEI. In our view the following projects should be made subject to EEEI:

- *Construction projects with significant impacts on a large area, region or river basin.* Such projects often have environmental impacts on a large area, often far beyond the area where the project makes economic influence. If the environmental impacts are not evaluated in the project EIA, it is very likely that the severity of the impacts will be underrated in the final decision.
- *Plans on economic development, natural resources exploitation, environmental protection and industry development on national, regional, and local levels.* The reasons are:
  - Plans have potentially large environmental impacts over a wide area, involving large populations,

- The area of environmental impacts from the plan is often almost the same as the area of economic impacts;
- Plans are normally comprised of many projects, which means many resources (related to those projects) can be re-allocated optimally by design of plan;
- Economic evaluation will be helpful for achieving the comprehensive goals of the plan, because plans comes earlier in the cycle than project decisions, so that economic evaluation of plans can force EIA to be integrated into decision making process at an earlier stage.

- *Policies on economic development, natural resources exploitation, environmental protection and industry development on national, regional, local levels* for the same reasons as above. In addition, at the policy formulation stage, there may be even more options for changing environmentally detrimental aspects, than for plans and programmes where more of the parameters have been decided.

The case of Zhengzhou Municipal Sewage Treatment Plant (STP) can justify these ideas. Zhengzhou Municipal STP has removed a pretty large amount of COD, so it is successful as a pollution reduction project. But the construction of this STP did not bring environmental benefits large enough as the quality of receiving water (Jialu River) continue to be worse than class V. If this project is taken as component of a pollution control plan of Jialu River, or if we do EEEI on the pollution control plan, then it will come out with the conclusion that this single project will bring low environmental benefits unless more STPs are constructed along Jialu River, or this project should be postponed until there are enough investments to support construction and operation of STPs along the whole river basin, which will end with much higher cost-effectiveness.

Institutions

Some of the gaps in this area are related to the gaps in current EIA practice (geographical scope of EIA, insufficient information in EIA reports etc) and gaps related to the environmental management bureaucracy (lack of staff trained in EEEI, and EEEI manuals, difficulties in getting hold of information from relevant institutions etc). SEPA should adjust its institutional arrangements to enhance the capacity of EEEI in the following aspects:

- Enlarge the geographical scope of the environmental impact assessment. This can either be done through extending the geographical scope of individual EIAs or (better) to conduct higher level EIAs, e.g. a regional EIA, rather than many individual EIAs that miss the cumulative and regional impacts (which are often very important).

- Strengthen the requirements that EIAs have to assess impacts on receptors and not just levels of emissions etc. All good EIAs should do this, regardless of EEEI. This point is also mentioned as part of the procedures and methodology section above.

- Strengthen the competence of EIA implementing institutions and practitioners in EIA, both through:

- Organising training for EIA practitioners. The current project has started this process through conducting several training workshops, but more are clearly needed.
- Drafting supporting manuals and materials on EEEI to guide practitioners who shall conduct EEEI.
- Basing training and manual drafting on international best practice EIA and EEEI (e.g. as conducted in the EU and USA).

Data and information availability

This is an area with many challenges related to the insufficient information about impacts provided in EIA reports, general lack of data, statistics and knowledge in China related to exposure/dose response relationships, and difficulties in obtaining data from the relevant institutions in China for use in EIA/EEEI. A thorough discussion of these challenges is given in chapter 8.5. Our policy recommendations are:

- Develop China's own Exposure-response functions based on a large statistical number of sampling, to match with China's social and economic statistical data (health, population, labour etc) and natural resource accounting data. This is however a long-term project. At present, the best approach is to use the existing data and information from Chinese and international sources to get the best possible picture of the environmental impacts. When research and data availability are improved over time, the environmental impact estimation can also be refined and improved to become more accurate.
- To establish a mechanism of public heath information sharing, at least among the relevant ministries of the Chinese government. It is often difficult to get hold of the relevant data even when the data exist and are collected by government institutions. A streamlining of procedures for getting hold of data for EIA practitioners would be of tremendous help.

In conclusion

This section has provided some key recommendations on how some of the gaps in the current EIA practice can be bridged to make it possible to introduce EEEI. Based on this study we think EEEI can be very useful, and we are optimistic regarding the future of EEEI as part of EIA and in planning more generally (plans, programmes, policies and cost-benefit analysis). However, SEPA will need to have another close look at the current EIA system to see how the practices can be changed to favour more economic analysis and to improve the influence on decision-making with the aim of reducing the overall environmental burden from economic development in China.

Despite the shortcomings of some of the current research on the relationships between human activities and environmental impacts, there is still a large body of knowledge of the severity of air, water and land pollution on human health and other end points. Especially air pollution is a heavily researched area. So, even if research results are imperfect and always being revised it would be a large mistake not to conduct EEEI on the basis that the current knowledge is insufficient. One cannot and should not wait for the research to become perfect (it never will!). It is much better to illustrate the potential severity of human health and other impacts in an EEEI, than to leave them out of altogether, effectively assuming impacts equal to zero value. Uncertainty can be accounted for by indicating a mean value and an uncertainty range around the mean.

The next section provides a more detailed set of recommendations on key elements that could be considered if SEPA should decide to develop a detailed EEEI guideline.

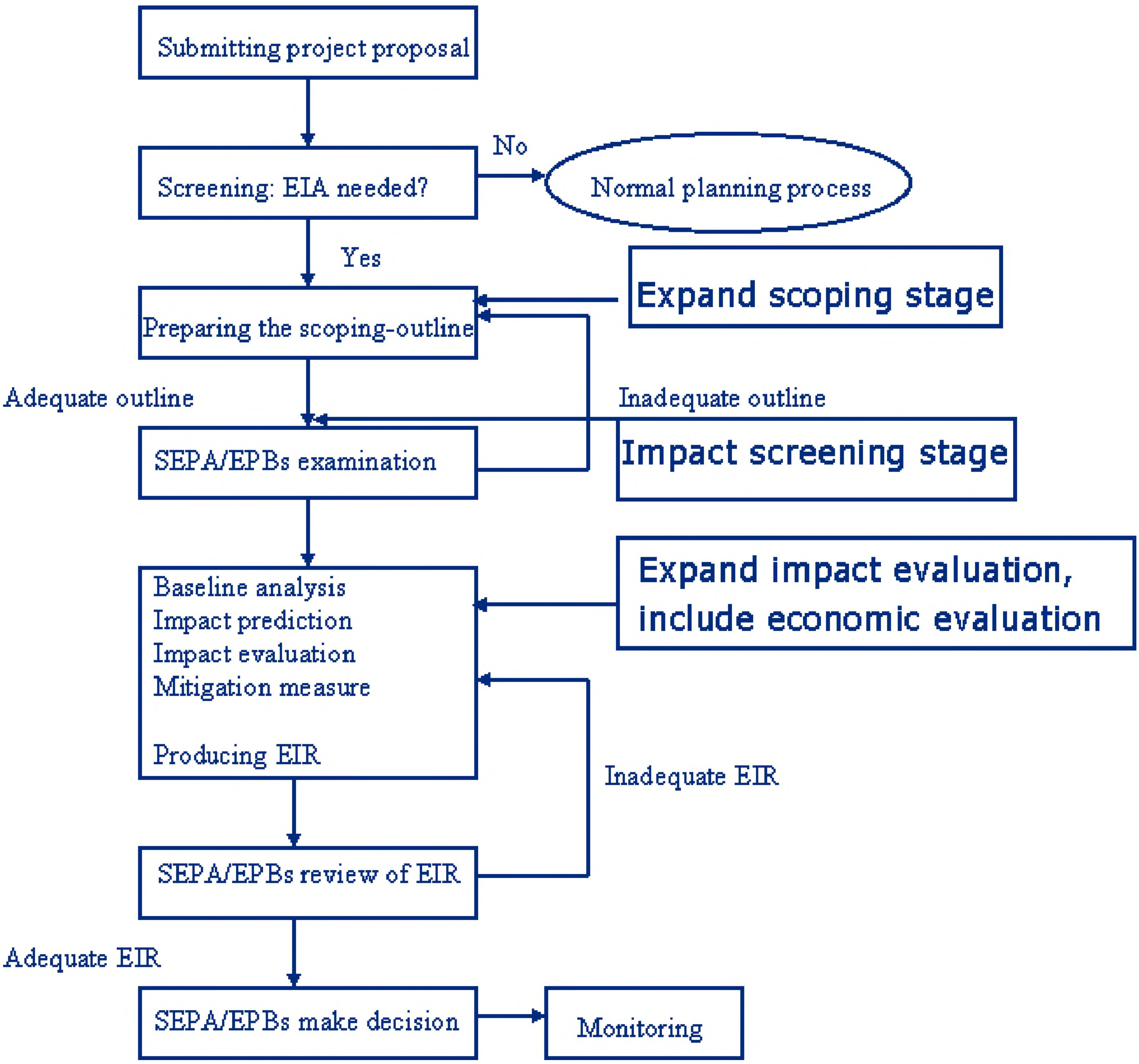
9.2 Core elements of a guideline for EEEI as part of EIA

This final part of the chapter offers suggestions on a guideline for performing an Economic Evaluation of Environmental Impacts (EEEI) that is part of EIA. The suggestions may make it easier to carry out an EEEI by agencies assigned to do EIA's with an EEEI included (the "EIA agencies"). The suggestions are for SEPA's consideration, and might prove useful should SEPA decide to work out detailed guidelines for EEEI as part of EIA.

The EEEI of suitable projects should follow the steps of the Chinese EIA process, and cover only the most important impacts that can be valued in economic terms based on the current state of knowledge. Project types that may not follow the standard EIA process, as for example some plans and policies, may need to utilise EEEI in a different way than the standard large, individual investment projects. We have not assessed specific procedures for plans and policies in this report.

Figure 1 shows how the new core elements could affect the existing EIA process.

Figure 9.1. Core elements to include in the existing EIA process to carry out an EEEI.



Scoping stage

In existing EIA procedures, after projects have been screened, whenever an Environmental Impact Report is required the EIA agency prepares an EIA outline. One step in the outline is to 'identify significant impacts'. In order to satisfy the needs of an EEEI we suggest to carry out the impact identification part in two steps:

3. Identify environmental stressors.

4. Identify potential impacts related to each stressor, and identify linkages.

Tables for these two steps are provided in Chapters 3, 5-7, and their use been demonstrated there.

As will be seen from the tables, the concept of impact, in the vocabulary of an EEEI, means *impact on* human health, human welfare, environmental resources or global systems.

Impact screening stage

The impact screening stage is a new stage required by the EEEI that is fitted between the scoping stage and the baseline analysis stage in the ordinary EIA. Environmental impacts should be screened in order to identify whether they should be subject to further, quantitative study.

4. In the screening, identify impacts that are the subject of further, quantitative study on the basis of the following criteria:

    a. Importance, which often is related to an impact being large in physical terms

    b. Concreteness, that is whether the impact relates to a physically concrete phenomenon (if the tables we provide to help the impact identification stage are used, the impacts are in general sufficiently concrete)

    c. Certainty, that is whether the impact is possible to assess with any degree of certainty and confidence.

Impact prediction stage

In an EIA that includes an EEEI, the impact prediction stage is significantly expanded compared to an ordinary EIA. The first new aspect of the impact prediction stage is:

8. Identify impacts that should be the subject of monetary evaluation. The identification should consider, on the one hand,

    a. which impacts are especially important for the subject under study (project, plan, program), and on the other hand,

    b. which impacts have available methods and tools for evaluation. The identification should also consider

    c. the amount of resources available for the EIA/EEEI study and

    d. the importance of the subject (project, plan, program).

9. Experience from this study and other studies in China and worldwide suggest that the following impacts are among the candidates for monetary evaluation:

    a. Impacts on human health from air pollution, in particular air pollution in the form of emissions of SO_2, NO_x and soot/dust (PM_{10}, $PM_{2.5}$)

    b. Impacts on materials from air pollution, in particular emissions of SO_2.

c. Impacts on vegetation and crop growth, in particular emissions of SO_2.

d. Impacts on human welfare from noise. Noise is not covered in our report.

e. Impacts on human health from water pollution, in particular impacts in the form of biological water-borne diseases (acute/short term impacts).

f. Impacts on water reliant crops, fish and industries from low water quality and pollution induced water shortage.

g. Impacts of land use changes.

h. It is sometimes possible to estimate benefits of a combination of impacts, and sometimes all impacts (i.e. total benefits) by using special methods.

10. To value in monetary terms the impacts a-g we suggest a three-step approach

    a. First, the linkage between emission/stressor and exposure to the change in environmental quality is estimated. For this linkage it is important that the surveyed area covers all or most of the exposed area. Simple dispersion models over the exposed population may be used to estimate the linkage. Practical examples can be found in the case studies of this study.

    b. Second, the linkage between exposure and impact is estimated, using so-called exposure-response methodology. The research on exposure-response methodology and exposure-response functions is rapidly evolving. A survey of current research results for air and water pollution is given in Part II of this report. For this linkage background data on health status, crop production etc. are needed, and data limitation may sometimes be a problem. Above we have recommended to increase the efforts to make available additional exposure-response functions.

    c. Third, the price of impacts is estimated. Many end-points have a market price, but some have not, and the price must be derived from e.g., cost data or similar. A survey of selected research results on this issue is provided in this study.

11. To value in monetary terms the impact h we suggest one or more of the following methods (see chapters 3, 4 and 5-7 of the report for a more comprehensive description):

    a. *Contingent valuation*, whereby the willingness to pay of subjects for changes in environmental quality is obtained. The concept "environmental quality" should be made as precise in the questionnaire as the subject allows, but will often cover more than one impact. Contingent valuation may also be suitable for step 6c above, especially when end-points primarily have a subjective aspect (morbidity and mortality risk, biodiversity loss etc)

b. *Defensive and averting expenditures*. Averting expenditures are expenditures designed to prevent or mitigate environmental degradation *before* it occurs. Corrective expenditures abate or reduce the impacts of pollution *after* it occurs. They may include the replacement or restoration of damaged assets. Actual defensive expenditures reveal the minimum amounts that producers and households are willing to pay to prevent environmental degradation.

c. *Hedonic pricing*. The method for estimating implicit prices is known as hedonic price analysis. Prices of housing location, wage compensation for risky jobs etc. are examples of implicit prices that provide much evidence on willingness to pay values for environmental quality.

d. *Travel cost method* is based on the common observation that the use of environmental services varies inversely with the costs of access to them. In effect, travel costs act as implicit prices for access to non-priced services. From variations in travel costs and use, we can deduce what individuals would be willing to pay for the services.

To the extent possible observed prices and costs in various markets should be used.

Use and reporting of environmental cost results

As discussed in Chapter 1, the EEEI should be designed, conducted and reported with the four main uses of the results in mind:

- *Enter into Cost Benefit Analysis:* This report does not give guidance on how to estimate and calculate the non-environmental costs and benefits (investment costs etc)
- *Motivate and prioritise mitigation options:* For this use, the environmental benefits can be estimated for different mitigation options to assist in the decision of level and type of mitigation.
- *Contribute to a compare significance of different impacts:* If the environmental costs/benefits of a construction project have been estimated, their significance can directly be compared since the unit of measurement for the impacts is RMB.
- *Make it easier to analyse alternative project designs, locations, etc.*: According to the EIA law alternatives to the project in question should be considered. EEEI results for different alternatives can be used to compare the significance of impacts between alternatives.

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Annex 1: EIA Classification System

Inventory of construction project classification for environmental management

Category of the project		EIR type project	Environmental Impact Form project	Register form of environmental Impact
Water basin development (including water basin layout and fathering of small water basin), coastal development , making soil by inning, making soil by filling sea		All	/	/
area development	Economic echnology development area ,high-tech industry development area, a tour and holiday area, bordering economy collaborative area , bonded area , industrial park and flaky ground development	All	/	/
opencast working		new building /rebuilding / largening area and sensitive area	Others	/
petroleum exploitation		not lessthan 200,000 ton per year, less than 0,000 ton per year, sensitive area	less than 0,000 ton per year, unsensitive area	/
natural gas exploitation		Not less than 1,000,000,000 m3 per year, less than 1,000,000,000 m3 per year, sensitive area	less than 1,000,000,000 m3 per year, unsensitive area	/
coal bed gas exploitation		sensitive area	unsensitive area	/
Coal Mining and Processing	new diggings	All	/	/
	unattached mine	sensitive area	unsensitive area	/
	Coal preparation plant	sensitive area	unsensitive area	/
Ferrous Metals and Non-ferrous Mining and Dressing		All	/	/
Nonmetal Minerals Mining and Processing	exploitation of chemical lodes	Over 200,000 ton annual mine production	below 200,000 ton annual mine production	/
	lacustrine and well salt	potassic and magnesian salt	Others	/
	sea and mineral salt	/	All	/
	Asbestos /mica/graphite	sensitive area	unsensitive area	/
	limestone/kaoline	/	Not less than 100,000 m3	less than 100,000 m3 , unsensitive area

	Earth, sand and stone		Not lessthan 200,000 m3 annual, less than 200,000 m3annual, not lessthan 100,000 m3annual,sensitive area	Others	less than 100,000 m3 annual, unsensitive area
Process Food-stuff	process foodstuff and feedingstuff		Not less than 250,000 ton annual process	Not less than 100,000 and less than 250,000 ton annual procession, less than 100,000 ton annual process, sensitive area	less than 100,000 ton annual process, un-sensitive area
	process botanic oil		Not less than 100,000 ton annual process	Not less than 20,000 and less than 100,000 ton annual process, less than 20,000 ton annual process, sensitive area	less than 20,000 ton annual process, unsensitive area
	Refine sugar		All	/	/
	Butch-er and meat proce-ss	butcher	Not less than 10,000 head per year	Others	/
		meat process	/	Not less than 20,000 ton annual process, less than 20,000 ton annual process, sensitive area	less than 20,000 ton annual process, unsensitive area
		egg process	/	/	All
	aquatic product		Annual production ≥ 100 million tons	Not less than 20,000 and less than 100,000 ton annual process, less than 20,000 ton annual process, sensitive area	less than 20,000 ton annual process, unsensitive area
	salt process		/	sensitive area	unsensitive area
	dairy product process		/	sensitive area	unsensitive area
	convenient product		/	sensitive area	unsensitive area
	zymolytic food such as vinegur		/	sensitive area	unsensitive area
monosodium glutamate /citric acid/amino acid process, faecula/diastase products			All	/	/
Beverage produce	liquor and inebriant produce		All	/	/

	Ade and other soft drink produce	/	sensitive area	unsensitive area
Cigarette		Not less than 300,000 boxes for new construction, arriving and more than 800,000 boxes after tech-reform ;sensitive area	Others	/
Spin	Spin programme includs scouring、dying and finishing、degluing, silk programme includes waste water of silkworm cy chrysalis, waste water from refining, etc	All	/	/
	Other spin programme	/	All	/
clothes and shoes produce	clothes produce	/	Large scale slope machining	Others
	shoes produce	/	Using organic solvent	Others
leather,plelage,feather,and their related products	leather /pelage produce	All	/	/
	feather machining	/	sensitive area	unsensitive area
	Leather/pelage/feather product	/	sensitive area	unsensitive area
saw /spill machining ,furniture produce		/	sensitive area	unsensitive area
man-made board produce		Not less than 200,000 m2 annual production for dry method ,all for waterish method	less than 200,000 m2 annual production for dry method	/
wood/bamboo/bine/palm/grass product		/	By chemical disposal craftwork	Not having chemical disposal craftwork
Paper making and paper product	Paper making including waste paper making ,paper pulp making	All	/	/
	paper product	/	Having chemical disposal craftwork	Not having chemical disposal craftwork
print/culture and education /physical education product making, magnet material product		/	All	/
petroleum machining	petroleum/natural gas machining, petroleum refinery, oil product	All except single packed equipment	single packed equipment	/
petroleum storeroom		Not less than 100,000 m3 in	Not less than 30,000 m3	Less than 10,000 m3 in

		gross；ot less than 30,000 m3 and less than100,000 m3 in gross, sensitive area	and less than100,000 m3 in gross, unsensitive area；Not less than 10,000 m3 and less than 30,000 m3 in gross,	gross
chemical materials and chemical product producing	basic chemical materials producing, chemical fertilizer producing, chemical pesticide/dyestuff producing, complex dyestuff producing, diaconal and organic poroduct producing, organic chemical materialand intermediate producing,complex material producing , complex colophony and other macromolecule material producing, special chemical stuff producing, bio-chemical and sencitive material producing,magnetic recording material producing,everyday chemical producing	All	/	/
	admixture and classify of simplex chemical product including everyday chemical product	/	All	/
	dip/reagent producing	sensitive area	unsensitive area	/
Medi-cine manufacture	Chemical medicine manufacture ,biological product	all except classify and redistribution of simplex medicine	classify and redistribution of simplex medicine	/
	mid-patent medicine manufature	/	sensitive area	unsensitive area
Chemical fibre Producing	artifical fibre producing , Synthetical fibre producing	All	/	/
Rubber product	Rubber machining ,rubber product reusing and overhauling	sensitive area	unsensitive area	/
	tyre producing	All	/	/
Plastic product	Foarm plastic \leatheroid \man-made leather and other plastic products	/	All	/
Metalloid mineral product	Cement produce ,graphite and ???? product	All	/	/

	Lime /tile / light architectural material producing		/	All	/
	Glass producing		Not less than 50 ton every day	less than 50 ton every day	/
	glass/chinaware /asbestos product , flameresistant materials such as asbestos /mica, mineral fibre and correlative products		/	All	/
	Cement products, Machining ,cement powdered station ,cement churned up station		/	sensitive area	unsensitive area
Black metal smelting and Depressive extending machining	Puddling , agglomerating , steel-making ,steel combining machining, ferroalloy smelting		All	/	/
	steel depressive extending and machining		/	All	/
	steel rolling	hot steel rolling	Not less than 1000,000 tons annual production	less than 1000,000 tons annual production	/
		cold steel rolling	Not less than 500,000 tons annual production	less than 500,000 tons annual production	/
Colored metal smelting and Depressive extending and machining	Colored metal smelting, Colored metal alloy		All	/	/
	Colored metal Depressive extending and machining		sensitive area	unsensitive area	/
Metal product	cast-iron metal accessory producing		not less than 100,000 tons annual production	Less than 100,000 but not less than 10,000 tons annual production	less than 10,000 tons annual production
	plating		All	/	/
	heat treatment and skin －deep treatment		sensitive area	unsensitive area	/
Machine producing	traffic transportation equipment, professional equipment, electric machine and equipment, weapon equipment		New-building /enlarged building area	rebuilding	/

	general machine ,apparatus , culture and office equipment		/	New-building /enlarged building area	rebuilding
	Other machines ,machine semi-manufactured goods machining and assembling		/	New-building /enlarged building area	rebuilding
electronic and communication equipment producing	Colored pipe , vitreous shell, new-style display part, fibre prefab club produing		all	/	/
	integrate circuit producing ,semiconductor part producing		Former working procedure producing, new-building	others	/
	Printing circuit board , electrical vacuum equipment		all	/	/
	Semiconductor material, electronic chinaware ,organic film, fluorescent powder ,valuable metal powder		sensitive area	unsensitive area	/
	electronic fitting assembling		/	All	/
	battery producing		/	All	/
electric power/ steam/hot water supply	electric power producing	generating electricity by Firepower (except natural gas), generating electricity by waterpower, accumulating by pumping water ,generating electricity and supplying energy by nuclear,generating electricity by reusing garbage	All	/	/
		electricity generating field by natural gas	Not less than 300MW, sensitive area	others	/
		to decarbolizing progect	to decarbolize sea water	others	/
		Generating electricity by wind/ terrestrial heat/tide/ marsh gas/solar	/	All	/

	Transport and transformer project and electricity supply	not less than 500 kv; less than 500 kv, sensitive area	less than 500 kv, unsensitive area ; direct current transportation	/
	Heat/steam/hot water production and supply	not less than 65 ton/h in boiler general capacity	Others	less than 10 tons/h in boiler general capacity,unsensitive area
Natural gas /coal gas production and supply	coal gas production	All	/	/
	Coal gas supply	/	All	/
	city natural gas supply	/	All	/
Tap water production and supply		Not less than 100,000 tons everyday supply, having leading water project	Others	/
city traffic establishment	city road	New-building ; rebuilding, sensitive area	rebuilding, unsensitive area	/
	city orbit traffic, trestle	All	/	/
town new area construction		All	/	/
town old area reconstruction		sensitive area	unsensitive area	/
Waste solid concentrated filling 、compost、setting on fire		All	/	/
Town riverway /lake repair		sensitive area	unsensitive area	/
City sewage concentrated disposal		not less than300,000ton/d;less than 300,000ton/d, sensitive area	less than 300,000ton/d,unsensitive area	/
city dejecta disposal		/	All	/
agriculture	agriculture integrated development	sensitive area	unsensitive area	/
	land reclamation	not less than 600 hektare	less than 600 hektare	/
sand preventing and fixation project		/	All	/
forestry	tree planting and forestation	/	sensitive area	unsensitive area
	deforestation	exhausting deforestation	distant deforestation	/

pasturage	breeding	Breeding pigs, not less than 3000 head annual amount of livestock on hand; meat cow , not less than 400 head annual amount of livestock on hand; milch cow, not less than 200 head annual amount of livestock on hand; poultry ,not less than 100,000 head annual amount of livestock on hand	Others	Breeding pigs, less than 500 head annual amount of livestock on hand; meat cow , less than 200 head annual amount of livestock on hand; milch cow, less than 100 head annual amount of livestock on hand; poultry , less than 10,000 head annual amount of livestock on hand
	breeding area	Breeding pigs, not less than 6000 head annual amount of livestock on hand; meat cow , not less than 800 head annual amount of livestock on hand; milch cow, not less than 400 head annual amount of livestock on hand; poultry ,not less than 200,000 head annual amount of livestock on hand	Others	Breeding pigs, less than 3000 head annual amount of livestock on hand; meat cow , less than 400 head annual amount of livestock on hand; milch cow, less than 200 head annual amount of livestock on hand; poultry , less than 20,000 head annual amount of livestock on hand
	livestock herding	not less than 5000 head annual herding amount	less than 5000 head annual herding amount	/
	other breeding	/	All	/
fishery	breed aquatics in freshwater	/	breeding aquatics in lakes	Others
	breeding aquatics in seas	not less than 2000 mu in close sea area	Not less than 200 mu for exalted pool;not less than 1000 mu for low level pool;not less than 5000 mu for open offing area	Others
transfer gene technology popularization and application, high-technology such as bringing in species		All	/	/

Geology perambulation	single well reconnoitre	/	sensitive area	unsensitive area
	district review and reconnoitre	sensitive area	unsensitive area	/
water conservancy	reservoir	large scaled reservoir (over 100,000,000 m3 in capacity);middle scale reservoir (over 10,000,000 m3 in capacity),sensitive area ;underground reservoir	Others	/
	irrigation area	new building ,not less than 50000 mu; rebuilding , more than 300000 mu ;rebuilding ,less than 300000 mu ,sensitive area	new building , less than 50000 mu; rebuilding ,less than 300000 mu ,unsensitive area	/
	bringing in water	moving water over drainage area ;annual moving amount taking up below 1/4 and over10% of the annual runoff in moved area ,sensitive area	annual moving amount taking up below 1/4 and over10% of the annual runoff in moved area ,unsensitive area ; annual moving amount taking up below 10% of the annual runoff in moved area ,sensitive area	annual moving amount taking up below 10% of the annual runoff in moved area ,unsensitive area
	embankment	new-building level one ;new-building level two, sensitive area	Others	/
	small scale cropland irrigation equipment	/	/	All
highroad		Not less than 50 km For Highroad in level 3 and over; less than 50 km For Highroad below level 3, sensitive area; not less than 1000 m for separate tunnel; less than 1000 m for separate tunnel,sensitive area	others	/

Railroad	new-building; extra-building	Railway plus line not less than 50 km ; Railway plus line less than 50 km ,sensitive area ; larger than section station(including large scale passenger station)	others	/
	electrization alteration	railway not shorter than 200 km ;railway shorter than 100 km(new-building, enlarging building),sensitive area	others	/
	rebuilding and enlarging programme	larger than section station(including large scale passenger station);railway hinge; critical goods field; current air /vehicle area; stone dreg field annual production over 300,000 ton	others	/
civil aviaton project	airport	airport project whose annual passenger thruput not less than 300,000 ; airport project whose annual passenger thruput less than 300,000 , sensitive area;airport project used for tour /general use/training whose everyday filght number not less than 30	Others	/
	navigation platform station	All	/	/
	Oil supply project, maintaining and ensuring project	/	All	/
haven ,dock	all-around port area, petrifaction transportation or critical goods port	All	/	/
	dispersed goods port	designed annual thruput not less than 1000,000 ton; designed annual thruput less than 1000,000 ton, sensitive area;	designed annual thruput less than 1000,000 ton, unsensitive area;	/

	containerport	annual thruput not less than 1000,000 standard box	annual thruput less than 1000,000 standard box	/
	passenger port	international port	Others	/
bridge project(including bridge approach and connecting line)		1000 m and longer ;shorter than 1000 m ,sensitive area	Shorter than 1000 m,unsensitive area	/
Sea petroleum and natural gas exploitation		All	/	/
Benthal pipe/cable laying		Not shorter than 50 km in length	shorter than 50 km in length	/
bulwark project		sensitive area	unsensitive area	/
pipe transportation		Not shorter than 100 km in length ; shorter than 50 km in length, sensitive area	shorter than 100 km in length, unsensitive area	/
sea-route dredge up and water carriage assistant project		digging not less than 15,000,000 m3; digging not less than 2,000,000 and less than15,000,000 m3, sensitive area	Others	/
water carriage hinge		new-building	rebuilding/enlarge-building	/
storage	poisonous and deleterious , Critical goods storage	All	/	/
	common goods storage(including foodstuff sorage)	/	All	/
shipbreak		All	/	/
imported waste dismantle		sensitive area	unsensitive area	/
wholesale and retail market		/	sensitive area	unsensitive area
dining		/	sensitive area	unsensitive area
real estate development		Occupy not less than 50，000 ㎡,sensitive area; architectural square not less than 100,000 ㎡,sensitive area	Others	architectural square less than 20,000 ㎡,unsensitive area
parking lots		/	position not less than 2000	position not less than 2000

long-distance passenger station		/	All	/
driver training base		/	All	/
car cleanout /maintain, laundering and dye, bathing ,gas station		/	sensitive area	unsensitive area
crematory, cemetery		/	All	/
school		/	teachers and students on campus not less than 1500	teachers and students on campus less than 1500
Waster purchase station, colored film and other community service equipment		/	/	All
cable car /ropeway building		all	/	/
amusement service		/	sensitive area	unsensitive area
exhibition hall, museum and carnie		occupy not less than 30,000 m^2,sensitive area	Others	/
theater, odeum		/	holding 1000 and more	holding less than 1000
Sanitation	hospital	Having bed not less than 500	Having bed less than 500	/
	sanatorium	Having bed not less than 700	Having bed less than 700	/
	special dispensary	Having bed not less than 200	Having bed less than 200	/
	sanitary station ,blood station	/	All	/
Physical Culture	palaestra	holding 50,000 and more	holding less than 50000	/
	gymnasium	holding 10000 and more	holding less than 10000	/
	golf course	All	/	/
movie base		sensitive area	unsensitive area	/
film developing		/	sensitive area	unsensitive area
broadcasting station,		medium wave not less than 50 kw;short wave not less than 100 kw ,sensitive area	Others	/
TV station		not less than 100 kw	Others	/

Nuclear equipment	nuclear-powered works(nuclear electric field, nuclear thermoelectric works,nuclear steam and heat supply works), reactor(research , experiment , critical equipment and so on), uranic exploitation /smelting ,nuclear fuel production/machining/storing/later-disposing high-octane accelerator, radioactive waster storing/disposing ,and the retirement of project mentioned above	all	/	/
	radioactive things’ transportation	all	/	/
	uranic geologic reconnoitre, uranic exploitation experiment ,and retirement of the project mentioned above	/	All	/
nuclear technology apply		radioactive isotope production, radioactive isotope field tracking experiment, large scale radiate equipment, and retirement of the project mentioned above	sell/use/transport high active radioactive isotope and its equipment; radioactive waster/isotope storage; neutron occurring place; accelerator; and retirement of the project mentioned above	sell/use/transport low active radioactive isotope and its equipment;X ray occurring place; and retirement of the project mentioned above
Associated radioactive mineral resourses development and using	minaral associated with radioactive natural uranium/ thorium exploitation /machining /using and waster disposal and storage	All	/	/
secondary earth up station		single station many platforms	single station single platform	/
radar		Many radar communication system	single radar communication system	/
wireless communication		one place many platforms ; many places emissive system	one place one platform	/

Annex 2: Supervision and approval: Project categories

The management of the EIA examination of the construction projects. See Table 2-3.

Project category	Sub-category	Investment or Construction Scale of the Projects
Investment project in budget		total investment not less than 200,000,000
Special construction fund project	irrigation works fund	total investment not less than 200,000,000
	Railroading fund	New railroading project total investment not less than 200,000,000 ; enlarging railroading project total investment not less than 1000,000,000 ;
	Port construction fund	coal / ore/gas / container berth designed with annual thruput not less than 1000,000 ton ;berth with over 10,000 ton deep water bank use
	freshwater construction fund	freshwater ship engineering span province/ section/city
	Highroad construction fund	National main road ,new-building highway ; Level one highroad spanning environmental sensitive area with length not less than 50 km; level one or two highway with length not less than 100 km; separate highway bridge /tunnel with length not less than 2 km;
	civil aviaton construction fund	Civil airport enlarging project total investment not less than 200,000,000 ; hollow-pipe and airplane maintaining project , army-civilian airport project total investment not less than 200,000,000 ;
nuclear project ,strictly confidential project		all
war industry project		total investment not less than 200,000,000 ;

Table 2 Catalogue of Non-governmental Large Investment Projects, the EIA reports of which are subject to the Examination and Approval of SEPA

Category of project	Investment Scale/Building Scale
1 agriculture irrigation irrigation project forest agriculture	total investment not less than 1000,000,000 ; total investment not less than 500,000,000 ; total investment not less than 500,000,000 ;
2 energy electricity	Water-electricity station: installed capacity no less than 100,000 kw Fire-electricity station: installed capacity no less than 200,000 kw Heat-electricity station : installed capacity not less than 50,000 kw Transport changing electricity project: project with total investment not less than 200,000,000 in and not less than 330 kv
coal	Coal mine :not less than 1500,000 ton annual production Coal liquefying /underground gasifying /coal bed gas developing project with total investment not less than 200,000,000 Other project with total investment not less than 500,000,000
Petroleum	crude oil: annual production 200,000 ton and more Natural gas :annual production 500,000,000 m3

	Gas /oil transportation main pipe spanning province and Liquefacient oil gas storage equipment ,annual turnover not less than 500,000 ton oil storage equipment ,annual turnover not less than 200,000 ton China and foreign countries cooperative oil and gas field project
3 traffic railway	New-building railway: total investment not less than 200,000,000 Enlarge-building railway: total investment not less than 1000,000,000 Other project : total investment not less than 200,000,000
highroad	National main road ,new-building highway not less than 50 km ; highroad spanning environmental sensitive area with length not less than 100 km; separate highway bridge /tunnel with length not less than 2 km;
water carriage	coal / ore/gas berth designed with annual thruput not less than 5000,000 ton ; all petrochemical and waste goods port bank line use with berth not smaller than 100,000 ton freshwater ship engineering spanning province/ section/city
civil airport	new-building airport : all project Enlarge building civil airport: total investment not less than 200,000,000 Enlarge building army-civilian airport: total investment not less than 200,000,000
4 Information industry Electronic information product making telecom project post project	total investment not less than 500,000,000 State Department specially stated project such as mobile communication system and terminal total investment not less than 500,000,000 total investment not less than 200,000,000
5 raw material steel	Puddling: annual production not less than 500,000ton steel-making by electric cooker : annual production not less than 300,000ton steel-making by converter : annual production not less than 500,000ton common steel :annual production not less than 500,000ton special steel :annual production not less than 350,000ton other project with total investment not less than 200,000,000
colored metal :copper, zinc, lead aluminium thulium and others	hypaethral mine :total investment not less than 200,000,000 underground mine : total investment not less than 200,000,000 smelting :annual production not less than 50000 ton machining :annual production not less than 100000 ton alumina :annual production not less than 300000 ton electrolytic aluminium: all project total investment not less than 100,000,000 total investment not less than 200,000,000
gold	total investment not less than 100,000,000
Building material cement	cooked foods annual production not less than 2000ton total investment not less than 200,000,000

others	
petrifaction oil refining ethene PTA others	total investment not less than 200,000,000 total investment not less than 200,000,000 total investment not less than 200,000,000 total investment not less than 200,000,000
chemical nitrogenous fertilizer phosphoric fertilizer kalium fertilizer others	compositive ammonia annual production not less than 300,000ton ; carbamide annual production not less than 300,000ton counted as P2O5 □ annual production not less than 240,000ton KCL: annual production not less than 500,000ton K2SO4 or KNO3 □annual production not less than 100,000ton total investment not less than 200,000,000
6□machine autocar others	All new building engine project New car model and engine technology bringing in project Existing car company extra-investing in not-having-product project total investment not less than 500,000,000 total investment not less than 500,000,000
7□ light industry wood plasm doffing ink plasm non-wood plasm paper making	annual production not less than 100,000ton annual production not less than 100,000ton annual production not less than 50,000ton annual production not less than 100,000ton
spin chemical fibre	total investment not less than 200,000,000
tobacco vinegar piece vinegar fibre used in tobacco	annual production not less than 300,000ton annual production not less than 300,000ton
8□city building and environmental protection city speedy orbit city sewage disposal municipal project	all project sewage disposal project relating to water basin /lake /sea area pollution disposal whose everyday disposing amount is not less than 100,000ton Bridge and tunnel project spanning big river and main bay garbage setting on fire with total investment not less than 200,000,000
9□High-tech industry	referring to industry technology developing trends ,total investment about 200,000,000
10□real estate project	□
11□social industry	□
12□ nuclear project (equipment) and strictly confidential project	all
13□War industry project	total investment not less than 200,000,000
14□others	1□Referring to new species bringing in project and producing transferring gene product project with total investment not less than 100,000,000 2□in medicine production , bacteriophage (raw material)composing and substrate producing with total investment not less than

	200,000,000 3□yellow phosphor producing and phosphor chemical with phosphor as main material with total investment not less than 200,000,000 4□cyanide production project 5□chinese uncisborder investment project ,Chinese investment coming to 30,000,000$ Notice: the classify of construction project production and investment scale applying tech-changing /enlarging project

To any construction project that involves NNR (National Natural Reserve), if the EIA report is to be examined by the local government environmental protection executive department, the related department should ask the SEPA for opinion before the department is to approve the document of the EIA of the construction project.

The development zone EIA. the administrative committee of the development zone (or other departments that have the same function) (mainly includes: economy and technology development zone approved by the state council, provincial government or autonomous region government, municipality directly under the jurisdiction of the Central Government, and the high and new technology industrial development zone, low-tax zone, national tourist holiday resort, border economic cooperation zone), should report the EIA to the environmental protection executive department of the same level government that approved the development zone for approval during the period of the general plan. The approved EIA report of the development zone is the main foundation of the making, amending and the perfecting of the general plan. The EIA works of the development zone should be undertaken by the unit of EIA construction project level I promulgated by the SEPA.

EIA of rural enterprises. the rural enterprises should carry through the EIA on any development and construction projects, including: infrastructure construction projects, technological transformation project and resources exploitation project. The specific procedure usually is: the rural enterprises contracts with the qualified assessment unit to consign them to engage in the investigation and assessment. The assessment unit makes the EIA report after the investigation and the assessment, and report to the project executive department for pre-examination and the examination by the environmental protection executive department that has the authorization power. Only after the EIA report is approved can the planning department implement the construction project plan. The disapproved project, the planning department does not transact the approval procedure of the design brief, the land management department does not transact the expropriation procedure, the bank does not lend. If any project is implemented without the approval, the principal of the construction unit will be fined besides the cease of operation and the re-make of the approval procedure.