CHAPTER 7

SENSITIVITY AND RISK ANALYSES

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7.1 Introduction

1. The financial and economic benefit-cost analysis of water supply projects (WSPs) is based on forecasts of quantifiable variables such as demand, costs, water availability and benefits. The values of these variables are estimated based on the **most probable** forecasts, which cover a long period of time. The values of these variables for the most probable outcome scenario are influenced by a great number of factors, and the actual values may differ considerably from the forecasted values, depending on future developments. It is therefore useful to consider the effects of likely changes in the key variables on the viability (EIRR and FIRR) of a project. Performing sensitivity and risk analysis does this.

Box 7.1 **Definitions**

Sensitivity Analysis shows to what extent the viability of a project is influenced by variations in major quantifiable variables.

Risk Analysis considers the probability that changes in major quantifiable variables will actually occur.

2. The viability of projects is evaluated based on a comparison of its internal rate of return (FIRR and EIRR) to the financial or economic opportunity cost of capital. Alternatively, the project is considered to be viable when the Net Present Value (NPV) is positive, using the selected EOCC or FOCC as discount rate. Sensitivity and risk analyses, therefore, focus on analyzing the effects of changes in key variables on the project's IRR or NPV, the two most widely used measures of project worth.

3. In the economic analysis of WSPSs, there are also other aspects of project feasibility which may require sensitivity and risk analysis. These include:

(i) Demand Analysis: to assess the sensitivity of the demand forecast to changes in population growth, per capita consumption, water tariffs, etc.

(ii) Least Cost Analysis: to verify whether the selected least-cost alternative remains the preferred option under adverse conditions;

(iii) Sustainability Analysis: to assess possible threats to the sustainability of the project.

(iv) Distributional Analysis: to analyze whether the project will actually benefit the poor.

This chapter aims at explaining the general concept of sensitivity and risk analysis.

4. Sensitivity and risk analyses are particularly concerned with factors, and combinations of factors, that may lead to unfavorable consequences. These factors would normally have been identified in the project (logical) framework as "project risks" or "project assumptions". Sensitivity analysis tries to estimate the effect on achieving project objectives if certain assumptions do not, or only partly, materialize. Risk analysis assesses the actual risk that certain assumptions do not, or only partly, occur.

7.2 The Purpose of Sensitivity Analysis

5. Sensitivity analysis is a technique for investigating the impact of changes in project variables on the base-case (most probable outcome scenario). Typically, only adverse changes are considered in sensitivity analysis. The purpose of sensitivity analysis is:

(i) to help identify the key variables which influence the project cost and benefit streams. In WSPs, key variables to be normally included in sensitivity analysis include water demand, investment cost, O&M cost, financial revenues, economic benefits, financial benefits, water tariffs, availability of raw water and discount rates.

(ii) to investigate the consequences of likely adverse changes in these key variables;

(iii) to assess whether project decisions are likely to be affected by such changes; and,

(iv) to identify actions that could mitigate possible adverse effects on the project.

7.3 Performance of Sensitivity Analysis

6. Sensitivity analysis needs to be carried out in a systematic manner. To meet the above purposes, the following steps are suggested:

(i) identify key variables to which the project decision may be sensitive;

(ii) calculate the effect of likely changes in these variables on the base-case IRR or NPV, and calculate a sensitivity indicator and/or switching value;
(iii) consider possible combinations of variables that may change simultaneously in an adverse direction;
(iv) analyze the direction and scale of likely changes for the key variables identified, involving identification of the sources of change.

The information generated can be presented in a tabular form with an accompanying commentary and set of recommendations, such as the example shown in 7.2. The different steps are described in the following paragraphs:

Step 1: Identifying the Key Variables

7. The base case project economic analysis incorporates many variables: quantities and their inter-relationships, prices or economic values and the timing of project effects. Some of these variables will be predictable or relatively small in value in the project context. It is not necessary to investigate the sensitivity of the measures of project worth to such variables. Other variables may be less predictable or larger in value. Variables related to sectoral policy and capacity building may also be important. As they are more difficult to quantify, they are not further considered hereafter but should be assessed in a qualitative manner.

8. As a result of previous experience (from post-evaluation studies) and analysis of the project context, a preliminary set of likely key variables can be chosen on the following basis:

(i) Variables which are numerically large. For example: investment cost, projected water demand;
(ii) Essential variables, which may be small, but the value of which is very important for the design of the project. For example: assumed population growth and water tariffs;
(iii) Variables occurring early in the project life. For example: investment costs and initial fixed operating costs, which will be relatively unaffected by discounting;
(iv) Variables affected by economic changes, such as, changes in real income.

Important variables to be considered in WSPs include :

Box 7.2 **Variables in Water Supply Projects to be considered in Sensitivity Analysis**

Possible Key Variables	Quantifiable Variables	Underlying Variables
Water Demand	• Population growth Achieved coverage Household Consumption • Non Domestic Consumption • Unaccounted for Water	• Price Elasticity • Income Elasticity
Investment Costs (Economic & Financial)	• Water Demand • Construction Period • Real Prices • Conversion Factors	
O&M Costs	• Personnel Costs (wages/No. of staff, etc.) • Cost of Energy • Cost of Maintenance • Efficiency of Utility	
Financial Revenues	• Quantity of water consumed • Service level • Income from connection fees	• Water Tariffs • UFW (bad debts)
Economic Benefits	• Water Demand • Resource Costs Savings	• Willingness to Pay
Cost Recovery	• Water Tariffs • Subsidies	

Step 2 and 3: Calculation of Effects of Changing Variables

9. The values of the basic indicators of project viability (EIRR and ENPV should be recalculated for different values of key variables. This is preferably done by calculating "sensitivity indicators" and "switching values". The meaning of these concepts is presented in Box 7.3 and a sample calculation immediately follows. Sensitivity indicators and switching values can be calculated for the IRR and NPV, see Box 7.3.

Box 7.3 **Use of Sensitivity Indicators and Switching Values**

	Sensitivity Indicator	Switching Value
Definition	**1. Towards the Net Present Value** Compares percentage change in NPV with percentage change in a variable or combination of variables. **2. Towards the Internal Rate of Return** Compares percentage change in IRR above the cut-off rate with percentage change in a variable or combination of variables.	**1. Towards the Net Present Value** The percentage change in a variable or combination of variables to reduce the NPV to zero (0). **2. Towards the Internal Rate of Return** The percentage change in a variable or combination of variables to reduce the IRR to the cut-off rate (=discount rate).
Expression	**1. Towards the Net Present Value** $SI = \frac{(NPV_b - NPV_1) / NPV_b}{(X_b - X_1) / X_b}$ where: X_b - value of variable in the base case X_1 - value of the variable in the sensitivity test NPV_b - value of NPV in the base case NPV_1 - value of the variable in the sensitivity test **2. Towards the Internal Rate of Return** $SI = \frac{(IRR_b - IRR_1) / (IRR_b - d)}{(X_b - X_1) / X_b}$ where: X_b - value of variable in the base case X_1 - value of the variable in the sensitivity test IRR_b - value of IRR in the base case IRR_1Value of the variable in the sensitivity test d - discount rate	**1. Towards the Net Present Value** $SV = \frac{(100 \times NPV_b)}{(NPV_b - NPV_1)} \times \frac{(X_b - X_1)}{X_b}$ where: X_b - value of variable in the base case X_1 - value of the variable in the sensitivity test NPV_b – value of NPV in the base case NPV_1 – value of the variable in the sensitivity test **2. Towards the Internal Rate of Return** $SV = \frac{(100 \times (IRR_b - d)}{(IRR_b - IRR_1)} \times \frac{(X_b - X_1)}{X_b}$ where: X_b - value of variable in the base case X_1 - value of the variable in the sensitivity test IRR_b - value of IRR in the base case IRR_1 – value of the variable in the sensitivity test d - discount rate

Box 7.3 **Use of Sensitivity Indicators and Switching Values**

	Sensitivity Indicator	Switching Value
Calculation example	**1. Towards the Net Present Value** Base Case: Price = P_b = 300 NPV_b = 20,912 Scenario 1: P_1 = 270 (10% change) NPV_1 = 6,895 $SI = \frac{(20{,}912 - 6{,}895) / 20{,}912}{(300 - 270) / 300} = 6.70$ **2. Towards the Internal Rate of Return** Base Case: Price = P_b = 300 IRR_b = 15.87% Scenario 1: P_1 = 270 (10% change) IRR_1 = 13.31% d = 12% $SI = \frac{(0.1587 - 0.1331) / (0.1587 - 0.12)}{(300 - 270) / 300} = 6.61$	**1. Towards the Net Present Value** Base Case: Price = P_b = 300 NPV_b = 20,912 Scenario 1 P_1 = 270 (10% change) NPV_1 = 6,895 $SV = \frac{(100 \times 20{,}912)}{(20{,}912 - 6{,}895)} \times \frac{(300-270)}{300} = 14.9\%$ **2. Towards the Internal Rate of Return** Base Case: Price = P_b = 300 IRR_b = 15.87% Scenario 1: P_1 = 270 (10% change) IRR_1 = 13.31% d = 12% $SV = \frac{(100 \times (0.1587-0.12))}{(0.1587 - 0.1331)} \times \frac{(300-270)}{300} = 15.1\%$
Interpretation	(i) percentage change in NPV respectively (ii) percentage change in IRR above the cut-off rate (12%)is larger than percentage change in variable: price is a key variable for the project.	A change of approximately 15 % in the price variable is necessary before the NPV becomes zero or before the IRR equals the cut-off rate.
Characteristic	Indicates to which variables the project result is or is not sensitive. Suggests further examination of change in variable.	Measures extent of change for a variable which will leave the project decision unchanged.

10. The switching value is, by definition, the reciprocal of the sensitivity indicator. Sensitivity indicators and switching values calculated towards the IRR yield slightly different results if compared to SIs and SVs calculated towards the NPV. This is because the

IRR approach discounts all future net benefits at the IRR value and the NPV approach at the discount rate d.

Table 7.1 **Base Case of a Water Supply Project**

Economic statement	PV @12%	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Benefits:											
- Non-incremental water	1,674	0	225	270	315	360	405	450	450	450	450
- Incremental water	167	0	23	27	32	36	41	45	45	45	45
- Non-technical losses	263	0	35	42	50	57	64	71	71	71	71
Total	2,104	0	283	339	396	453	509	566	566	566	566
Costs:											
- Investment	1,687	1,889	0	0	0	0	0	0	0	0	0
- O&M	291	0	61	61	61	61	61	61	61	61	61
Total	1,978	1,889	61	61	61	61	61	61	61	61	61
Net cash flow	126	-1,889	222	278	335	391	448	505	505	505	505

11. In the base case, the ENPV is 126 and the EIRR is 13.7 percent. The sensitivity of the base case ENPV has been analyzed for (adverse) changes in several key variables, as follows:

(i) An increase in investment cost by 20 percent;

(ii) A decrease in economic benefits by 20 percent;

(iii) An increase in costs of operation and maintenance by 20 percent.

(iv) A delay in the period of construction, causing a delay in revenue generation by one year.

Proposed changes in key variables should be well explained. The sensitivity analysis should be based on the most likely changes. The effects of the above changes are summarized in Table 7.2 below.

Table 7.2 **Sensitivity Analysis: A Numerical Example**

Item	Change	NPV	IRR %	SI (NPV)	SV (NPV)
Base Case		126	13.7		
Investment	+ 20%	- 211	9.6	13.3	7.5%
Benefits	- 20%	-294	7.8	16.6	6%
O&M Costs	+ 20%	68	12.9	2.3	43.4%
Construction delays	one year	-99	10.8	NPV 178% lower	
SI = Sensitivity Indicator, SV = Switching Value					
Source: Based on the data in Table 7.1.					

12. Combinations of variables can also be considered. For example, the effect on the ENPV or EIRR of a simultaneous decline in economic benefits and an increase in investment cost can be computed. In specifying the combinations to be included, the project analyst should state the rationale for any particular combination to ensure it is plausible.

Step 4: Analysis of Effects of Changes in Key Variables

13. In the case of an increase in investment costs of 20 percent, the sensitivity indicator is 13.34. This means that the change of 20 percent in the variable (investment cost) results in a change of (13.3 x 20 percent) = 266 percent in the ENPV. It follows that the higher the SI, the more sensitive the NPV is to the change in the concerned variable.

14. In the same example, the switching value is 7.5 percent which is the reciprocal value of the SI x 100. This means that a change (increase) of 7.5 percent in the key variable (investment cost) will cause the ENPV to become zero. The lower the SV, the more sensitive the NPV is to the change in the variable concerned and the higher the risk with the project.

15. At this point the results of the sensitivity analysis should be reviewed. It should be asked: (I) which are the variables with high sensitivity indicators; and (ii) how likely are the (adverse) changes (as indicated by the switching value) in the values of the variables that would alter the project decision?

7.4 Risk Analysis

7.4.1 Qualitative Risk Analysis

16. In cases where project results are expected to be particularly sensitive to certain variables, it has to be assessed how likely it is that such changes would occur. This likelihood can be assessed by studying experiences in earlier, comparable projects and by investigating the situation in the sector as a whole.

17. Steps should be taken to reduce the extent of uncertainty surrounding those variables where possible. This may require remedial actions at the project, sector or national level. Examples of actions are:

(i) At the project level,

(a) make specific agreements to ensure contractor performance and project quality during construction works to reduce the likelihood of delays;

(b) enter into an agreement of long term supply contracts at specified quality and prices to reduce uncertainty of operating costs;

(c) formulate capacity building activities to ensure appropriate technical and financial management of water supply systems;

(d) conduct information or awareness building/educational programs to ensure the involvement of customers and to improve the hygienic use of water;

(e) incorporate the cost of sanitation or wastewater collection and treatment into project economic costs to ensure that environmental effects can be mitigated;

(f) implement a pilot phase to test technical assumptions and observe user's reactions, in case there is considerable uncertainty in a large project or program;

(g) set certain criteria which have to be met by subprojects before approval; for example, in rural WSPs, villages would have to fulfill

certain criteria (e.g., community involvement) to be included in the program. This is especially important in sector loans where most (small) subprojects will be prepared after loan approval.

(ii) At the sector level,

(a) make price and tariff adjustments to ensure sufficient revenues for utilities and to ensure their financial liquidity and sustainability;

(b) conduct technical assistance programs to develop appropriate project and operational management skills for staff in water enterprises;

(c) implement loan covenants to prompt necessary (policy) institutional and legal reforms.

(iii) At the national or macro level,

(a) implement changes in tax and credit policy to influence incentives and simplify procedures for the import of goods;

(b) reformulate incentives (e.g. corporate taxes for utilities) to encourage higher levels of investment;

(c) implement legislative reform and regulation to provide an enabling environment for productive activities.

18. The results of the sensitivity analysis should be stated along with the associated mitigating actions being recommended, and the remaining areas of uncertainty that they do not address. Sensitivity analysis is useful at all stages of project processing: at the design stage to incorporate appropriate changes; at the appraisal stage to establish a basis for monitoring; and, during project implementation to take corrective measures. The uncertainty surrounding the results of the economic and financial analysis is expected to decrease as the project moves into the operational phase.

19. For the key variables and combinations of such variables, a statement can be presented including: the source of variation for the key variables; the likelihood that variation will occur; the measures that could be taken to mitigate or reduce the likelihood of an adverse change; and the switching values and/or sensitivity indicators.

7.4.2 Quantitative Risk Analysis

20. The purpose of quantitative risk analysis is to estimate the probability that the project EIRR will fall below the opportunity cost of capital; or that the NPV, using the EIRR as the discount rate, will fall below zero. A statement of such an estimate means that decisions can be based not just on the single base-case EIRR but also on the probability that the project will prove unacceptable. Projects with smaller base-case EIRRs may involve less uncertainty and have a higher probability of being acceptable in implementation. Projects with higher base-case EIRRs may be less certain and involve greater risk. Risk analysis can be applied also to projects without measurable benefits, for example to assess the probability that unit costs will be greater than a standard figure.

21. Undertaking a risk analysis requires more information than for sensitivity analysis. It should be applied to selected projects that are large or marginal, or where a key variable is subject to a considerable range of uncertainty. A large project is one which takes a high proportion of government or the country's investment resources, for example a project using more than 5 percent of the government's investment budget in the peak project investment years. A marginal project is one where the base-case EIRR is only marginally higher than the opportunity cost of capital. A decision should be taken at an early stage of analysis whether to include a risk analysis in the appraisal or not.