

## **PROJECT RISK EVALUATION METHODS - SENSITIVITY ANALYSIS**

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**ABSTRACT:** *The viability of investment projects is based on IRR and NPV criteria. In the economic analysis of the projects there are some aspects of project feasibility which may require sensitivity and risk analysis. Sensitivity analysis estimates the effect on achieving project objectives if certain assumptions materialize or not. This paper presents the purpose of sensitivity analysis and the steps that must be followed in order to perform a sensitivity analysis as well as a numeric example.*

**KEY WORDS:** *investment project, NPV, IRR, sensitivity analysis, base-case, key variables, sensitivity indicator, switching value*

### **1. INTRODUCTION**

The financial and economic benefit-cost analysis of investment projects is based on forecast of quantifiable variables. 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 - economic internal rate of return and FIRR - financial rate of return). We can do this performing sensitivity analysis.

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 analysis focuses analyzing the effects of changes in key variables on the project's IRR or NPV, the two most widely used measures of project worth.

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

1. demand analysis: to assess the sensitivity of the demand forecast to changes in population growth, per capita consumption, prices, etc.
2. least cost analysis: to verify whether the selected least-cost alternative remains the preferred option under adverse conditions
3. sustainability analysis: to assess possible threats to the sustainability of the project
4. distributional analysis: to analyse whether the project will actually benefit the poor.

Sensitivity analysis is particularly concerned with factors and combinations of factors that may lead to unfavourable 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 of achieving project objectives if certain assumptions do not, or only partly, occur.

## **2. THE PURPOSE OF SENSITIVITY ANALYSIS**

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:

1. to help identify the key variables which influence the project cost and benefit streams
2. to investigate the consequences of likely adverse changes in these key variables
3. to assess whether project decisions are likely to be affected by such changes
4. to identify actions that could mitigate possible adverse effects on the project.

## **3. PERFORMANCE OF SENSITIVITY ANALYSIS**

Sensitivity analysis needs to be realized in a systematic manner. To meet the above purposes, the following steps are recommended to be followed:

1. identify key variables to which the project decision may be sensitive
2. 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
3. consider possible combinations of variables that may change simultaneously in an adverse direction
4. analyze the direction and scale of likely changes for the key variables identified, involving identification of the sources of change.

**Step 1: Identifying the key variables.** 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 sectorial 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.

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:

1. variables which are numerically large, ex. investment cost
2. essential variables, which may be small, but the value of which is very important for the design of the project
3. variables occurring early in the project life, ex. investment costs and initial fixed operating costs, which will be relatively unaffected by discounting
4. variables affected by economic changes, such as, changes in real income.

**Table 1. Base Case of an Investment Project**

Economic statement	PV	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	@12%										
Benefits	2,104	0	283	339	396	453	509	566	566	566	566
Costs:	1,978	1,889	61	61	61	61	61	61	61	61	61
-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
Net cash flow	126	-1,889	222	278	335	391	448	505	505	505	505

**Step 2 and 3: Calculation of effects of changing variables.** 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 table 2 as well as a sample calculation.

**Table 2. Use of Sensitivity Indicators and Switching Values**

	Sensitivity Indicators	Switching Value
Definition	<p><b>1. Towards the Net Present Value</b> Compares percentage change in NPV with percentage change in a variable or combination of variables.</p> <p><b>2. Towards the Internal Rate of Return.</b> Compares percentage change in IRR above the cut-off rate with percentage change in a variable or combination of variables.</p>	<p><b>1. Towards the Net Present Value</b> The percentage change in a variable or combination of variables to reduce the NPV to zero.</p> <p><b>2. Towards the Internal Rate of Return.</b> The percentage change in a variable or combination of variables to reduce the IRR to the cut-off rate (=discount rate).</p>
Expression	<p><b>1. Towards the Net Present Value</b>  <math display="block">SI = \frac{(NPV_b - NPV_1) / NPV_b}{(X_b - X_1) / X_b}</math>           where:  <math>X_b</math> – value of variable in the base case  <math>X_1</math> – value of the variable in the sensitivity test  <math>NPV_b</math> – value of NPV in the base case  <math>NPV_1</math> – value of the variable in the sensitivity test</p>	<p><b>1. Towards the Net Present Value</b>  <math display="block">SV = \frac{(100 \times NPV_b) (X_b - X_1)}{(NPV_b - NPV_1) X_b}</math>           where:  <math>X_b</math> – value of variable in the base case  <math>X_1</math> – value of the variable in the sensitivity test  <math>NPV_b</math> – value of NPV in the base case  <math>NPV_1</math> – value of the variable in the sensitivity test</p>

	<p><b>2.Towards the Internal Rate of Return</b></p> $SI = \frac{(IRR_b - IRR_1) / (IRR_b - d)}{(X_b - X_1) / X_b}$ <p>where:  <math>X_b</math> – value of the variable in the base case  <math>X_1</math> – value of the variable in the sensitivity test  <math>IRR_b</math> – value of IRR in the base case  <math>IRR_1</math> – value of the variable in the sensitivity test  <math>d</math> – discount rate</p>	<p><b>2.Towards the Internal Rate of Return</b></p> $SV = \frac{(100 \times NPV_b)}{(NPV_b - NPV_1)} \times \frac{(X_b - X_1)}{X_b}$ <p>where:  <math>X_b</math> – value of variable in the base case  <math>X_1</math> – value of the variable in the sensitivity test  <math>IRR_b</math> – value of IRR in the base case  <math>IRR_1</math> – value of the variable in the sensitivity test  <math>d</math> – discount rate</p>
Calculation example	<p><b>1.Towards the Net Present Value</b>            Base Case:            Price = <math>P_b = 300</math>  <math>NPV_b = 20,912</math>            Scenario 1:  <math>P_1 = 270</math> (10% change)  <math>NPV_1 = 6,895</math></p> $SI = \frac{(20,912 - 6,895) / 20,912}{(300 - 270) / 300} = 6.70$ <p><b>2.Towards the Internal Rate of Return</b>            Base Case:            Price = <math>P_b = 300</math>  <math>IRR_b = 15,87\%</math>            Scenario 1:  <math>P_1 = 270</math> (10% change)  <math>IRR_1 = 13,31\%</math>  <math>d = 12\%</math></p> $SI = \frac{(0,1587 - 0,1331) / (0,1587 - 0,12)}{(300 - 270) / 300} = 6,61$	<p><b>1.Towards the Net Present Value</b>            Base Case:            Price = <math>P_b = 300</math>  <math>NPV_b = 20,912</math>            Scenario 1:  <math>P_1 = 270</math> (10% change)  <math>NPV_1 = 6,895</math></p> $SV = \frac{(100 \times 20,912)}{(20,912 - 6,895)} \times \frac{(300 - 270)}{300} = 14.9\%$ <p><b>2.Towards the Internal Rate of Return</b>            Base Case:            Price = <math>P_b = 300</math>  <math>IRR_b = 15,87\%</math>            Scenario 1:  <math>P_1 = 270</math> (10% change)  <math>IRR_1 = 13,31\%</math>  <math>d = 12\%</math></p> $SV = \frac{(100 \times (0,1587 - 0,12))}{(0,1587 - 0,1331)} \times \frac{(300 - 270)}{300} = 15,1\%$
Interpretation	a) percentage change in NPV respectively b) 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.

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

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:

1. an increase in investment cost by 20 percent
2. a decrease in economic benefits by 20 percent
3. an increase in costs of operation and maintenance by 20 percent
4. 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 3.

**Table 3. Sensitivity Analysis – 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					

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.

**Step 4: Analysis of effects of changes in key variables.** 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 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.

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.

At this point the results of the sensitivity analysis should be reviewed. It should be asked: 1. Which are the variables with high sensitivity indicators; 2. How likely are the (adverse) changes (as indicated by the switching value) in the values of the variables that would alter the project decision?

#### 4. CONCLUSIONS

The paper presents two concepts: sensitivity indicator and switching value, used to perform a sensitivity analysis as well as the meaning of them. Sensitivity indicators and switching values are calculated for the NPV and IRR, as we can see in the numerical example, so we can analyze the effects of changes in key variable and minimize the project risk.

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