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TRANSPORT NOTES

TRANSPORT ECONOMICS, POLICY AND POVERTY THEMATIC GROUP

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Notes on the Economic Evaluation of Transport Projects

In response to many requests for help in the application of both conventional cost benefit analysis in transport and addressing of the newer topics of interest, we have prepared a series of Economic Evaluation Notes that provide guidance on some of issues that have proven more difficult to deal with.

The **Economic Evaluation Notes** *are arranged in three groups. The first group (TRN-6 to TRN—10) provides* **criteria** *for selection a particular evaluation technique or approach; the second (TRN-11 to TRN-17) addresses the selection of values of various* **inputs** *to the evaluation, and the third (TRN-18 to TRN-26) deals with specific* **problematic issues** *in economic evaluation. The Notes are preceded by a* **Framework** *(TRN-5), that provides the context within which we use economic evaluation in the transport sector.*

The main text of most of the Notes was prepared for the Transport and Urban Development Department (TUDTR) of the World Bank by Peter Mackie, John Nellthorp and James Laird, at the Institute for Transport Studies (ITS) , University of Leeds, UK (The draft text of Note 21 was prepared for ITS by I.T. Transport Ltd). TUDTR staff have made a few changes to the draft Notes as prepared by ITS.

The Notes will be revised periodically and we welcome comments on what changes become necessary. Suggestions for additional Notes or for changes or additions to existing Notes should be sent to rcarruthers@worldbank.org

[1]WHEN AND HOW TO USE NPV, IRR[2] AND MODIFIED IRR

BACKGROUND TO NPV, IRR AND MODIFIED IRR

All three are summary measures of project performance. Each one provides a single figure summarizing the impact of the project on economic welfare. Each of the three measures does, however, give subtly different information:

❑ NPV focuses on the total welfare gain over the whole life of the project;

❑ IRR and Modified IRR focus on the rate at which benefits are realized following an initial transport investment[3]. **Table 1** gives an illustrative example of some results.

As we will see below, these results would indicate that the project met the World Bank's basic acceptability criterion. They also provide a basis for comparison with other uses of the resources. First, though, we consider the meaning and calculation of the NPV, IRR and Modified IRR.

Table 1. Example Results - Highway Rehabilitation

Economic analysis over 30 years:

NPV@12% per annum = $530m

IRR = 20% per annum

Modified IRR = 15% per annum

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[1] The abbreviations stand for: Net Present Value (NPV), Internal Rate of Return (IRR) and Modified Internal Rate of Return (MIRR)

[2] Economic Rate of Return (ERR) is a near-identical concept. The formula is the same - the only difference is in the application. 'IRR' can be used to decribe financial or economic flows. The label 'ERR' indicates that the flow being described is a flow of economic costs and benefits.

[3] Note that the IRR only works in situations structured like this. It does not work in situations such as a tax reform, where there is no initial investment. See the Handbook Technical Appendix Paragraphs 10-12 for further guidance.

Net Present Value

NPV is a measure of the absolute welfare gain over the whole life of the project[4]. Future benefits and costs are discounted at a compound rate, r, typically 12% per annum[5]. Benefits, net of costs, are then summed across all years. **Box 1** shows how the calculations are made.

Box 1. Calculating the NPV

$$\text{Net Present Value} = B_0 - C_0 + \frac{B_1 - C_1}{(1+r)} + \frac{B_2 - C_2}{(1+r)^2} + ... + \frac{B_t - C_t}{(1+r)^t} + ... + \frac{B_n - C_n}{(1+r)^n}$$

$$= \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t}$$

where B_t are the benefits in year t,
C_t are the costs in year t,
r is the discount rate, and
n is the horizon year.

$\frac{1}{(1+r)^t}$ is called the **discount factor** in Year t.

Note that if **Present Value of Benefits (PVB)** is the sum of the discounted benefit stream,

$$\sum_{t=0}^{n} \frac{B_t}{(1+r)^t},$$

and **Present Value of Costs (PVC)** is the sum of the discounted cost stream, $\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$,

then NPV = PVB – PVC.

An example is given in **Table 2**.

The NPV can be calculated using spreadsheet software such as Microsoft Excel, most of which conveniently have an NPV function built-in.

Caution Excel users:
Users should exercise caution, since Excel starts discounting from the first year of the series. In an appraisal for the World Bank, the first year will often be the Base Year (the year in which t = 0 and the discount factor is 1.0). Under these circumstances, take care to calculate the NPV from year t = 1 onwards and add the undiscounted net benefit in year t = 0 to the result.

Note also that if costs are being calculated for each calendar year, benefits must be calculated for the same period. Care should be taken when inputting benefits from HDM-4 to ensure that the time periods are consistent.

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[4] See the *Framework (Section on CBA Parameters and Note 13: Projects with a Very Long Life).*

[5] There are two principal rationales for discounting: (i) to reflect the Opportunity Cost of Capital; or (ii) to reflect Social Time Preference. According to current evidence, these rationales lead to discount rates in the region of 10-12% or 5% respectively. The latter might be appropriate for a project which made no draw on capital, however such projects are presumably not likely to be funded by the World Bank. See Paragraphs 49-57 of the Technical Appendix to the *Handbook on Economic Analysis of Investment Operations* (World Bank, 1998) [1] for more detailed guidance on determining the appropriate Opportunity Cost of Capital, if required.

Internal Rate of Return

IRR is the rate at which benefits are realized following an initial transport investment. It can be thought of as the constant compound rate of return which is **equivalent** to the actual – fluctuating – rate of return over the project lifetime.

IRR is also closely related to the NPV: the IRR is the rate of discount at which the NPV of the project is reduced to zero.

Box 2. Calculating the IRR and the MIRR

$$B_0 - C_0 + \frac{B_1 - C_1}{(1 + IRR)} + \frac{B_2 - C_2}{(1 + IRR)^2} + ... + \frac{B_t - C_t}{(1 + IRR)^t} + ... + \frac{B_n - C_n}{(1 + IRR)^n} = 0$$

This can be solved by a search procedure, which is available in most spreadsheet packages - such as Microsoft Excel.

An example is given in Table 2,.

Table 2. Example Calculations - Highway Rehabilitation Project

Benefits, B_t	Costs, C_t	Discount factor @12% $DF_t = 1/1.12^t$	Discounted benefits, $B_t * DF_t$	Discounted costs $C_t * DF_t$	Discounted net benefits $(B_t - C_t) * DF_t$	Net benefit, $(B_t - C_t)$
	325.0	1.00		325.0	-325.0	-325.0
	285.0	0.89		254.5	-254.5	-285.0
110.0		0.80	87.7		87.7	110.0
113.6		0.71	80.9		80.9	113.6
117.3		0.64	74.6		74.6	117.3
124.6		0.57	70.7		70.7	124.6
128.3		0.51	65.0		65.0	128.3
135.6		0.45	61.4		61.4	135.6
143.0		0.40	57.7		57.7	143.0
150.3		0.36	54.2		54.2	150.3
157.6		0.32	50.8		50.8	157.6
165.0		0.29	47.4		47.4	165.0
176.0		0.26	45.2		45.2	176.0
187.0		0.23	42.8		42.8	187.0
198.0		0.20	40.5		40.5	198.0
205.3		0.18	37.5		37.5	205.3
212.6		0.16	34.7		34.7	212.6
223.6		0.15	32.6		32.6	223.6
230.9		0.13	30.0		30.0	230.9
238.3		0.12	27.7		27.7	238.3
241.9		0.10	25.1		25.1	241.9
245.6		0.09	22.7		22.7	245.6
249.3		0.08	20.6		20.6	249.3
252.9		0.07	18.7		18.7	252.9
256.6		0.07	16.9		16.9	256.6
260.3		0.06	15.3		15.3	260.3
267.6		0.05	14.1		14.1	267.6
274.9		0.05	12.9		12.9	274.9
278.6		0.04	11.7		11.7	278.6
274.1		0.04	10.2		10.2	274.1

Present Value of Benefits (PVB) =   1109.4

Present Value of Costs (PVC) =   579.5

Net Present Value (NPV) =   530.0

Internal Rate of Return (IRR) =   20%

Modified Internal Rate of Return (MIRR)

The Modified IRR is similar to the IRR, but overcomes two weaknesses of the IRR. The MIRR provides a test of the robustness of the IRR to one of the underlying assumptions: The IRR assumes that all the benefits from the project under review are re-invested at the internally generated rate of return, yielding further benefits in the next period. However, benefits from transport projects – for example, in the form of travel time savings – may not be re-investible. If the benefits cannot be re-invested or if they are re-investible but only at a lower rate, then the IRR will overstate the true rate of return. The MIRR corrects for this by assuming benefits are re-invested at the opportunity cost of capital. It then calculates the IRR which gives an estimate of the true value of the returns. The MIRR also avoids the problem of multiple IRRs, discussed earlier.

Box 3: Calculating the Modified IRR

The MIRR can be calculated using the following steps:

- **Estimate all cash flows as for the IRR**

- **Calculate the future value (FV), at time n, of all cash inflows, using the cost of capital as the interest rate**

- **Find the PV of all cash outflows, using cost of capital as the discount rate**

- **Find the modified IRR as the rate which equates the FV of inflows to the PV of outflows**

  $$PV_{costs} = FV / (1 + MIRR)^n$$

The Modified IRR can be calculated using the MIRR function in Microsoft Excel.

MIRR = (values, finance rate, reinvest rate)

The Reinvest Rate has to be entered in the form R%; Excel will then calculate the modified IRR.

In the example given in **Table 2,** if the benefits cannot be re-invested at all, the Modified IRR will be 8%. If the benefits can only be invested at a market interest rate of 12% rather than at the IRR, the Modified IRR will be 15%. Again, the calculations can be made using spreadsheet software. In practice, it might be reasonable to assume simply that:

❑   the revenue stream is fully reinvestible;
❑   the user benefits are not reinvestible, or reinvestible only at a lower rate.

Box 4: China: Liaoning Urban Transport Project.
        Incorporating the MIRR

The Liaoning Urban Transport project (USD 150 million) offers an example in the use of the modified ERR, in addition to the ERR and the NPV. The project included investments in, and improvements to, the operation of the urban transport system in the cities of Shenyang, Fushun, and Anshan in the Liaoning province of China. In each city, the project provided funds for public transport, traffic management, road infrastructure and road maintenance activities. Investments covered junction improvements, road maintenance and reconstruction, construction of cycle routes, designating and adapting infrastructure for bus-only lanes, and equipment for traffic management.

The evaluation of economic benefits followed a conservative approach and was restricted to reductions in vehicle operating costs (VOC) and savings in travel time for transport system users, including cyclists. Benefits / costs to pedestrians were excluded from the analysis due to data constraints, as were benefits resulting from safety improvements. A substantial share of overall benefits, 25%, was those due to time savings – under the straight ERR calculations, it is assumed that all benefits are re-invested at the internally generated ROR. In cases where it is believed that some or all of the benefits cannot be re-invested (for example, time savings), the use of the modified rate of return offers a more realistic estimate of economic returns. When comparing projects, the ranking of projects using the IRR and MIRR remains unaffected so long as the same set of benefits are evaluated under both criteria.

For the project, the economic evaluation included calculation of the MIRR assuming that project benefits were reinvested at the average rate of return on public investments, that is, 12 %. For all components, the change in reinvestment rate led to a decline in the MIRR by approximately half but was still well above the Bank cut-off rate of 12% for project acceptability. If time savings are assigned a zero value in this example, the project would still be acceptable (per Bank norms) with an MIRR of approximately 13 percent (assuming a12% return on other savings).

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ERR (%)	32.2	42.8	44.9	34.9
MERR (%)	16.7	20.8	19.8	17.4

WHEN AND HOW SHOULD EACH MEASURE BE USED?

A Net Present Value *or* an Internal Rate of Return is an essential result from any economic appraisal, including appraisals of transport projects. The *Handbook on Economic Analysis of Investment Operations* (World Bank, 1998) [1] is a source of general advice on the usage of NPV and IRR.

The appropriate use of NPV and IRR (or Modified IRR) depends on the decision context. Four important types of decision are worth highlighting.

(i) The accept/reject decision. The World Bank considers a project to be **acceptable** if it reaches the following minimum standard of performance [6]:

Criteria for acceptability**:**

NPV > 0

or

IRR > the **discount rate**, r

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[6] For further guidance see the *Handbook on Economic Analysis of Investment Operations*, Chapter 12 Paragraph 14 (World Bank, 1998) [1].

This test will be applied to all projects, however, it is only the first of several hurdles to be jumped.

(ii) Choosing between mutually exclusive alternatives. Economic appraisal is also used to inform the choice between alternative courses of action. In transport, these choices include:

❑ choice between different routes for road and rail links, and different locations for ports and interchanges of all types;

❑ choice between different engineering solutions, eg. tunnels versus bridges, or metro versus light rail solutions;

❑ choice between different approaches to improving transport, eg. infrastructure investment versus improved maintenance (see *TRN 13: Treatment of Maintenance* versus organisational reform (see *Note 24: Economic Appraisal of Regulatory Reform* versus pricing options (see *Note 23: Evaluation Implications of Sub-Optimum Pricing*);

❑ choice between public provision, private provision and partnership arrangements; and

❑ choice of projects to include within a Programme or Plan for transport.

Here the question is not simply whether the project would contribute to economic welfare, but whether is it has been shown to be the best of the available alternatives in these terms. This can be tested by comparing projects in terms of their NPV and IRR, as follows.

When all the alternatives being compared are **investment projects**, featuring an initial investment followed by a flow of benefits in the future, one (or preferably both) of the following summary measures should be provided:

− NPV for both projects A and B

− Incremental IRR of Project A over Project B, IRR_{A-B}

(for calculations see Box 4)

When the alternatives being compared do not fit the standard investment profile, the appropriate comparison is:

− NPV for both projects A and B

To start with, there is a presumption in favor of the solution with the lowest capital cost. This can be designated Project A. Alternatives to Project A can be compared with Project A either based on their NPV – a higher NPV is preferred – or by undertaking an incremental analysis, as follows.

Box 4. Incremental Analysis

Project	Benefits in each Year, $000							Incremental NPV	Incremental IRR
	0	1	2	3	4	5	6		
A	-12,000	3,500	3,500	3,500	3,500	3,500	3,500	1,268	14.1
B-A	-8,000	2,500	2,500	2,500	2,500	2,500	2,500	1,477	17.0
C-B	-8,000	2,000	2,000	2,000	2,000	2,000	2,000	-418	7.9
D-C	-4,000	800	800	800	800	800	800	-967	0.0

The projects are introduced in ascending order of capital cost. This example shows that switching to Project B from Project A has a high return – a positive Incremental NPV and an Incremental IRR greater than the discount rate. Project C is poor value, however – it has a negative incremental NPV and Incremental IRR less than the discount rate. Project D has nothing to contribute in welfare terms.

Incremental analysis applies where the choice is between one solution or another. There may of course be situations where **both** projects could usefully be undertaken. If so, the relevant criterion is the **total** NPV of the set of investments proposed.

In practice, projects are often composed of **packages** of components. In this case, incremental analysis should be used to test whether particular components are worthwhile, in terms of their incremental NPV or IRR.

(iii) Timing of investment. The timing of a project is an important decision that needs to be analyzed in every case. Just because a project's benefits exceeds its costs it does not mean that the project should be started immediately. Postponing a project may change the time profile of benefits and costs and hence the project's NPV. If the profile of benefits and costs is not changed, but only postponed, then timing is not an issue, as the present value of the benefits and costs will change proportionally by the discount factor used. Thus, if (a) the present value of a project's benefits discounted at 20 percent is $12M, (b) the present value of costs is $6M, and (c) postponing the project one year merely shifts all costs and benefits by one year, the present value of both benefits and costs will be reduced by the same percentage, as will the NPV of the project itself. In these cases, the sooner the project starts, the higher the NPV.

If, on the other hand, the benefit or cost profile changes with postponement, then timing becomes an issue. Consider a project that begins to generate benefits during its third year of life, two years after its initiation (Table 3 – top panel). The project has a four year operating life.

Table 3. Postponement of Project

Year	0	1	2	3	4	5	6
Benefits, $M	0.0	0.0	2.0	7.0	7.0	8.0	0.0
Costs, $M	-3.0	-2.0	-1.0	-1.0	-1.0	-1.0	0.0
Net Benefits, $M	-3.0	-2.0	1.0	6.0	6.0	7.0	0.0
...after postponement:							
Benefits, $M	0.0	0.0	0.0	7.0	7.0	8.0	8.0
Costs, $M	0.0	-3.0	-2.0	-1.0	-1.0	-1.0	-1.0
Net Benefits, $M	0.0	-3.0	-2.0	6.0	6.0	7.0	7.0

The net present value of this flow, discounted at 12%, is $8.1M. If we were to postpone the project by one year and thereby shift all benefits and costs one year into the future, the net benefits as well would be shifted by one year and hence their present value would be reduced in proportion to the discount rate and the project's net present value would fall to 7.2 = 8.9 ÷ 1.12. In this case waiting would not pay.

Suppose, however, that a one year postponement were to shift all costs by one year, leaving the gross benefits unchanged. The new net benefits profile would be as shown in the bottom panel of Table 3. By postponing the project we would be forgoing $2M of gross benefits in year two in exchange for $8M of gross benefits in year six. The net present value of this new flow, discounted at 12 percent, would be $11.3M, indicating that postponement would be advisable. The difference between these two examples is that in the first case postponement merely shifted the cost and benefit streams by one year, while in the second case postponement altered the streams. The optimal timing for a project occurs in the year in which its NPV peaks. The best way to identify that year is to examine the effects of postponement year by year until the optimal year is found. It should be noted that in both cases we evaluated the NPV of the project with respect to the same base year, namely year zero, when t = 0. In all cases we need to evaluate the present value of the flows with respect to the same base year.

THE ROLE OF THE DISCOUNT RATE

It is clear that a key variable when calculating the NPV, IRR and Modified IRR is the **discount rate**.

Box 5. Discount Rate

> The World Bank convention is to use a discount rate of 12 percent when evaluating Bank–financed transport projects.
>
> This figure is not necessarily a precise reflection of the opportunity cost of capital in borrower countries, instead it can be viewed as a rationing device for World Bank funds.
>
> If appraisal requirements at the country level call for a different discount rate, then the 12% rate and the country-specific rate may **both** be tested. The results using the 12% rate should be reported in the Project Appraisal Report and will be important in the World Bank's decision-making. Bear in mind that the discount rate is one of the easiest appraisal parameters to vary – particularly once a spreadsheet has been set up to make the calculations.

A strong justification is required if a discount rate other than 12% is to be used as the main rate. A discount rate lower than 10% is unlikely to be justified, since most research has shown that the cost of capital for developing countries is higher than 10%. Task managers will need to demonstrate that any alternative rate has been justified in the Country Assistance Strategy. Further advice and further reading references on discounting are given in the earlier section on **Net Present Value**.

Some consideration is now being given to the possibility of using the standard 12% for all financial costs and benefits and a different, and probably lower, rate for non-financial costs and benefits that more closely reflects the social time preference rate. Should this result in any change in the recommendation of what discount rate to use, this will be reported in an update to this Framework.

SUMMARY

Summary measures of project performance, such as the NPV, IRR or AIRR, are used to indicate the overall performance of a project under economic evaluation:

- ❑ either an NPV *or* an IRR (or AIRR) is an essential result, to be included in the Project Appraisal Report;
- ❑ as a minimum, to be 'acceptable' a project should have an NPV greater than zero or an IRR (or AIRR) greater than the discount rate, which is conventionally 12% for Bank-funded transport projects;
- ❑ the NPV or IRR (or AIRR) measure should also be used to compare alternative solutions, for example alternative routes for road and rail links, and different locations for ports and interchanges of all types;
- ❑ The World Bank has a presumption in favour of the solution with the lowest capital cost – incremental analysis can then be used to assess the value for money offered by more expensive alternatives;
- ❑ sometimes it can pay, in economic terms, to postpone the implementation of a project to a later date – the NPV can be used to test whether the timing of investment is optimal.

FURTHER READING

[1] The World Bank (1998), *Handbook on Economic Analysis of Investment Operations.* Washington, DC: The World Bank. Technical Appendix. Available online at:
http://www.worldbank.org/education/economicsed/project/projwork/Handbook.pdf

Transport Infrastructure Notes are available on-line at:
http://www.worldbank.org/html/fpd/transport/publicat/pub_main.htm

Transport Notes are available on-line at:
http://www.worldbank.org/html/fpd/transport/publicat/pub_main.htm

Urban Infrastructure Notes are available on-line at:
http://www.worldbank.org/html/fpd/urban/publicat/pub_note.htm

Urban Notes are available on-line at:
http://www.worldbank.org/urban/upgrading/urban-notes.htm