

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. Funding was provided from the Transport and Rural Infrastructure Services Partnership (TRISP) between the Department of International Development (DFID) of the Government of the United Kingdom and the World Bank.

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

TREATMENT OF MAINTENANCE

Maintenance is an often overlooked aspect of appraisal. The effective treatment of maintenance within an appraisal is, however, fundamental to informing the decision regarding the optimum investment strategy. This is because the nature of the maintenance strategy can have direct implications on operating costs and other benefits (e.g. travel time savings). As such the impact of maintenance within an appraisal extends far beyond a simple consideration of its financial cost.

Section 0 introduces the importance that the correct treatment of maintenance has with respect to an economic appraisal. Sections 0, 0 and 0 present the primary components of maintenance costs and introduce the notion of whole life costing and the fact that there is a risk that maintenance may not occur. Section 0 discusses the issues associated with deriving future maintenance costs, whilst Sections 0 and 0 discuss the need for the inclusion within the appraisal of firstly delays to transport users during maintenance works and secondly of the amount of induced and re-assigned traffic. Section 0 presents a summary of the key points that should be borne in mind with respect to the treatment of maintenance within an economic appraisal.

MAINTENANCE COSTS

Costs accrued during the operating life of the transport infrastructure are borne by:

- ❑ Users (e.g. vehicle owner drivers and ships whilst in port);
- ❑ Service providers (e.g. the operators of public transport services (e.g. rail service) or the owners of vehicles driven by others (e.g. road haulage firm));
- ❑ Infrastructure "Landlord" or owner.

This note concerns the last cost bearer (i.e. the infrastructure "Landlord" or owner). The costs borne by users and service providers are described in *TRN 9: Sources of Operating Costs*.

Maintenance costs, whilst only accounting for a small fraction of the initial investment costs, can very often represent a vital component of the investment strategy. This is because the maintenance strategy can have a direct influence on the scale of operating costs incurred during the investment's lifetime. The economic cost of poor maintenance is borne primarily by the users and service providers through increased operating costs. For example, when a road is not maintained – and is allowed to deteriorate from good to poor condition – each dollar saved on road maintenance increases vehicle operating costs by \$2 or \$3 [i]. An effective maintenance strategy can therefore increase the economic benefit of a project through reductions in user costs.

As a result of increased usage or towards the end of a project's life the cost of maintenance can be quite substantial. In such instances an investment representing an upgrading of the infrastructure to a standard requiring less maintenance (e.g. the paving of a gravel road) can incur cost savings in the long term.

Additionally, maintenance forms an important element of an investment strategy: firstly, as the loss in capital value of the infrastructure caused by lack of maintenance can significantly exceed the cost of maintenance required to maintain that value; and secondly as in certain situations annual maintenance costs are both high and essential in order to ensure the transport facility remains useable. For example in Nepal, many roads in mountainous areas are closed due to landslides during the monsoon, and require considerable organisation and expenditure to be re-opened every year [ii].

MAINTENANCE TYPES

To develop future estimates of maintenance costs it is necessary to have a consistent set of definitions regarding the manner that these costs are incurred within the country concerned. It is suggested that such a categorisation should be based around the operational characteristics of undertaking maintenance. Table 1 illustrates a set of operational descriptions for road network maintenance. Additional, to such a categorisation would be overhead and planning costs that are incurred by say the railway infrastructure authority, or the port authority or the road highway authority.

Table 1. Road Maintenance Types

Maintenance Cost Category	Description
Routine Maintenance	Simple operations required on a regular, almost continuous, basis such as cutting grass, cleaning side ditches, street lighting, policing.
Periodic Maintenance	Operations of a more substantial nature required at intervals of several years such as re-shaping of a road bed and/or re-gravelling
Urgent (or Special) Maintenance	Operations to remedy defectives which cannot be easily foreseen which must be dealt with immediately, such as landslips and other blockages.
Recurrent Maintenance Costs	Operations required at frequent intervals, i.e. not continuous but at intervals of a year or less, such as grading the surface of earth and gravel roads

Adapted from DFID (undated) [ii]

A categorisation process as detailed in Table 1, could however vary by mode, for example Lethridge (1990) [iii] categorises port maintenance into the following categories:

- Preventive maintenance;
- Predictive maintenance;
- Corrective maintenance;
- Component rebuild and spare parts fabrication;
- Rehabilitation/up-grading; and
- Failure analysis.

WHOLE LIFE COSTING

The consideration of maintenance within an appraisal implies a need for whole life costing. This is because it is the cost of the project over its entire life that is important to the appraisal, i.e. the cost of the initial investment plus all necessary maintenance costs, rather than just the cost of the initial investment.

There are two significant implications of whole life costing and these are set out below.

Firstly, there is a trade off between the initial investment cost and future maintenance costs. That is there is a choice between developing transport infrastructure of a high design standard that will be quite costly in the first instance, but will require little future maintenance, or developing infrastructure of a lower standard that will require significant maintenance expenditure in the future.

Secondly, the investment strategy that has the least whole life cost may not always be the optimum strategy. This is because the optimum strategy will be determined by the combination of whole life costs and whole life benefits. Whole life benefits would accrue through say vehicle operating cost savings and time savings. The optimum strategy may therefore differ from the least financial cost option.

RISK OF MAINTENANCE NOT BEING UNDERTAKEN

The above sections have introduced and discussed the relationship between maintenance costs and user and operator benefits, most notably vehicle operating costs as well as the notion of whole life costing. As such it can be seen that the maintenance strategy can be a fundamental part of the proposed investment strategy. However, as maintenance is a future expenditure, there can be a risk that it may not be undertaken and the full benefits of the project may not be realised.

The consequence of the incorrect treatment of the risk associated with maintenance being undertaken or not is one of the two following situations:

- ❑ The provision of higher design standards than are justified in order to reduce future year maintenance outlays. This would draw investment funds away from other priority areas.
- ❑ The construction of a project that requires a level of maintenance that can never be delivered by the host nation. As such anticipated benefits will not be fully realised and in the worst situation, the case for the project maybe negated.

Such problems can be most acute in developing countries with tightly constrained government budgets and for projects where foreign aid donors cover investment costs, but maintenance costs must be financed locally. In such situations, maintenance can sometimes be delayed from one year to another. Such delays do not have an immediate effect but their cumulative impact can be disastrous. A key strategy of the World Bank transport sector has therefore been the delivery of effective national maintenance strategies (e.g. Jordan Third Transport Project, Zambia Investment Program and Pakistan Highways Rehabilitation Project)

An important part of the economic appraisal is therefore a consideration as to the likelihood that maintenance will be undertaken. It is considered unrealistic to assume that a new project will be better maintained than any other aspect of the existing network (road or rail). Appraisals should therefore be based upon measurements of maintenance capability in the existing maintenance organisation. Unless the project forms part of a strategy aimed at improving maintenance performance the appraisal and design of the project should be based firmly on the premise that the project will receive the same level of maintenance as other parts of the network [iv].

For situations in which some form of maintenance reform is to occur simultaneously with the proposed transport investment it is recommended that the case for the project be also examined for a situation in which the proposed reform is not successful (i.e. there is no change in the level of maintenance received by the transport network under consideration).

Overseas Road Note 5 [iv] contains advice regarding the assessment of the maintenance capability of the host maintenance organisation. *Note No. 2 on Risk and Uncertainty* contains advice regarding the incorporation of these factors into the overall economic appraisal.

ESTIMATING FUTURE MAINTENANCE COSTS

Local data on maintenance costs is an absolute necessity when estimating future maintenance cost levels and recommending a combined investment-maintenance strategy.

There are two main cost items associated with maintenance, under each of the maintenance types discussed in Section 0. Firstly, there is the cost associated with sourcing and transporting the materials used during the maintenance. Such costs would include, for example, the cost of quarrying and transporting (to the maintenance site) aggregate for use as a road base, or the purchase and possible importation costs of replacement rails for a railway.

Secondly, there are the costs associated with undertaking the work once the required materials have been purchased; that is laying the new road surface or the new rails. Within developing countries it is possible to use both labour based and equipment based methods for undertaking such work. For a discussion of the relative merits of these methods the reader is referred to World Bank Technical Paper No. 347 [v] and Infrastructure Note RD-21 [vi] for roads and World Bank Infrastructure Note RW-11 [vii] for rail and World Bank Infrastructure Note PS-2 [iii] for ports.

With respect to rural roads that are lightly trafficked, the World Bank has for the last 25 years been promoting labour based methods. Labour based methods have been shown to be both technically feasible and cost effective in addition to generating rural employment. Box 1 presents a discussion on the derivation of maintenance unit costs for labour based methods. It should, however, be noted that it may not be possible at the appraisal stage to determine which type of approach to maintenance will be used – labour or equipment based. This is especially the case when the work will be carried out by private sector contractors and both labour-based and equipment-based contractors compete together in the market. In these cases both options may have to be appraised.

Unfortunately, obtaining reliable estimates of local unit costs in some countries can be quite problematic. In many situations the costing systems implemented within the relevant organisations do not allow the separate identification of maintenance cost components from other cost components, such as operating costs. Additionally, costing systems typically undervalue the plant and equipment associated with maintenance through the failure to include interest charges or replacement costs of equipment. Costing systems can also include unrealistic overheads for employing personnel and providing buildings and other facilities.

Despite these difficulties it is important to try and derive reliable base cost data. The failure to do so can be disastrous and may far exceed the expense required obtaining such data. For example, a port maintenance project was abandoned after significant expenditure on replacement parts and manpower had been incurred leading almost to the virtual destruction of the fleet of vehicles that were being maintained. This occurred as a direct result of poor base cost data in the decision making process [iii].

With respect to roads the World Bank transport knowledge database contains information and references to construction and maintenance unit costs [viii] including a review of average road works costs under bank financed projects [ix].

Box 1. Derivation of Labour Based Costs for Road Maintenance Appraisal

Most operations required for the construction and maintenance of gravel and earth roads are suitable for carrying out by some form of labour-intensive technique i.e. using labour plus hand tools. The two main exceptions are the long haulage of material such as gravel for surfacing and the compaction of the road surfacing and embankment fills. To address these issues, labour is often supported by suitable light equipment in an approach termed "labour-based". The principle of labour-based methods is that labour is used but is supported by equipment for those operations that are clearly less efficient by labour.

In an appraisal where both equipment-based and labour-based methods are to be costed, the first point to determine is that, whichever method is used, the technical quality of the end result will be the same. Extensive pilot and full-scale programmes since the 1970s have established that this is technically feasible for rural transport infrastructure in most situations. The economic cost of both methods will then be comparable.

A number of studies have been carried out to compare the cost of road operations by labour-based and equipment-based operations. Most have been inconclusive due to the poor quality of the available data. The accurate costing of equipment has often proved particularly difficult due to inadequate records. One study in Ghana compared the cost of the rehabilitation of feeder roads that had been carried out over a period of several years on similar roads by both labour-based and equipment-based contractors. This study showed that labour-based contracts were, on average, around 20% cheaper per kilometre than equipment-based contracts. This is similar to results recorded elsewhere in sub-Saharan Africa where a figure of 15% cheaper by labour-based methods is often quoted.

The information required to determine the economic cost for construction and maintenance operations is the breakdown of the financial cost into wages, materials, plant costs, etc. The Minor Roads Programme in Kenya produced information on cost breakdowns for rehabilitation, periodic maintenance and routine maintenance works by labour-based methods on rural gravel roads in its annual reports in the late 1980s and early 1990s. This provides useful averages for these operations. The typical financial cost breakdowns for rehabilitation and periodic maintenance were similar at around 45% for labour, 15% for supervision, 20% for equipment, 10% for construction materials and 10% for other costs. For routine maintenance, the breakdown was 60% for labour, 15% for supervision, 20% for equipment, and 5% for construction materials.

The next step in the procedure for determining economic costs requires consideration of shadow prices (accounting prices) and, in particular, shadow wage rates. Ideally an assessment of macro-economic effects should also be undertaken. There is a cost associated with developing and managing the labour based work programme known as the cost of participation, which needs to be included into the analysis. The reader is referred to DFID (2002) for a fuller discussion.

Source: DFID (undated) [ii]

In addition to information on unit costs and the cost of materials an estimation of future maintenance costs requires a detailed consideration of the Do Minimum situation. Table 2 illustrates the data required by the Highway Development Management System (HDM) for the assessment of roads. Similar analysis of the existing situation would be required for railways and ports.

Table 2. Data Requirements for Determination of Road Maintenance Strategy

Data Type	Data Requirements
Climate Zone Data	Moisture Classification Temperature Classification
Traffic Level	Traffic volumes (AADT)
Road Geometry	Hilliness Bendiness
Pavement Structure and Strength	Pavement Type (Bituminous, Concrete or Unsealed) Structural Adequacy Layer thicknesses and material types Miscellaneous property data relating to pavement type
Road Condition	Ride quality Surface condition Surface texture
Pavement History	Construction Quality (surfacing, road base, compaction) Age Previous Condition
Miscellaneous	Shoulders Drainage

Source : HDM 4 User Manual (Volume 2 Application Guide)[^x]

The HDM software suite (PIARC, 2002) [^x] is an extremely valuable resource for evaluating alternative maintenance strategies for roads. It integrates the maintenance strategy with the impact on vehicle operating costs and travel time benefits, thereby allowing an assessment of whole life cost and benefits. The current version of HDM is HDM 4 and this is the recommended tool for assessing road maintenance on World Bank projects. It should of course be noted that HDM 4 will require to be populated with local maintenance unit cost data and local data relating to the characteristics of the road network.

MAINTENANCE AND OPERATOR DELAYS

When maintenance works are undertaken delays are generally imposed on the users of the transport system be that a private car, a passenger or freight railway company or a port operator. These delays can vary in scale from slight delays to the significant disruption that can be caused through the complete closure of the infrastructure for scheduled repairs.

When evaluating alternative investment and maintenance strategies (including staged construction) it is therefore important to include the impact of delays imposed on the users or operators of the infrastructure, particularly if these delays occur early in the project’s life. For works that occur late in the project’s life the effect of discounting will reduce the impact that such delays will have on the present value of benefits and as such a lump sum “contingency” estimate should be made for infrastructure where the disruption is expected to be high [iv].

If the disruption is not expected to be large (e.g. a lightly trafficked road or railway) then the inclusion of such lump sums may not be necessary. In heavily congested sections of the network, alternative options for managing structural maintenance need to be evaluated, which should include consideration

of delays to traffic while the link is under maintenance. Models such as the UK Government's QUADRO (Queues and Delays at Roadworks) [xi] may be helpful. In some countries, concepts such as lane rental may be used to incentivise the contractors to complete the job within the planned availability of the road for maintenance.

MAINTENANCE AND RE-ASSIGNED AND INDUCED TRAFFIC

The scale of maintenance costs is related to the usage that the transport facility is subjected to. In situations where induced traffic effects are important (see Induced Traffic note) the level of induced traffic should be accounted for within the appraisal. The consequence of excluding induced traffic could be the adoption of a sub-optimal design standard and associated maintenance strategy.

In situations where traffic has been re-assigned from other routes or facilities of a similar nature (e.g. competing ports) there may also be a small reduction in network wide maintenance costs required on the existing network.

SUMMARY

The key points that this note promotes are as follows:

- ❑ The treatment of maintenance whilst forming a small component of the overall financial budget can have a significant influence on the design standard and the viability of a project;
- ❑ A whole life approach to both costs and benefits is needed to identify the optimum investment and maintenance strategy;
- ❑ The appraisal must take account of firstly the manner that induced and re-assigned traffic may influence the level of maintenance and secondly should reflect delays to users of the transport system, particularly if the maintenance strategy includes significant disruption to the transport system (e.g. closures);
- ❑ The best indicator as to the likelihood of maintenance being undertaken in the future is the current likelihood of maintenance within the recipient country. It should not be assumed that maintenance will occur if there is no track record to demonstrate it;
- ❑ Should the investment form part of a package that includes reform of the organisation responsible for maintenance, the robustness of the case for investment to a failure to deliver the reform should be examined;
- ❑ Estimates of unit costs for maintenance are difficult to obtain. However, every effort should be made to do so. If it is considered considerable error lies within the unit costs estimates this should be input to the risk assessment.

The Project Appraisal Document (PAD) should clearly set out the approach adopted to each of the above points.

FURTHER READING

[i] De Richecour, Anne B, 1994. Review of African Road Funds: What Works and Why? SSATP Working Paper 14, World Bank, Africa Technical Department. Washington DC, USA.

[ii] Department For International Development, DFID, (undated). DFID Economist Guide (The Core Guide, Section 6). TRL Crowthorne, UK. [Available on-line at http://www.transport-links.org/Economist_Guide/Economist_Guide.htm]

[iii] Lethridge (1990), The Use of Outside Contractors for Port Maintenance, Infrastructure Note PS-2, World Bank, Washington DC. [Available on-line at <http://www.worldbank.org/transport/publicat/td-ps2.htm>]

[iv] Overseas Road Note 5 (1988) A guide to Road Project Appraisal, Overseas Development Administration, Chapters 2 and 11. TRL, Crowthorne, UK. [Available on-line at http://www.transport-links.org/transport_links/]

[v] Stock, E.A. and de Veen, J. *Expanding Labour based Methods for Roadworks in Africa*, Technical Paper 347, World Bank, Washington DC, USA. [Available on-line at http://www.worldbank.org/transport/roads/c&m_docs/cn_ntk3c.pdf]

[vi] Stock, E.A. (1996) *Expanding Labour Based Contractor Programs: Lessons from Ghana*. World Bank Infrastructure Note RD-21, World Bank, Washington DC, USA. [Available on-line at <http://www.worldbank.org/transport/publicat/td-rd21.htm>]

[vii] Anderson, P. and J.S. Mundrey (1995). *Cost Effective Measure for Track Improvement*, World Bank Infrastructure Note RW-11, World Bank, Washington DC, USA. [Available on-line at <http://www.worldbank.org/transport/publicat/td-rw11.htm>]

[viii] World Bank Knowledge Database: [Available on-line at <http://www.worldbank.org/transport/publicat/td-rd21.htm>]

[ix] Archondo-Callao, R. (2000) Road Works Cost per km : Source World Bank Reports. Available on-line at http://www.worldbank.org/transport/roads/c&m_docs/kmcosts.pdf

[x] PIARC (2002) *The Highway Development and Management Model (HDM4), User Manual (Volume 2 - Application Guide)*. [Documentation and Software available on line <http://hdm4.piarc.org/>]

[xi] Department for Transport (2002). QUADRO 4 User Manual, HMSO, UK. [Available on-line at <http://www.roads.dft.gov.uk/roadnetwork/heta/highway/index2.htm - quadr04>]