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An Overview of Critical Issues in Transport Planning and Appraisal for LMICs with a Focus on New Approaches, User Benefits and the Environment

Economic Assessment of Transport Impacts

John Hine

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Abstract	
The purpose of this paper is to investigate and provide an overview of critical issues in transport planning and appraisal with a focus on new approaches, user benefits, economics and the environment.	
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Acronyms

ADB	Asian Development Bank
AFCAP	Africa Community Access Programme
AfDB	African Development Bank
AHP	Analytical Hierarchy Process
BCR	Benefit Cost Ratio
BRT	Bus Rapid Transit
CBA	Cost Benefit Analysis
COBA	Cost Benefit Analysis (programme for the Department for Transport)
CO_2	Carbon Dioxide
CGE	Computable General Equilbrium (Model)
DFID	Department for International Development
DfT	Department for Transport
DT	Delphi Technique
EIRR	Economic Internal Rate of Return
EMME2	Multimodal Equilibrium Model
ESMAP	Energy Sector Management Assistance program
EV	Electric Vehicle
GHG	Green House Gases
GTZ	German Corporation for Technical Cooperation
HDMIII	High Design and Maintenance Standards Model
HDM-4	Highway Development and Management Model
HrDM5	An update of the Highway Development and Management Model
HVT	High Volume Transport
i.c.e.	internal combustion engine
IEG	Independent Evaluation Group (of World Bank)
IRAP	Integrated Rual Accessibility Planning
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
LMICs	Low and Middle-Income Countries
MCA	Multi-Criteria Analysis
MCDA	Multi-Criteria Decision Analysis
MDB	Multilateral Development Bank
MAUT	Multi-Attribute Utility Theory
MPI	Maintenance Priority Index
NATA	New Approach to Appraisal
NOx	Nitrogen Oxides
NPV	Net Present Value
OECD	Organisation for Economic Cooperation and Development
OSeMOSYS	Open-Source Energy Modelling System

PAD	Project Appraisal Document
PIR	Poverty Impact Ratio
RED	Road Economic Decision Model
RMMTPM	Reed-Muench Median Threshold Population Method
$PM_{2.5}$,/ PM_{10},	Particulate matter less than 2.5 /10 micrometres in diameter.
RECAP	Research for Community Access Partnership
ROADEO	Road Emissions Optimisation
RPPM	Rural Road Planning and Prioritisation Model
UN HABITAT	United Nations Human Settlement Programme
SAM	Social Accounting Matrix
SAVi	Sustainable Asset Valuation
SEACAP	South East Asia Community Access Programme
SLoCaT	Partnership on Sustainable, Low Carbon Transport
STAR	Sustainable Appraisal Framework for Transport
STRADA	System for Traffic Demand Analysis
SUMP	Sustainable Urban Mobility Plans
TEAM	Transport Energy Air pollution Model
TEEMP	Transport Emissions Evaluation Models for Projects
TAG	Transport Analysis Guidance
TOD	Transit Orientated Development
TUBA	Transport Users Benefit Appraisal
VfM	Value for Money
VOC	Vehicle Operating Costs
VoSL	Value of Statistical Life
VOT	Value of Time
WEB	Wider Economic Benefits
WebTAG	Department for Transport suite of guidance on transport appraisal
WEI	Wider Economic Impacts
WFH	Working from Home

1. Introduction

The purpose of this paper is to investigate and provide an overview of critical issues in transport planning and appraisal with a focus on new approaches, user benefits, economics and the environment.

A key theme of the paper is to test the validity of the conventional transport cost benefit analysis (CBA) and appraisal approaches that are central to transport planning. In **Section 2** four reviews of current transport appraisal practises are presented. Overall, the reviewers were keen to reflect the need for sustainability, fairness and environmental concerns that are difficult to capture under a CBA framework. In **Section 3**. a review of road appraisal within the development banks is presented. Here it can be seen that, over time, there has been a shift in approach away from economic CBA in key decision documents, as more emphasis is placed on environmental and social effects. However, the question arises, has the pendulum swung too far?

In **Section 4**. The UK's Government's five stage business model is presented along with a framework for 'Value for Money'. The use of monetised benefit cost ratios along with non-monetised Impacts is outlined to provide the best solution. In **Section 5**. Multi-Criteria Analysis (MCA) and Multi-Criteria Decision Analysis (MCDA), are explored as an approach for combining economics, the environment and social considerations. Overall, it appears that views are in flux on this. In **Section 6**. 'Wider Economic Impacts' are considered. Is it possible to push CBA to include more scenarios? The arguments in this area are often difficult to follow with little international consensus.

In **Section 7**. Some aspects of Sustainable Urban Transport are considered. Are active transport, a healthy lifestyle, and good access to bus rapid transit (BRT) sufficient to make us give up our beloved cars? If we can't afford to live in high-rise developments, can we make do with high density, low rise living? How does 'working from home' change the argument? In **Section 8** the impact benefits of rural roads are considered and look impressive. How do we adjust our CBA calculations to take account of this?

Transport and poverty is considered in **Section 9**. Should we consider providing distributional weighting in a CBA? Or should we try to predict the distribution of benefits following an investment? Optimism bias is considered in **Section 10**. The impact of issues such as consultant bias, investment cost overruns, and poor traffic forecasts need to be taken into account.

The further development of the Highways Development Model- HDM-4, as it transitions to HrDM5.0 is outlined in **Section 11**. The disconnect between freight tariffs, loading efficiency and operating costs is discussed in **Section 12.** There is a need to better understand how these issues are likely to affect the outcomes of road investment. Outstanding issues with the modelling of vehicle operating costs and the introduction of electric vehicles are considered in **Section 13**. Finally incorporating carbon emissions into road construction and building climate resilience are considered in **Section 14.** Recommendations for further work are given in **Section 15**.

2. Suggestions and Lessons from Transport Planning and Appraisal

This section draws on three reports relating to transport appraisal in the UK and other high- income countries. A fourth report relates to improving the appraisal of transport worldwide, (but with a focus on urban transport) through sustainable low carbon solutions.

2.1 A review of Transport Appraisal for Seven High-Income Countries (2013)

A review of transport appraisal in seven different high-income countries (England, Germany, Netherlands, Sweden, USA, Australia (NSW), and New Zealand) was undertaken in 2013. It found that a very similar analytic framework for transport cost benefit analysis was adopted by the different countries. The UK government's Department for Transport (DfT) WebTAG[1] approach was identified as a leading model of open documentation of appraisal guidance and is reported to be a benchmark by other countries. Recent changes were identified, in particular with the valuation of 'Reliability, Comfort and Crowding', 'Fitness and Health' and 'Wider Impacts', where again, the UK is regarded a leader.

Amongst the seven countries differences were found in discount rates, the treatment of risk and uncertainty, and small differences in the metrics used, such as benefit cost ratios, use of first year rate of return. Non-monetised impacts were always presented in a framework table, and not 'traded off' although Australia was an exception. Germany had a 'red flag' procedure when environmental constraints were violated. Four detailed tables are presented showing the detailed differences in 'General Appraisal Framework Rules', 'Impact Unit Values' (i.e. discount rates, values of time etc), 'Impact Research Sources', and 'Applicability of Appraisal' (broken down by mode, and institutional component) (Mackie, P. and T. Worsley, 2013).

2.2 Transport Planning Society Review (2020)

A report commissioned by the Transport Planning Society (2020) has identified a range of changes taking place in the UK that have important implications on transport planning and appraisal. It is pointed out that even without the effects of the COVID-19 pandemic, overall travel, journeys and mileage have declined in the last 20 years. Car journeys have fallen, van traffic has increased by over 50%, and rail use has increased. Similarly, technological developments are changing travel patterns, mobile phones and apps are changing the way people travel. New mobility options such as driverless cars, electric cars and e-bikes have the potential to change travel significantly.

The dominance of the car for personal travel has brought benefits but also huge downsides, both to the vehicle owner and to wider society. Issues include health problems from air pollution and lower physical activity, a continued high number of deaths and injuries from road crashes, severance of communities, and economic impacts from congestion. Transport is the largest source of GHG emissions in the UK. It is argued that transport planning needs to be more inclusive: it needs to reduce car dependence and give people healthier and more sustainable travel choices, as well as encouraging less travel altogether.

Transport policies need to provide a clear route map to net zero by 2050 and to meet the five-year carbon budgets set under the Climate Change Act. This will involve "avoid, shift, improve" strategies – reducing travel through better planning, shifting travel from low occupancy motor vehicles to shared, active and sustainable transport, and electrifying and improving motor vehicles. These policies should also inform transport spending priorities.

The existing systems of transport appraisal, forecasts and modelling do not reflect current realities and priorities, notably decarbonising transport, support for disadvantaged people and communities and the promotion of active travel.

The following points are made:

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[1] TAG An Overview of Transport Appraisal

- Forecasting Forecasting and modelling are very much based on extrapolating past trends (i.e. 'predict and provide'). This can lead to overpredicting road traffic growth. A better solution would be a radical rethink of what is required, such as 'predict and decide' or 'vision and validate'. - "This approach allows us to shift away from the status quo, and create places for people built around a healthy, safe, prosperous and carbon neutral vision for our new communities."[2]
- Less emphasis should be placed on forecasting and more on scenario analysis.
- Inevitably measures relying on changing travel behaviour will score badly in appraisal procedures. So, measures based on higher levels of active travel (walking and cycling) and bus use will be seen as unrealistic because of current high levels of car use.
- There is a focus on travel time by motorists within appraisals. Small time savings of a few seconds per trip over a 60-year time frame can often dominate a proposal while other road users are undervalued. Those on foot, bikes or in buses have time values of £9.41 per hour compared with car drivers of £16.61 per hour (2010 prices).
- People with disabilities or without access to a transport service are missed out in modelling.
- The impacts of road traffic on poorer people (such as pollution or severance) tend to be ignored.
- There is too much emphasis on cost benefit analysis, when many of the underlying value assumptions are uncertain. More emphasis should be placed on cost-effectiveness analysis.
- Insufficient attention is given to climate change impacts. CO_2 emissions and climate change should be evaluated on a "showstopper" basis with a pass/fail test.

2.3 International Transport Forum (2022)

A recent review, undertaken through the International Transport Forum (ITF) for the OECD (2022), examined the ongoing shifts in transport policy and the consequences for transport project appraisal and the planning process. They found an increasing shift from providing mobility to ensuring accessibility, giving greater access to equitable access for all, recognising the urgency to decarbonise transport and making urban environments healthier, safer, affordable and more liveable.

It is suggested that there is a need to capture more impacts that are harder to express in purely monetary terms. This could be addressed through multi-criteria analysis (MCA) that could supplement CBA, together with short summaries exploring the implications that could provide more meaningful insights for decision making.

The following recommendations were made:

Develop long-term strategic infrastructure plans that explicitly identify transport policy objectives

- Develop long-term strategic infrastructure plans that explicitly identify transport policy objectives
- Broaden project appraisal to ensure its processes and practices take account of all transport policy objectives, as embedded in strategic infrastructure plans
- Incorporate accessibility indicators, or other relevant tools, to assess equity impacts in transport project appraisals
- Provide detailed guidance on accounting for climate change impacts in transport project appraisals, incorporating clear linkages between shadow carbon prices and emissions reductions commitments
- Present the results of transport project appraisals in a transparent and concise format that highlights needs case assessments
- Ensure decision-making processes for large investments in transport systems account for uncertainties and the need for broad stakeholder support
- Integrate technical assessment, process management and public engagement into decision processes for major transport infrastructure investments

[2] ITP's approach to vision-led transport planning - Integrated Transport Planning

- Undertake systematic ex-post evaluation for all transport infrastructure projects entailing expenditure above an identified level
- Consider the merits of the permanent observatory model as a means of maximising the quality of evaluations

(ITF, OECD 2022)

2.4 Evolving Economic Appraisals for Land Transport Investments

The Last review was prepared by the Partnership on Sustainable, Low Carbon Transport (SLoCaT). and the Transformative Urban Mobility Initiative (TUMI). The focus is on improving the appraisal of transport worldwide, through adopting sustainable low carbon solutions in urban areas.

It is argued that the main issues with conventional economic appraisals of transport are:

- The narrow scope of quantitative analysis.
- The disconnect between the investor and beneficiaries.
- Absent or limited economic valuation of so-called intangible benefits
- Limited systematic vision and integration of knowledge across different stakeholder groups.

To 'evolve' conventional economic appraisals for land transport it is suggested that a more accurate valuation of the financial and economic case for investing in integrated public transport, walking and cycling is required. The following four recommendations are suggested:

- Establish suitable policy and institutional frameworks
- Standardise comprehensive and integrated economic appraisal approaches and tools
- Build multistakeholder engagement in the economic appraisal process
- Quantify and monetise all costs and benefits.

The overall approach adopts the avoid-shift-improve framework for sustainable low carbon transport. This involves avoiding and reducing the need for unnecessary motorised transport, shifting to more sustainable modes and improving vehicle design and energy efficiency. There should be a focus on people and goods instead of vehicles, as well as on the whole transport system rather than infrastructure.

To fully capture social, economic and environmental impacts of sustainable low-carbon transport projects it is argued that a diversity of information and model approaches are likely to be required. The SAVi[3] approach and database, from the International Institute of Sustainable Development, is suggested. This will help estimate the performance, costs, value of externalities, and climate risks of different types of infrastructure. And to assess economic viability then a combination of cost benefit analysis, cost-effectiveness analysis and multi- criteria analysis may be used. (SLOCAT, 2024)

[3] https://www.iisd.org/publications/guide/savi-database-primer?q=library/savi-database-prime

3. A Review of Road Appraisal Within Multilateral Development Banks

Cost benefit analysis has been an important tool for project appraisal in the development banks. However, a World Bank report (2010) reported that there had been a long-term decline in the use of cost benefit analysis and the reporting of the economic internal rates of return in World Bank appraisal documents, across all sectors. In part this is a reflection of a move towards sectors and approaches (i.e. health, environment or technical assistance) where CBA is difficult to apply. The decline in economic appraisal was noted in the 1990s with for example a report entitled "Reviving project appraisal at the World Bank" (Devarajan et al. 1995). Nevertheless, CBA is used to a much greater extent in transport than in most other sectors and the use of the HDM-4, and its derivative the Road Economic Decision Model (RED) are very commonly applied to road projects.

A brief review of road appraisal procedures relating to the World Bank, the Asian Development Bank and the African Development Bank, was undertaken using online information from project documents. A sample of 23 recent project appraisals were examined. A range of different documents are published online for each different project. The key project document for the World Bank is the 'Project Appraisal Document' (PAD), (average length 77 pages), for the Asian Development Bank (ADB) it is the 'Report and Recommendation of the President to the Board of Directors' (average length 22 pages) and for the African Development Bank (AfDB) it is the 'Project Appraisal Report' (average length 34 pages). In addition to these key documents there are often a large number of other associated project reports that cover environmental and safeguarding issues, progress reports, procurement reports and audits.

Although the documents differ in length and style they cover similar topics. As an example, the current World Bank PADs have the following headings and content:

Strategic Context (country context, sectoral and institutional context)

- Strategic Context (country context, sectoral and institutional context)
- Project Description (Development Objective, Project Components, Beneficiaries, Results Chain, Rationale for Bank involvement)
- Implementation Arrangements (Institutional Arrangements, Results Monitoring and Evaluation, sustainability)
- Project Appraisal Summary (Technical, Economic and Financial Analysis, Fiduciary, Legal, Environmental and Social)
- Grievance Redress Services,
- Key Risks
- Results Framework and Monitoring.

In the economic analysis sections of all of the key project documents provided economic 'net present values' (NPVs) and 'internal rates of return' (IRRs/EIRRs). Of the 23 projects considered, 19 projects referred to the road appraisal model HDM-4 or RED. One urban transport project referred to the travel demand and forecasting model, EMME2 (a bilingual acronym for multimodal equilibrium/equilibre multimodal).

Project completion reports and post evaluations are also provided in association with the other project reports. These reports can show cost overruns and provide an indication as to how successful the project was. Retrospective CBAs are often undertaken showing internal rates of return (IRRs) and net present values NPVs (see Section 10 on Optimism Bias). Post evaluation reports are often carried out by independent bodies such as the World Bank's Independent Evaluation Group (IEG), the Asia Development Bank's Independent Evaluation Department and the International Initiative for Impact Evaluation (3ie).

Although project beneficiaries were identified in many projects, a detailed quantitative analysis of the distribution of benefits, between the poor and vulnerable and the rest of the population, were found in two ADB project reports. However, no evidence was found of the differential 'weighting of project benefits' within the calculation of any NPVs or ERRs. A number of ADB projects had a separate three-page report covering the project's 'Poverty Reduction and Social Strategy'.

Calculated traffic greenhouse gas (GHG) CO_2 emission reductions were reported in all World Bank, (and for some ADB and AfDB) project reports, post 2017. These are calculated by the HDM4 and RED models and, through carbon pricing, the reductions in traffic-based CO_2 occur through reduced road roughness and smoother running, and appear to have been included in the NPV and ERR calculations, although this is not always clearly stated. Only internal combustion engines are assumed. However, in only one project was the increase in GHG emissions associated with construction clearly referred to.

The amount of documentation relating to economic analysis appears to be declining. Within the key documents the economic analysis currently covers a quarter of a page to one page and a half. For the World Bank it had been common practise to include a four- to-five-page separate economic annex. However, in the last four years the separate economic analysis for transport projects appears to have been dropped. The ADB key reports still have a separate economic annex of 5 to 8 pages, while there are no economic annexes for the African Development Bank road appraisals.

Overall, it appears that economic analysis is now only a very minor feature of road project appraisal reports. It is now rare to see IRR or NPV data relating to alternative design solutions, although sensitivity analysis (eg. relating to construction cost escalation) is reported, particularly by the ADB. Hence, there appears little evidence of discussion or scrutiny of the merits of alternative solutions[4]. In most instances the initial economic analysis of a project is undertaken by a consultant, reporting to the host government.

However, this report is <u>not</u> made available, by any of the three MDB websites, and therefore it is not accessible to the wider Bank staff or to the public. In contrast there is often a huge amount of environmental and safeguarding material, including resettlement issues, that are published on Bank websites, and much of this is prepared directly by consultants working for host governments.

As an example, for the Tanzania Roads to Inclusion and Socioeconomic Opportunities (RISE) Project (2021), at the time of publication of the World Bank PAD, there were listed 1069 pages of additional environmental and safeguarding reports, in comparison there was only one page devoted to economic analysis, within the PAD of 125 pages. This disparity is not confined to the World Bank. The ADB's Bhutan Thimpu road improvement project (2016), at the time of publication of the 'Recommendation of the President' report, 290 pages of additional documentation were published, on the ADB project website, mostly related to environmental and safeguarding issues, while the economic analysis accounted for just five and half pages.

[4] From personal experience of attending key project meetings at the World Bank, from 2005 to 2009, the author was surprised at the dominance of environmental, safeguarding and sometimes political issues within the meetings. There was usually no (or very little) discussion on the merits of proposed design solutions, or of alternative solutions.

4. The UK Government's Five Case Business Model

In the UK since 2013 all centrally funded projects (including the Department of Transport) must present a business case for funding. The business case must cover the five components listed below. (HM Treasury, 2018). In 2018 it was adopted by the G20 as an international standard as best practise (OECD 2018)[5].

- **The Strategic Case.** This makes the case for change and it should demonstrate how the proposal has a strong strategic fit with the organisation's priorities and government ambitions. (Key examples of the latter include 'the levelling up agenda', the commitment to 'net zero' and the 'green industrial revolution')
- **The Economic Case.** This helps in identifying the proposal that delivers the best 'value for money' in maximising welfare, including wider social and environmental effects. It requires a wide range of realistic options to be appraised (the long-list), in terms of how well they meet the desired outcomes and critical success factors for the scheme; and then a reduced number of possible options (the short-list) to be examined in further detail. The Department of Transport Web Tag reports feed into this component. This is discussed below.
- **The Commercial Case.** This helps demonstrate that the preferred option will result in a viable procurement deal between the public sector and its service providers. It requires an understanding of the marketplace, knowledge of what is realistically achievable by the supply side, commercially viable procurement routes that will deliver best value to both parties, the services, outputs and milestones required to be achieved and how the potential risks can best be allocated.
- **The Financial Case.** This helps demonstrate the affordability and funding of the preferred option, including the support of stakeholders and customers, as required. It requires a complete understanding of the capital, revenue and whole life costs of the scheme and of how the Deal will impact upon the balance sheet, income and expenditure and pricing arrangements (if any) of the organisation.
- **The Management Case.** This helps demonstrate that robust arrangements are in place for the delivery, monitoring and evaluation of the scheme, including feedback into the organisation's strategic planning cycle..

4.1 How Value for Money is Assessed in UK Appraisal

The economic case is presented within the value for money (VfM) approach. Details are provided within DfT's 'Value for Money Framework' (2015) and DFT's 'Value for Money Framework: Supplementary Guidance on Categories'. This approach now replaces the 'New Approach to Appraisal' or NATA that used multicriteria analysis, and introduced in 1998 (see **Section 5.1** of this report)

For conventional transport investment projects benefit cost ratios (BCRs) are calculated (based on the present values of costs and benefits over the appraisal period) and from these the following 'standard' value for money categories are used:

i) **Very High**, BCR> or = 4

ii) **High**, BCR between 2 and 4

iii) **Medium**, BCR between 1.5 and 2

iv) **Low**, BCR between 1 and 1.5

v) **Poor**, BCR between 0 and 1

vi) **Very Poor**, BCR <0 or -0

To calculate the benefit cost ratio four different types of impacts are considered: established monetised impacts, evolving monetised impacts, indicative monetised impacts and non-monetised impacts. These are shown in the table below and the way they are used to calculate the BCR.

[5] UK_FiveCaseModel.pdf

Table 1: How types of impact are used in the calculations of the BCR

Type	Description	Use in Assessment
Established Monetised Impacts (Level 1)	Monetary values are well researched and fully accepted. (eg. journey time savings, vehicle operating costs, accidents, greenhouse gases)	Included in initial BCR and adjusted metrics
Evolving Monetised Impacts (Level 2)	Evidence exists to support monetary values but this is less widely-accepted. Reliability, output in imperfectly competitive markets, labour supply	Included in the adjusted BCR
Indicative Monetised Impacts (Level 3)	Monetary valuation methods not considered sufficiently widely accepted or well researched to be definitive. Eg. moves to more or less productive jobs, induced investment, supplementary modelling.	Considered at the last stage of the assessment. Can be considered after metric using switching values between the standard Value for Money categories.
Non-monetised Impacts	Estimated magnitude of impact assessed on a seven-point scale. Approach can be informed by a variety of evidence sources and analytic judgement. Eg. security, severance, environment, bio-diversity, townscape	

(Note. Evolving and Indicative Monetised Impacts are further discussed in the section on Wider Economic Impacts, Section 6.2)

The initial BCR is calculated from the ‘established monetised impacts’. This is then adjusted with evidence from the e’evolving monetised impacts’. To take account of risk the expected value (defined as the average of possible outcomes, taking account of different probabilities) is used. So, the construction cost estimate will be ‘risk adjusted’. By considering the necessary increase in benefits required to switch the BCR between the different categories, ‘switching values’ are calculated. Finally, the ’indicative monetised impacts’ and ’non-monetised Impacts’ are considered. If the increase in additional value from these categories are believed to be above the switching value, then the final value for money category can be increased.

So if the switching value was estimated to be £10m, in benefits, to move from ’medium’ to ’high’ categories, and the non-monetised benefit was believed to be worth more than £10m, then the final VFM category would be reclassified as ‘high’. This last step can be based on judgement or from numerical calculations.

In the supplementary guidance an example was given of using ‘stated preference’ analysis to estimate the value of non-monetised impacts. In such an analysis surveys are carried out whereby people are provided with a range of choice options, using different values, to find out how much something is worth. In this case the value of an historic building was considered.

In the value for money submission the distribution of income, or benefits, between different groups can be considered. But in this case the Value for Money category is not affected. A separate statement on the effect on income distribution provided in addition.

5. Multi-criteria analysis

Multi-Criteria Analysis (MCA) is a broad term that covers various methods used to evaluate multiple criteria in decision making. MCA can include both qualitative and quantitative criteria. MCA is flexible and does not necessarily involve a structured mathematical approach. Multi-Criteria Decision Analysis (MCDA) is a subset of MCA that provides a structured approach whereby the different components are numerically weighted. However often the terms are sometimes used interchangeably.

In comparing different options, or solutions, to a given problem, multi-criteria analysis requires decision makers to:

a) Establish a set of key objectives

b) Identify measurable criteria to meet each of these objectives

c) Assess, for each option, how far each criteria meets each specified objective on a scale

d) Tabulate the results

For MCDA, weightings can be applied for each criterion to provide a composite score to help rank each option (Department of Communities and Local Government, 2009).

MCA and MCDA have been widely used in the transport sector. Macharis and Bernardini (2015) found a total of 276 publications that referred to the use of MCDA for transport projects, with a growing trend in the period from 1985 to 2012. Every transport sector was represented, and the approach was found to cover operations, policy, the application of new technology and infrastructure. Stakeholder participation is an important part of MCDA. Stakeholders can help structure the problem, help define criteria, identify alternatives and provide weights.

For transport investment planning MCA/MCDA is frequently compared with cost benefit analysis (CBA). CBA focusses on economic effects, and can provide universally recognised decision criteria such as the net present value (NPV) or internal rate of return (IRR). CBA is recognised as being ‘theoretically unambiguous’ (Mouter et al. 2020). However, the approach can be criticised for not directly taking into account environmental and social effects which are difficult to value in monetary terms. In contrast these effects can be incorporated into an MCA /MCDA framework, so that, in choosing between different options, decision makers can them take account, if necessary, also including the economic effects.

A limitation of MCA, as with cost-effectiveness, is that it cannot show that the ‘best option’ actually improves overall welfare, so doing nothing could in principle be preferable. (Department of Communities and Local Government, 2009). It is also claimed that there is a much greater risk of double counting impacts in MCA (Mouter et al. 2020).

In France there has been a move away from MCDA, due to problems of subjective weighting, and discrepancies in features such as the value of time and subjectivity of the expert (Macharis. C, and A. Bernardini, 2015).

A review of several papers advocating the use of MCA found that CBA is often included as part of the final criteria considered. So, MCA is not a complete alternative to CBA (see Appendix 2). CBA is also used, particularly HDM-4 as a guide to project design. So, changes in say road widths, pavement thicknesses, or geometric design, can be tested to see how they affect the overall viability of the investment. In contrast MCA cannot be used in this way.

5.1 UK’s New Approach to Appraisal

In In 1998 the UK’s Department of Transport introduced a form of MCA with the ‘New Approach to Appraisal’ or ‘NATA’. NATA provided a framework for decision makers to consider the economic, environmental and social impacts of transport projects and policies in a standardised way. An appraisal summary table or ‘AST’ was prepared for each project of policy. For each criteria and sub criteria in the table qualitative impacts, quantitative measures (if appropriate) and a final assessment box is provided. However final weightings for each criterion are not provided. So, no overall score is given.

The Criteria adopted in the AST are as follows:

- Environment (sub criteria: noise, local air quality, landscape, biodiversity, heritage and water)
- Safety

- Economy (sub criteria: journey times and vehicle operating costs, cost, reliability, regeneration)
- Accessibility (sub criteria: public transport, severance, pedestrians and others
- Integration (this reflects integration with wider policies and plans)
- Cost Benefit Analysis (COBA)

It was generally recognised that the approach did improve clarity in decision making (Department of Communities and Local Government, 2009). However, the approach was still criticised, and calls were made to include weightings for each component, so an overall score can be obtained. (Sayers, et al. 2003). The approach has now been replaced with the Value for Money Framework (see section 4.1).

5.2 Asian Development Bank's 'Sustainable Framework for Transport'

The ADB's Sustainable Appraisal Framework for Transport, or 'STAR' approach is an example where social and environmental effects are considered together with economic effects in an MCDA approach. Here the following criteria are considered:

- Economic effectiveness (sub-categories: efficiency -people, efficiency -businesses, quality and reliability, fiscal burden, wider economic benefits)
- Social sustainability (sub-categories: basic accessibility, employment, affordability, safety, social cohesion and inclusion)
- Environmental sustainability (sub-categories: greenhouse gas emissions, resource efficiency, emissions and pollution, natural and built environment, climate resilience)
- Risk to sustainability (sub-categories: design and evaluation risks, implementation risks, operational sustainability risks)

The approach has three steps:

- The rater assesses project performance against each of the 18 sub criteria, through a qualitative rating. For economic, social and environmental, on a seven-point scale. And for risk on the three-point scale.
- In the second step the rater rates the four core criteria through aggregating the sub criteria ratings. It is recognised that the final rating is not simply a weighted average of the sub criteria. Professional judgment is involved. A seven-point scale is used (-3 to 3).
- In the third step the overall rating is derived by aggregating the core criteria score together. The ratings range from highly sustainable to highly unsustainable. A 30% weighting is given to the economic, social and environmental criteria, with 10% rating to risk. However, the highest ratings of highly sustainable and sustainable cannot be given to projects with a negative rating on any criterion.

Finally, a presentation on the ratings is made which involves i) a narrative assessment including description of weak points and areas for improvement, ii) the appraisal matrix, with supporting evidence and a diagram displaying the sub criteria ratings. (Véron-Okamoto, A and K. Sakamoto. 2014)

5.3 Application of the Sustainable Framework for Transport Approach by the MDBs

In June 2013 eight Multilateral Development Banks (MDBs)[6] made a commitment to play a leading role in providing support for transport in developing countries. The investments would be accessible, affordable, efficient, financially sustainable and safe. By 2022 a target of $175 bn was set to be mobilised for transport. Under a working group on sustainable transport (WGST) harmonised definitions, indicators and reporting mechanisms were to be developed with support from the Partnership on Sustainable, Low

[6] including the African Development Bank, Asian Development Bank, , Development Bank of Latin America,, European Bank for Reconstruction and Development, , European Investment Bank (EIB), Inter-American Development Bank (IADB), Islamic Development Bank, and the World Bank

Carbon Transport (SLoCaT). The Annual Reports of the WGST were planned to provide information on the types of projects supported by the MDBs, as well as ways in which the MDBs can induce changes in developing countries through policy support, capacity building and knowledge transfer.

From 2013 to 2016 sustainability assessments were made of each MDB's transport programme. The ADB's 'Sustainability Appraisal Framework for Transport" (the STAR Approach) was used directly or in a modified version by seven of the MDBs for assessment, while the World Bank used its own methodology. For each of the seven banks, using the STAR Approach, for each year, projects were assessed as either 'sustainable', 'moderately sustainable', 'marginally sustainable' or 'less sustainable' and bar charts were presented for each MDB. Detailed data on the individual components or sustainability (i.e. economic, social or environmental) were not provided, however in the supporting text it appears that social sustainability (involving addressing vulnerable groups, gender and road safety) and economic sustainability were marked higher than environmental sustainability. The World Bank maintained that all of their projects comply with mandatory "sustainability" requirements. Instead, they presented the percentage of transport projects including climate finance, road safety and gender informed components.

In 2017 it was planned that a new methodology for assessing sustainability would be developed. However, the 2016-2018 progress reports did not contain sustainability rankings. It is unclear why the approach was not continued. There are clearly major challenges in sustaining an MCA approach, involving subjective judgements, across multiple organisations, applying different regulatory procedures. (MDB Working Group on Sustainable Transport. Progress Reports for: 2014-2015, 2015-2016, 2016-2018)

6. Wider economic impacts

6.1 An Overview of Wider Economic Impacts/Benefits (WEIs/WEBs)

The economic impacts of transport investment may be classified as 'direct' or 'indirect'. Direct effects are changes in user costs and in the external costs of transportation (e.g. example road maintenance) while indirect effects relate to the economic effects in markets not directly associated with transportation (e.g. labour and commodity markets). Transport cost benefit analysis (CBA) is founded on the assumption of perfect competition. In which case the direct effects measure the total impacts of an investment. However, if there is market failure then CBA will not capture the full effects of transport investment, hence wider economic impacts occur. For the most part WEIs have been regarded as positive, however impacts can be negative if, for example, an increase in economic activity in one area may be more than counterbalanced by a decline elsewhere.

Wangsness et al (2017) provides a detailed outline of the approach to WEIs in the transport appraisal procedures of 23 industrialised countries. The following main categories of impacts are identified:

- Agglomeration impacts. These are often the main focus of attention in the literature. Improving access increases the effective density of an area bringing people, businesses and jobs together, which increases overall productivity.
- Labour market effects. Lower commuting costs will induce changes in the number of workers choosing to work and the total number of hours worked
- Negative WEIs.
- Impacts in markets with imperfect competition. The absence of well-developed infrastructure may act as an entry barrier to goods and service markets in less developed areas. Lower transport costs will increase competition and lead to an expansion of markets, reduced prices and rise in production.
- Other impacts. These include impacts from inefficient land use regulations, reorganisation impacts and innovations in the construction and transport sector.

It was found that there are major conceptual issues and no universal agreement on the best approach. 15 countries adopted some form of wider economic impact in their transport appraisals, with 12 different types of impact identified. In general, there was no consistency in approach, with little consensus on methods. Although the UK's DfT approach did influence six other countries.

6.2 The UK Approach to Wider Economic Impacts (WEIs)

The UK's DfT advice on transport planning is covered in approximately 30, interrelated, 'tag' reports. The approach to wider benefits is outlined in Tag Unit A2.1 'Wider Impacts at Appraisal'. However, a range of other 'supplementary analyses' also need to be considered and undertaken, depending on the circumstances. Separate reports cover induced investment (Tag Unit A2.2), employment effects (Tag Unit A2.3), productivity impacts (this covers agglomeration) (Tag Unit A2.4), 'Supplementary Economic Modelling' (Tag Unit M5.3).

To calculate wider impacts, and fully appreciate the data inputs, it is necessary to use the WITA model together with its user manual, (provided by Atkins UK). These models supplement the DfT TUBA software that can carry out the initial Transport Cost Benefit Analysis.

The total economic impacts identified are classified as:

- Changes in generalised travel costs (i.e. conventional transport cost savings)

And wider economic impacts:

  - Induced investment
  - Employment effects
  - Agglomeration economies

However, these impacts are further broken down according to the way they interact with land use for the final value for money analysis, that are incorporated into the Transport Business Cases (see Section 4.1 above). This relates to the 'maturity of analytical techniques', or overall certainty of the approach. Three levels of analysis are adopted. These are:

- Level 1. Fixed land use, excluding wider economic impacts (i.e transport cost savings)
- Level 2 includes wider economic impacts which assume fixed land use, or do not require land use to be explicitly quantified. This includes 'static clustering' of agglomeration economies as well as output change imperfectly competitive markets, and labour supply impacts
- Level 3 includes wider economic impacts where land use change is explicitly quantified. This includes 'dynamic clustering' of agglomeration economies, labour moving to more or less productive jobs, and further dependent development

In the value for money analysis for Level 1, (established monetised impacts) the initial benefit cost ratio (BCR) is calculated. For Level 2, (evolving monetised impacts) the 'Adjusted BCR' is calculated. For Level 3, indicative monetised impacts are given. However, for Level 3 the BCR is not calculated.

A brief review was made of the supplementary reports namely 'Induced Investment' (Tag Unit A2.2), 'Employment Effects' (Tag Unit A2.3), 'Productivity' (this covers agglomeration) (Tag Unit A2.4). Although they provided a theoretical and mathematical framework, they appear complex, and difficult to follow. As an example, to test for 'dependent development', because each situation is unique, a process of 23 sequential steps is specified, with many steps involving both calculations and judgment (Appendix A of Tag Unit A2.2 'Induced Investment').

Graham (2007) provides further information on the data and approaches used in the UK to estimate agglomeration benefits. The largest calculated elasticities with respect to agglomeration were found for transport storage and communications (0.223), banking finance and insurance (0.237) and business services (0.224) while the lowest were for construction (0.072), manufacturing (0.077) and IT (0.082). (The higher the elasticity the greater the wider economic benefits).

It was found that agglomeration benefits accounted for 19.4% of total benefits, (including conventional transport cost savings) for the London Crossrail, 22% for Leeds Urban area Improved Highway, and 21% for Leeds to Bradford Improved Highway. In contrast the agglomeration benefits of the South Yorkshire bus subsidy were 3% of total benefits (Graham, 2007). Other WEBs also need to be considered. So, for London's Crossrail other WEBs were estimated at 32% of conventional benefits. (Douglas and O'Keeffe, 2016)

6.3 The Treatment of Wider Economic Benefits in Australia and New Zealand

Douglas and O'Keeffe (2016) reviewed how the UK WEB approach could be applied to Australia and New Zealand and they compare differences in agglomeration elasticities between the UK and Australia and New Zealand.

In addition, the Australian Department of Infrastructure, Transport, Regional Development and Communications (2023) provides summary guidelines for the inclusion of WEBs into transport appraisal. The following components are considered:

- Agglomeration impacts
- Labour market and tax impacts
- Output change in imperfectly competitive markets
- Change in Competition

6.4 'Quantification of Wider Economic Impacts in Least Developed Countries: Phase 1' Laird et al 2023 World Bank.

This This report provides a useful overview to establish 'whether and how WEIs (wider economic impacts) can be incorporated into cost benefit analysis (CBA) of the World Bank's transport investment Projects.'

The report is timed to coincide with the update of HDM-4 and, as the title suggests, further advice will follow.

It is argued that conventional CBA approaches, such as HDM-4, can miss important benefits (and sometimes dis-benefits) that may occur in the wider economy. It is argued that, theoretically, these occur because of economic distortions. The following factors that promote WEBs were:

a) Agglomeration economies
b) Employment taxation and change in employment
c) Market impacts related to imperfect competition
d) Land use change in presence of inefficient land use regulations and monopolistic landowners
e) The divergence between private and social returns in education and health

The report lists a wide range of data (classified as desirable or essential) required for the calculation of WEIs. Besides a conventional transport CBA, essential data to cover agglomeration, employment and land use change, include:

- Generalised costs and travel times within and between zones
- Wage or GDP/worker at zonal level
- Number of permanent jobs created by the project
- Average wage where jobs are created
- Income tax rates (in formal sector)
- The Shadow Wage rate for different employment groups
- Market demand elasticities
- Price cost margins for the economy
- Area of land to be developed dependent on the project
- Land values per hectare for different uses
- Volume of traffic and transport costs associated with the development

Additional health and education related data are also specified.

Because of the prevalence and complexity of market failures involved, particularly for LDCs it is suggested that 'a systematic assessment of the transport-economy interactions may require a step change in the resources devoted to transport appraisal'. Two case studies (Buenos Aires Rail rehabilitation and improvement, and Burkina Faso strategic corridors and tertiary roads) have been identified. Evidence of worked examples of WEIs from these studies will help for the basis for further guidance.

6.5 Impact Studies of Wider Economic Benefits

Graham and Gibbons (2019) analyse 47 studies from different high-income countries, together with China, and provide point estimates of urban agglomeration elasticities. Of the 47 studies quoted, 43 have positive elasticities. This data can be a key input into WEI appraisal models but, of itself, is not conclusive proof of the existence of Wider Economic Benefits.

Three review papers (listed below) were found where the title indicated an investigation of 'wider economic impacts /benefits /development'. For these three papers it appears that the interpretation of 'wider economic impacts/benefits' includes conventional transport cost savings, which is different to the approaches discussed above.

Quium (2019) undertook a literature review of large number of studies. For Sub-Saharan Africa, and South Asia substantial positive impacts on the economy (from less than 1% to more than 10% of GDP) were identified following transport infrastructure investment, with lower impacts from transport investment in developed economies (less than 1%) of GDP.

In contrast Alam et al. (2019) studied 47 corridor projects in 16 countries undertaken by ADB, JICA and World Bank, covering 34 road, 9 rail and 2 inland waterways. To identify the corridor development effects the intensity of night time lights was used in mapping the effects along each corridor. Overall, no significant effect was found. However, the analysis does not rule out the possibility that the main beneficiaries of the investment may have been at the towns and cities at the end, or beyond, the end of each corridor.

Roberts et al. (2018) undertook a literature review of 78 papers providing 243 individual results relating to large transport corridor investment projects. Significant beneficial results were found for economic welfare (80 results), social inclusion (22 results), equity (16 results) and environmental quality (18 results).

None of the reviews separately identified conventional ‘transport cost savings’ hence it was not possible to exactly differentiate wider economic impacts from total impacts.

7. Sustainable Urban Transport in LMICs

In recent years there has been a strong move toward adopting a new approach towards urban transport planning. There is strong dissatisfaction with trying to accommodate rising car fleets, through, for example, increasing radial route capacity. This gives rise to low density urban sprawl while severe congestion in city centres remains. The planning process has not considered the full external costs of accommodating private car use in urban areas.

The increase in motorization leads to a decline in air quality resulting in serious health implications, and to an increase in greenhouse gases. The poor are marginalised as road space is made available to the privileged few who own private cars (ADB 2009). Controlling car use through congestion charging and parking control together with better public transport provision is required (Litman 2014). There are many calls for improving traffic management, traffic signals and pavement markings and making provision for cyclists (Ardila-Gomez, et al, 2021).

It is argued that higher density development that is fully integrated with public transport, and making adequate provision for pedestrians, would provide a healthier solution that would ensure both improved access and mobility, with less carbon emissions. Improving transportation and land-use planning should also be pro-poor (Cervero, 2013).

Transport professionals have been asked to move away from 'predict and provide' rationale towards adopting a more balanced view of mobility and accessibility. The new approach is generally referred to as 'sustainable mobility' which in urban areas involves moving away from car-based solutions towards public transport, walking and cycling. The approach reduces greenhouse gas emissions, air pollution, and promotes a healthier lifestyle. (Banister, 2008)

In calling for 'A New Paradigm for Sustainable Urban Transport' the ADB (2009) has promoted more sustainable solutions in which traffic capacity is no longer automatically expanded in response to demand forecasts. The following key constraints were identified:

- Absence of a city development strategy
- Unsustainable transport policies
- Ineffective transport planning
- Little implementation
- Little data about success or failure of implementation
- Government Problems in which technical endeavours were used to justify political decisions rather than provide sound advice to set priorities and inform political action

With regard to transport planning, too often plans stem from transport model 'black boxes' rather than from empirical evidence. Ways need to be found to reduce the need for travel and facilitate the provision of public transport. (ADB 2009).

Although there is clear enthusiasm amongst planners for sustainable solutions, it should be recognised that there are major constraints to contend with. Firstly, car populations continue to rise. In China, for example, the car population has risen from 182 million in 2017 to 275 million in 2022. In India the car population has risen from 33.6 million in 2017 to 43.7 million in 2020, while the motorcycle and moped fleet in India has risen from 187 million in 2017 to 244 million in 2020 (IRF data)[7]. One can imagine that people who have recently bought a new car will not be enthusiastic to support measures to curtail their use.

An evaluation of the World Bank's Urban Transport Portfolio FY07-16 found little evidence of a shift away from car use as a result of the projects. It is reported that *"World Bank staff questioned whether a modal shift can be achieved without instituting both politically difficult policy options (reducing incentives for automobile purchases, increasing fuel prices, rationalizing bus services, and aggressively rationing private vehicle traffic in congested areas) and a substantial further increase in mass transit capacity." (IEG, World Bank, 2017)*

Secondly, some of the interventions can be extremely expensive and may be difficult to 'sell' to the wider population. The Dar es Salaam BRT system has cost around $ 400 million (World Bank 2017). The first

[7] https://datawarehouse.worldroadstatistics.org/

Phase ($150 m) had a major impact in reducing vehicle travel time along the main corridor, and, more generally, a 10-minute decline in travel time to work. However, only 7% of commuters use it to get to work, and, although other changes were taking place, (including other public transport investment and a new phase of relocating ministries to the capital, Dodoma) there has been no difference in peoples' general satisfaction with commuting (Morton et.al 2020). Because of costs, a BRT 'light' version was introduced in Lagos without separate boarding platforms. This has obviously affected the speed and comfort in boarding and the utilisation of the BRT buses. Lastly, high rise developments (see Transit Orientated Development below) are unaffordable for poor countries.

7.1 Sustainable Urban Mobility Planning Advice

Sustainable Mobility for All (SUM4ALL) (2019) has produced a 'Universal Urban Access' paper that provides a comprehensive framework of regulatory and institutional policy measures to promote sustainable urban transport. A range of implementation experiences are also provided.

In Europe, the European Commission has promoted the adoption of city-wide Sustainable Urban Mobility Plans (SUMP). So far there are 150 case studies are available. The approach has the following characteristics:

- The focus is on people - rather than on traffic
- The primary objective is on accessibility and quality of life -rather than on traffic flow capacity and speed
- There is integrated development of all transport modes
- It has a combination of infrastructure, market, regulation, information and promotion rather than just infrastructure
- The planning document is consistent with related policy areas
- It has a long-term vision and strategy
- It covers the functional urban area based on travel to work flows rather than just an administrative area
- It involves interdisciplinary teams rather than just traffic engineers
- Planning involves stakeholders and citizens using a transparent and participatory approach
- There is systematic evaluation of impacts to facilitate learning and improvement

Rupprecht et al. (2019)

The German Corporation for Technical Cooperation (GTZ) (2004) has produced a useful source book for policy makers on land use planning and urban transport. It outlines various solutions to reduce transport demand when planning new developments, through, for example, the Dutch ABC scheme, which creates commercial sub-centres within a city to help reduce travel distances. Likewise, in China, the creation of 'relief cities' a clear distance from megacities. Each relief city has around 100,000 inhabitants with shopping and businesses. So, the self-supporting relief cities gain from the relative proximity to megacities, but far away to discourage commuting. (Peterson, R. 2004)

7.2 Transit Orientated Development

There has been a growing interest in transit orientated development (TOD), when concentrated urban development takes place that maximises the amount of residential, business and leisure space within walking distance of public transport. The concept was first used in 2007 and, between then and 2019, 627 articles were reportedly published on the topic by 2019, (Renne and Appleyard, 2019). However it is not clear how many 'TOD' projects have been formally implemented.

TOD is often associated with high-rise development. However, in most instances these can be extremely expensive. The report 'Pancakes to Pyramids: City Form to Promote Sustainable Growth' (Lall et al. 2021) points out the relationship between income and building height. Only rich countries and rich cities can afford high-rise development. It is also reported that high density low-rise development is frequently associated with poor-quality slums with limited space per family. This may be seen as a limitation to introducing TOD to low-income countries. However, a detailed review of six case studies, involving upgrading low-rise informal settlements, in Tanzania, Ethiopia and India, using a 'TOD' methodology to assess new developments, was undertaken under the HVT programme, and indicates the TOD approach maybe usefully applied in these circumstances. (Mason et al 2021)

7.3 Walking and Cycling should be fully incorporated into Urban Transport Planning

The poor often try to minimise their cash expenditures by walking or cycling. It has been suggested that walking is used by at least half the urban population and accounts for 80% to 90% of all trips among the poor (Cook et al, 2005). Data from Tanzania showed that walking accounted for the majority of trips up to 5 km, for Temeke in Dar es Salaam and for trips up to 8 km in Morogoro (Howe and Bryceson, 2000).

Common issues faced by walkers are described below:

"Perhaps the most fundamental problem confronting the pedestrian is that many roads are only designed for motor vehicles. Sidewalks for pedestrians are non-existent or comprise the bare earth. If they do exist their condition is normally unsatisfactory due to lack of maintenance. Open manholes and trenches, resulting from vandalism and the incomplete activities of various public utilities – water, electricity, telecommunications, sanitation, etc - are recurrent complaints. Conditions are particularly bad during the rainy seasons when pools of water present a major problem to pedestrians. Walking is especially difficult during rush hours when many people have to compete for the restricted space. Most are forced to walk in the road or along the corridors between buildings in town. The end result is a congestion of human traffic that makes walking unpleasant, time consuming and tiring. It can also be very dangerous. Waste, parked vehicles or informal businesses often obstruct walking routes making them generally unsafe and inconvenient. Consequently, pedestrians are again forced to walk in the carriageway, or on unprotected road shoulders, exposing themselves to traffic hazards. There are few constructed footways and those that exist are generally filthy and in very poor condition, since they frequently are used as dumping grounds for solid waste or serve as drainage channels." (Howe and Bryceson, 2000).

Neves and Brand (2018) have investigated the potential for switching short car trips to walking and cycling in the UK. They found that 49% of all trips in their survey were less than 3 miles. It was found that the physical environment needs to be supportive and inviting for pedestrians and cyclists of all ages and skills. A network of high quality, safe and well-connected routes for walking and cycling needs to be in place alongside policies that support a mix of uses and restrictions to car use. While cultural and individual factors also play a critical role as do individuals' attitudes and preferences. It was found that 41% of short car trips could realistically be made by walking and cycling, and this would save 4.5% of all emissions from car travel. Shopping and escort trips were responsible for the largest share of short car trips. It was suggested that shopping trolleys, pushchairs, bike panniers cargo bicycles, electric bikes should enable these trips to be made entirely by bike or on foot. It was pointed out that in Copenhagen 25% of families with two or more children have a cargo bike and 50% of those with cargo bikes use it to transport children.

7.4 Implications for the rise in motorcycle population

Over the last twenty years there has been a massive rise in the numbers of motorcycles and mopeds across Asia and Africa. In India, the IRF has reported that in 20 years the numbers of motorcycles and mopeds has increased from 34 million to 244 million in 2020[8]. The implications for planning urban and rural transport need to be properly assessed.

7.5 Land Use Planning and Land Value Capture for Public transport

There are increasing calls for the much greater use of fully integrated Land Use Transport Planning, which appears to be rarely undertaken in LMICS. A recent systematic review of 677 urban land change study models found that only 5 studies incorporated the interaction between transport and land change, while 128 studies used transport related variables as part of an urban land change model (Ahasan and Guneralp, 2022).

[8] https://datawarehouse.worldroadstatistics.org/

From an institutional perspective there is a major problem in the disconnect between land use and transport planning. Many agencies that influence and/or regulate land use have little or no responsibility for mobility policies. The result prevents integrative actions, especially in cities that have a weak tradition of urban land-use planning and control (UN Habitat 2013).

Another issue involves the financial viability of public transport and secure sustainable infrastructure funding. A high proportion of urban transit operations are heavily subsidised. Of the 65 systems (listed by Wikipedia), where data was available (for developed countries in North America, Europe and Asia) only in six systems –principally in Japan, Taiwan, Singapore and Hong Kong did the fare-box revenue cover the direct operating costs. For most European cities fare-box recovery ratios are in the 30-50% range. Of the 65 systems listed, 16 had fare-box recovery rates that were under 30% of the direct operating costs. Policies vary from country to country. Hong Kong metro projects are self-financing through full integration of land-use and transport planning land value capture through rail orientated property development. The New York Metropolitan Transport Authority collects tolls on bridges and tunnels together with small local taxes on transactions and business activities (UN Habitat, 2013). In 2012 London introduced a community infrastructure planning levy on new property developments to help finance Crossrail (ITF, 2024).

When modelling the benefits of the TransMilenio BRT in Bogota, Tsivanidis (2018) calculated a very substantial increase in welfare benefits, up to 24.4% of benefits of the BRT scheme, that could be captured by the government, if it adjusted zoning regulations and plot sizes, in the area affected by the BRT, to allow an increase in permitted housing density.

7.6 Sustainable Urban Transport Appraisal

Transport appraisal procedures are intimately based on the underlying data and models. In reviewing Multilateral Development Bank Appraisals, virtually all interurban roads were found to be appraised using HDM-4 and its derivative RED. These models have a cost framework and can produce a cost benefit analysis providing NPVs and IRRs. Several urban road projects were also found to be appraised with the HDM-4 and RED models, although the models were not designed for this purpose, because they cannot model road junctions. The urban transport planning models EMME2, STRADA, and a purpose-built model, were also used for urban transport projects. However, there is natural concern that complex transport planning models are not transparent or accessible to decision makers, and the wider public. Simpler models are often called for (Givoni et al 2016)

A range of transport modelling procedures can, in principle, be employed for sustainable transport interventions. The introduction of a new metro or Bus Rapid Transit (BRT) may require a comprehensive multi-modal model, based on a large household survey. An analysis of an extension of bus operations, where the ridership comes from existing public transport may be usefully met by a survey of existing users and analysed by simpler monomodal model. While developing the fare policy for a public transport route may be covered by a relatively small Stated Preference survey[9].

Multi-criteria decision analysis (MCDA) coupled with participatory data collection methods are widely employed in the assessment of sustainable urban transport (Karjalainen, L. and S. Juhola 2021). Cost benefit analysis is, of course, employed for major investment schemes such as for the appraisal of BRT or metro schemes. However, CBA has also been used to compare car transport with cycling and walking. It has been calculated that in the EU, every kilometre driven by car incurs external costs of Euro 0.11 while cycling and walking provide health benefits of Euro 0.18 and Euro 0.37 per km respectively (Gössling et al 2019).

When evaluating urban transport schemes, it should be remembered that ‘wider economic benefits’ may occur. Feldman et. al (2008) calculate wider economic benefits from a number of UK urban road improvements and public transport schemes. The latter category includes changing service frequency, different fare strategies as well as better public information.

7.7 The Implications from Working from Home (WFH)

Following the COVID-19 pandemic, coupled with the increase in internet use, in the last three years there has been a massive rise in the number of people ‘working from home’, which particularly affects office workers. At the same time, there has also been a substantial rise in richer countries of online shopping, which has caused a large rise in the use of delivery vans. These trends look likely to continue. If so, they

[9] www.mobiliseyourcity.net

may well have an important impact on travel demand, vehicle composition, and the ridership of public transport. The increase in WFH will reduce congestion and crowding on public transport. There are also suggestions that it may also increase the proportion of commuting journeys carried out by car (Beck, M. and D. Hensher (2021)

The assumption that focussing on a ‘typical commuting day’ in modelling modal choice and expanding travel behaviour to a week or year, is no longer valid. It is now necessary to develop a model to predict the number of weekly days working from home, as well as the incidence of trip making and the time of travel. (Hensher et. al 2021)

8. Rural Road and Transport Planning and Impact

Investment in road roads is planned by a combination of approaches, including cost benefit analysis (CBA), cost effectiveness (i.e. a measure of benefits divided by infrastructure costs) and multi-criteria analysis. CBA is widely undertaken using the RED spreadsheet model. Changes in transport costs arising from faster vehicle speeds and lower road roughness are compared with the infrastructure cost. However, studies of the impact of rural roads on the local community appear to indicate that the transport cost approach could substantially underestimate the total benefits.

Studies carried out in Uganda and Tanzania found benefit cost ratios of 9.1 and 7.2 respectively (Fan et al 2004, and 2005). A systematic review of 56 studies in low-and-middle countries, found rural road investment had a beneficial effect on incomes, consumption and poverty reduction, as well as on agricultural production, employment, health and educational outcomes. With the strongest impacts experienced in countries with the lowest road densities (Hine et al. 2016). A later review of 20 additional studies confirmed the findings (Hine et al 2019).

The implications for the steep rise in motorcycle fleets over the last 20 years has yet to be fully assessed. In rural areas, motorcycles now provide taxi services, making use of the spread of mobile phones. For the same trip, motorcycle taxis can be two to five times as expensive as buses and minibuses (Starkey et al. 2020).

8.1 Rural Road Appraisal Approaches

Secondary r roads and roads carrying over 50 conventional vehicles per day are typically appraised using RED or HDM-4. In this case cost benefit analysis is applied and decision criteria such as NPVs and IRRs are calculated. The benefits from transport investment occur with a reduction in vehicle operating costs associated with reduced road roughness and faster vehicle speeds as road geometry and road surfaces are improved.

For example, by building an engineered gravel or paved road to replace an earth road. However, difficulties arise if the road is impassable for part of the year. This can have huge consequences for the local population that need the road to access markets, schools and hospitals[10]. Predicted changes in transport costs and conventionally valued time savings can be irrelevant if someone has to be urgently carried to hospital by local villagers, because a road is impassable to conventional vehicles. (Hine 2014)

A range of alternative approaches have been developed. For example, the agricultural producer's surplus approach was recommended for rural road planning (Carnemark et al 1976). However, predicting agricultural response following road investment proved to be extremely difficult.

Cost effectiveness criteria are also often recommended for prioritising rural road investment. An example is the approach suggested by Lebo and Schelling (2001).

$$Cost\ Effectiveness\ Indicator\ of\ link(j) = \frac{Cost\ of\ Upgrading\ link(j)\ to\ basic\ access\ standard}{Population\ served\ by\ link(j)}$$

In this case priorities are based on the least cost solution, per head of population, of bring roads up to a basic minimum standard. Key drawbacks of this approach are:

a) there is no direct measure of benefits resulting from the change in road condition

b) no importance is attached to traffic

c) often the population to benefit may be difficult to estimate

[10] From personal experience of working in many rural areas, the biggest accessibility issue mentioned, particularly by women, was the fear of having to go urgently to hospital-particularly for child birth, when the road was impassable.

Airey and Taylor (1999) have suggested another approach that uses two indices. One for impassable roads, and a second for passable roads.

For impassable roads (for example where a bridge or culvert is broken) ranking is based upon the minimum cost per head (person), of the population in the catchment area of the road, for establishing access.

$$\textit{Cost/head} = \frac{\textit{Estimated cost of minimum improvement works}}{\textit{Population served by or living in the zone of influence of the improvement}}$$

So, the lowest cost per head of establishing access would have the highest priority.

For passable roads the prioritisation is based on the predicted traffic multiplied by an access change and divided by the cost of the proposed improvement. Simplifying

$$\textit{Prioritisation Index} = \frac{\textit{Traffic x Access Change}}{\textit{Improvement Cost}}$$

In this case the highest value has the highest priority. The access change is calculated from an estimate of the change in road condition. Here road condition is based on a scale of 0 to 5, where a rating of "0" is for very poor and a rating of "5" is good. The access change is then rating for the “after” condition minus the rating of the “before” condition. Again, population may be difficult to estimate as will the likely traffic after the road investment.

In Ghana an approach was developed that had a strong community consultation component to help identify roads that should be improved which was combined with road condition, population, traffic, and engineering cost data. Although initially there was strong interest, however the approach was abandoned because of the costs of repeated community consultation. (Hine, et al 2002, Hine, 2014)

For planning transport infrastructure at the village level, such as a bridge, a new access track or footpath and or for the siting of new facilities such a school or market, then the **Integrated Rural Accessibility Planning (IRAP) Tool** may be used. **(**Donnges, 2003). The approach has been widely used in many countries (including the Philippines, Nepal, India and Malawi) with help and advice of the International Labour Organisation.

To apply the approach a wide range of data is collected on the general village characteristics; including sources of livelihoods, agriculture and marketing; the existing transport system; location and availability and quality of services; travel times, frequencies, costs and modes; perceived problems and priorities. A variety of accessibility indicators will be used within IRAP. However personal travel time from household to different facilities may be regarded as the core indicator for planning infrastructure. So, projects may be prioritised by dividing annual time savings by investment costs. If vehicle transport is involved or more complex infrastructure is planned then a full cost benefit analysis may be required.

Multi criteria analysis is also often used for rural road planning. An analysis of six different approaches that were applied in Bangladesh, India, Nigeria and Thailand is presented in Appendix 1.

9. Poverty and Transport and The Distribution of Benefits

It is recognised that conventional planning using cost benefit analysis will not necessarily best meet the needs of poor people. As a result, many projects may be deliberately targeted to where poor people live (i.e. for example rural roads). Distributional weights within a CBA are sometimes suggested, although this is rarely undertaken (Gannon and Liu, 1997). A poverty impact ratio (PIR), defined by the benefits to the poor divided by total economic benefits is also suggested (World Bank, 2005).

In a literature review of poverty and transport Starkey and Hine (2014) investigate the relationship between poverty and rural accessibility and the way poor people are affected by urbanisation. Rural isolation is a major cause of poverty, and numerous studies have shown that rural road investment has a positive beneficial effect on incomes, access to health care and to education (Hine et al, 2016). However, access to affordable transport services in rural areas is often more problematic.

In urban areas road building is much more likely to help the car owning rich and middle-income sections of the population. For poor people the main methods of transport are by walking and cycling which are often adversely affected by road development. New urban transport infrastructure is often scheduled to be located on land and corridors that has been settled, sometimes illegally, by poor squatter communities that have little or no legal rights.

Sometimes the housing may be ‘bulldozed’ away to make room for development, with little consideration for the housing or livelihoods of their occupants. A wide range of difficulties arise with the resettlement process. Inevitably most resettlement takes place on available land on the outskirts of the city making it difficult for residents to access jobs in the inner city. Poor people are also disproportionately affected by urban air pollution and, when travelling, by urban congestion. (Starkey and Hine, 2014).

In a series of studies undertaken in Asia (Tajikistan, Philippines, India, Timor Leste, and Bangladesh) for the ADB, Greg Gajewski has investigated different methods for addressing poverty and distribution issues within transport projects. These include undertaking detailed surveys of traffic composition, the number of poor people that each mode employs, and the number of poor people who use the road or transport facility, (Gajewski et al, 2004). A more complex approach was used to investigate and quantify the poverty impacts of the Jamuna Bridge in Bangladesh. This included the use of social accounting matrix (SAM) analysis, (based on input output tables) and the use of a regional computable general equilibrium (CGE) analysis. These models make use of very detailed industry data together with fine detail of labour and household income classification. (Luppino, et al., 2004)

10. Optimism Bias, Outturn against Expectations

Particular attention should be paid to the possibility of optimism bias, and the inaccuracy of costs and traffic forecasts in planning new transport investment. Optimism bias occurs in all sectors, but the issues and consequences will be more important for large complex projects that have long lifespans. For transport it usually takes the form of underestimating construction costs and overestimating traffic volumes. There is often strong pressure on consultants to provide answers the client wants. Wachs found that "success in the consulting business requires the forecaster to adjust results to conform with the wishes of the client," (Wachs, 1990).

Drawing on a large Worldwide database, over a 70-year period, Flyvbjerg found that the average cost overrun, in real terms, was much higher for rail (45%) than for roads (20%) or bridges and tunnels (34%). In the first full year of rail operations there was 51% shortfall in rail passenger traffic, while for roads the outturn was 10% higher than expected. There are substantial variations in the outturn of construction costs and traffic volumes, which given by the standard deviation. The more complex the project the greater the variation in actual costs compared with the initial estimate. The details are shown below (Flyvbjerg, 2005).

Table 2: Inaccuracy in costs and traffic forecasts from worldwide databse

	Inaccuracy of construction costs at constant prices			Inaccuracy of traffic forecasts (rail passenger and road vehicle traffic)		
	Cases	Average Cost overrun %	Standard deviation	Cases	Average inaccuracy %	Standard deviation
Rail	58	44.7	38.4	25	-51.4	28.1
Road	167	20.4	29.9	183	9.5	44.3
Bridges/ Tunnels	33	33.8	62.4	-	-	-

Source: Flybjerg, 2005.

A more optimistic view is given by the IEG review of World Bank operations. The EIRR of road projects at appraisal was the same at the completion of construction (29%). For rail projects the EIRR at appraisal fell from 32% to 22% at construction completion. However, it should be remembered that substantial uncertainty remains with the estimate of EIRRs at construction completion.

The future growth in forecast traffic is not known, the economic evaluation model has uncertainties (vehicle operating cost assumptions, values of time etc.) and the counterfactual assumptions are not tested.

Table 3: Average economic rates of return of World Bank transport projects 1995-2005

Mode	Projects at appraisal with EIRRs	EIRR at appraisal %	EIRR range at appraisal	Projects at completion With EIRRs	ERR at Completion %	EIRR range at Completion
Multiple Modes	13	36	(16-91)	11	31	(14-78)
Urban transport	11	26	(13-40)	8	30	(13-60)
Roads/ highways	59	29	(1-65)	53	29	(10-79
Trade facilitation	1	19	19	1	27	27
Railways	7	32	(15-68)	5	22	(-14-64)
Ports/waterways	5	26	(18-37)	4	16	(11-22)
All transport	**96**	**30**	**(12-91)**	**82**	**28**	**(-14-79)**

Source: IEG, World Bank, 2007.

Nevertheless, cost overruns can still be substantial. An analysis of urban transport projects at World Bank, for the Period FY 2007 to 2016, found a quarter of the projects experienced cost overruns averaging 61 %, (IEG, World Bank, 2017).

11. The Development of the Highway Development and Management System (HDM-4)

HDM-III model, released around 1987, stands for Highways Design and Maintenance Standards model. HDM-III was designed to make comparative cost estimates and economic evaluations of different construction and maintenance options, either for a given road project or for a group of roads on the network, being used mostly at the project level.

Many of the technical models in HDM-4 also date back to the technical work underpinning HDM-III. The HDM-4 model, released around 2000, kept the same structure as the HDM-III model and was used both as a technical tool for the economic appraisal of road projects and to perform road network economic strategic analysis. The model contains a range of engineering relationships governing the behaviour of road pavements, and their deterioration based on maintenance treatments, traffic, climate and ageing. The model also contains vehicle operating cost (VOC) relationships, that vary with factors such as gradient, road width (for speed calculations) and road roughness (World Bank, 2000).

In 2005 HDMM (HDM4 version 2) was produced as a pc-based software package. This has been the primary tool of analysis since then. The HDM-4 model is by far the most dominant model for planning interurban roads in most LMICs. In 2015 it was estimated that $35 billion of road works had been evaluated by the model. The widespread use of HDM-4 has, in large part, occurred through the strong support of the multilateral development banks and development agencies[11]. Currently 67 countries around the world hold licences for the software. In 2024 the World Bank had an active portfolio of US $ 20 billion for road projects.

However, there is now a need to review and update the model. The update known as HrDM5 will take into account the latest research in terms of roads appraisal, especially the impact of climate change on road infrastructure, the new vehicles and social aspects linked to mobility. A new version will be available in 2025[12].

There will be five complementary initiatives to inform the new HrDM5. HVT will work on three of them: analysis of the current gaps in the model; analysis of emissions and fuel consumption using updated models and taking into account new fleet; new models for tyre consumption taking into account the change in load and fleet especially in LICs.

In moving towards the development of ‘HrDM-5.0’ Complementary work includes:

1. A meta-analysis of the value of time (VoT) studies
2. A similar meta-analysis of all work of freight VoT
3. A similar meta-analysis of all work on the value of statistical life (VoSL)
4. A scoping paper on the inclusion of wider economic benefits. Phase 1 is complete (see section 6.4 above)

Currently a GAP analysis is underway covering pavement technologies, road user and environmental effects, software, fuel and tyres.[13]

It is recognised there is demand from clients for additional functionality for:

- Climate change;
- Resilience;
- Greenhouse gas emissions;
- Road safety benefits;
- Tertiary roads;

[11] http://www.ukcds.org.uk/ourwork/theglobalimpactofukresearch/buildingbetterroadnetworks
[12] https://www.worldbank.org/en/topic/transport/brief/highway-development-and-management-model
[13] https://thedocs.worldbank.org/en/doc/88fe0c3df672f58ba5cb1f5ab9b45de6-0090062024/original/Upgrade-Ensuring-the-centrality-of-resilience-and-climate-change-in-Road-Management.pdf

- Changes in the vehicle fleet;
- Wider economic impacts;
- Indexing of the real value of time and life; and
- Changing to a cloud-based service.

12. The Implications of Uncompetitive Practises and High Transport Tariffs

A number of studies have found that cartels and a lack of competition in the trucking industry have led to very high road freight tariffs in Africa, where freight tariffs can be up to four times those in Pakistan, (Rizet, and Hine,1993, Teravaninthorn and Raballand, 2009, Bove et al, 2018).

There are also reports of uncompetitive freight practises in Latin America (Londono-Kent, 2009), and China. In China it was found, from a freight survey in Zhengzhou, that about 30% of long distance (above 100 km) road freight travel was empty compared with about 16% for Pakistan which has a similar range of trip distances. Many vehicles in China travel well over 1000 km empty. It is believed that out-of-town drivers were discriminated against when trying to pick up return loads. Through load matching O-D simulations, it was estimated that 4% of total freight running could have been avoided with comparable load matching strategies to that of Pakistan (Hine et al. 1995).

A comparative study was carried out in Africa and the United States. In 2010 it was found that transporting a 20-foot container from Tema port in Ghana to Ouagadougou in Burkina Faso cost US$3,200 (of which bribes were US$207) and took 13 to 22 days. In comparison, transporting a container a comparable distance from Newark to Chicago cost US$ 654 (i.e. one fifth of the price in Africa) and took just five days. Similarly an export container from Ouagadougou to Tema cost US$ 1,755 (of which bribes were US$66) and took six to nine days, while an export container from Chicago cost $990 and took 2.5 days.

The comparison with the United States is more surprising than with Asia, because labour costs are around 25 times higher than in West Africa (Annequin and Eshun, 2010). It is also important to emphasize that high long distance transport costs in Africa appear not to be related to the quality of road infrastructure. For example, 82% of the Tema to Ouagadougou route, discussed above, is in good or fair condition (Beuran et.al. 2015).

The implications from these studies are extremely important and may, in part, help to explain the slower economic growth in Africa, (where cartels and restrictive practises appear common), compared with much of Asia. As a result, Raballand and Macchi (2008) call for a major change in donor policies within the transport sector in Africa.

Furthermore, the HDM-4 road planning model calculates vehicle operating costs based on ‘without tax’ input prices. It assumes a competitive transport market, and, for any given vehicle type, common levels of utilisation. (A major issue in Africa are the cross-border delays which affect utilisation.) At the moment we do not know the extent to which road improvements lead to lower freight tariffs or bus fares, or what the differential impact of high transport tariffs is on development, following road investment.

13. Modelling Vehicle Operating Costs, Emissions, Vehicle Fleets and Impact Infrastructure

Besides the issue of uncompetitive practises and high transport tariffs there are also outstanding issues in estimating transport costs within cost benefit models such as HDM-4 and RED. The vehicle related issues are:

- Imported used vehicles
- The variability of vehicle maintenance costs
- Electric vehicles maintenance costs, lifetimes and emissions
- Fleet modelling
- Electric vehicle impact on infrastructure

13.1 Imported Used Vehicles and the Variability of Vehicle Maintenance Costs

Currently the HDM-4 vehicle operating cost models do not recognise the impact of used vehicles, which dominate most vehicle fleets in Africa, and are widely used in the Middle East, Central America, Eastern Europe and many of the smaller Asian countries (UNEP 2020, 2021). The vehicle depreciation and maintenance models work on the principle that, within standard vehicle lifetimes, there is an even spread of vehicle ages.

Background research on vehicle maintenance was based on analysing data from vehicle fleets where there was a full spectrum of vehicle ages from new. Similarly, the model input data requires new vehicle prices (without tax) together with estimated vehicle lifetime (Bennett and Greenwood 2004). So, the assumption is that where vehicles are not manufactured locally then all vehicles are imported new. Likewise, there is no recognition of the wide differences in maintenance standards, or the sheer variability of maintenance costs (Cundill et al 1997).

Although there is opportunity within HDM-4 for local ‘calibration’ for each situation there is anecdotal evidence that this rarely done, because of the costs, difficultly and delays of undertaking new surveys. So, the standard default coefficients are inevitably used.

13.2 Modelling EV Operating Costs and Emissions

Current VOC models do not model the operating costs of electric vehicles. Various reports suggest that maintenance costs for electric vehicles are substantially lower. For example, one estimate is that lifetime maintenance and repair could be around half that of an equivalent i.c.e. vehicle (Harto, 2020). Although until recently there was concern that batteries have limited range and will expire long before the vehicle, this now appears not to be the case. However there appears to be little or no research on the effects of road roughness (a key parameter in VOC models, and critical for the appraisal of rural and interurban roads) and on battery life. With far fewer moving parts there are some grounds to believe that EV operating costs will be much less sensitive to road roughness. This is likely to have major long-term consequences to estimation of vehicle operating cost savings from improving road surfaces.   A related problem is predicting vehicle lifetimes.

Recent research on emissions of PM_{10} and $PM_{2.5}$, (arising from brakes, tyre and road surface wear) from battery electric vehicles suggest there will only be modest changes with a move to EVs. However, the heavier weights of EVs could increase PM_{10} for motorway driving (Beddows and Harrison 2021). The research was done on paved roads. It would be useful to see how the results vary with different road surface types, particularly gravel roads.

13.3 Fleet Modelling

To introduce carbon emissions from EVs into road planning will also require information on the carbon intensity of the source of electricity, which of course varies from country to country, as well as modelling to predict the change in vehicle mix as EVs replace i.c.e vehicles. Separate to this there has also been a major increase in the use of motorcycles across Asia and Africa over the last twenty years. Current road appraisal models have 20 to 30-year time horizons, hence over that time there is likely to be a major change in fleet composition as more EVs are introduced.

There are a range of models which could be used in LMICs to predict vehicle composition change. A brief review of these models is provided by Dixon et al (2023). For example, OSeMOSYS, a flexible open-source energy modelling framework, has been used for the transport sector in Costa Rica and is currently be explored for use in Lao PDR and Vietnam. Another example is TEAM (Transport Energy Air pollution Model) developed for the UK (Brand et al 2017), which has been adapted to fit Kenyan conditions and has been used to develop different forecasting scenarios (Dixon et al. 2024).

13.4 Modelling the Effect of Electric Vehicles on Infrastructure

Finally, there is some concern that the weight of vehicle batteries may have an adverse effect on infrastructure and maintenance costs. It is reported in the popular press that the heavy weight of electric cars has had an adverse effect on multi-story car parks (with some recent closures) which were not designed for the weight.

Road pavements could also be seriously affected when battery, and to a lesser extent hydrogen, heavy goods vehicles and buses are introduced. In different vehicle categories, the weights for battery goods vehicles could be increased by up to 25%. The damaging effect will depend on the number of axles.

Road deterioration modelling has long assumed that wear is a function of the 4^{th} power of the axle load. A recent paper has suggested that road wear could increase by around 3l% for battery trucks and 6% for hydrogen fuelled trucks (Low et al. 2022).

14. The Incorporation of Carbon Emissions and Climate Resilience into Transport Planning

14.1 Road Construction and Transport Investment

Currently the HDM-4 model, and it's derivative RED, does estimate carbon emissions from conventional i.c.e. vehicle models. However, HDM-4 does not cover emissions from road construction which needs separate modelling. In reviewing available road appraisals, it has been found that it is now common to estimate reductions in GHG from road improvements. For example, reducing road roughness will also reduce fuel consumption.

These benefits are then incorporated into the final estimate of the Economic IRRs and NPVs through carbon pricing. However, it is far less common to take account of emissions during construction. This was found with two recent rural road appraisals, in Tanzania. (Tanzania Roads to Inclusion and Socioeconomic Opportunities (RISE) Project (2021).

A number of models and procedures have been developed to estimate carbon emissions from construction. These include:

- The World Bank's ROADEO Model[14]
- Microsoft's TEEMP Model[15]
- Highways England Carbon Tool Guidance

For or most transport projects construction emissions are generally accepted to be small in proportion to operations emissions. However, this is not the case for projects involving substantial tunnelling or elevated structures that involve a lot of concrete or structural steel which are carbon intensive (ADB 2010).

The following table shows three sets of carbon intensity indicators to assess the total of 78,083 km of transport infrastructure assistance projects approved by ADB between 2000 and 2009. The output emissions relate to both infrastructure and operations over the 20-year project life cycle. (ADB, 2010)

Table 4: Carbon dioxide intensity per unit of output and mobility of Asian Development Bank's transport projects approved during 2000-2009

	Business as Usual Scenario			With-Project Scenario		
	CO_2 tons/km Transport Infrastructure	Passenger Mobility CO_2 grams/pass/km	Freight Mobility CO_2 grams/ton/km	*CO_2 tons/km* Transport Infrastructure Improved	Passenger Mobility CO_2 grams/pass/km	Freight Mobility CO_2 grams/ton/km
Expressways	63,650	59	81	88,000	47	61
Rural Roads	10,000	84	73	10,000	74	61
Rehabilitated Roads	800	149	199	600	55	68
Bus Rapid Transit	134,000	137	NA	44,000	28	NA
Railways	63,650	59	81	42,000	20	23
Metro Rail Transit	134,000	137	NA	48,000	38	NA

Source: Independent Evaluation Department estimates using the transport emissions evaluation model for ADB projects (ADB,2010)

[14] ROADEO – Road Emissions Optimization: A Toolkit for Greenhouse Gas Emissions Mitigation in Road Construction and Rehabilitation | ESMAP

[15] These models can be downloaded using the following link – http://www.adb.org/evaluation/reports/ekb-carbon-emissions-transport.asp.

For all project types one can see substantial reductions in CO_2 per passenger-km and per ton-km. However, because of the substantial induced traffic for expressways it is forecast that there will be a net rise in emissions. In this case CO_2 increases from 63,000 ton/km to 88,000 ton/km. For rural roads, where induced traffic is less, no net change in CO_2 is forecast. However, for the other categories of investment an overall reduction is forecast. The largest proportionate reductions were for Bus Rapid Transit, Metro Rail Transit and rehabilitated roads.

The ADB also carried out an analysis incorporating carbon emissions into the economic appraisal. In this case CO2 considered at $85 per ton, particulate matter (PM_{10}) considered at $15,000 per ton, and NOx considered at $3,500 per ton. Overall, the economic analysis was found to be marginal and, in most cases, would not have influenced decision making. However, for a few projects that were found to have an EIRR of around 11% to 13% the impact could be decisive.

This type of analysis clearly needs updating to take account of changes in vehicle fleet, and sources of energy for the analysis of emissions for construction.

14.2 Building Climate Resilience

change is a major issue for the transport sector, in terms of its effects on infrastructure, the need to install adaptation measures, and the need to adopt low-carbon solutions within the sector. A range of research has been done on adaptation measures in the road sector, but because regions and countries will be affected differently blanket prescriptions should be avoided.

Weather and climate affect the planning, design, construction, maintenance and performance of infrastructure throughout its service life. Infrastructure is built to withstand a wide variety of weather and environmental conditions. Until recently the design of infrastructure was largely based on historical evidence such as the predicted 50-year or 100-year flood event. However now with climate change, predictions are much more uncertain.

A study by the World Bank for Vietnam provides a comprehensive investigation into the vulnerability, criticality and risk assessment of national road, rail and port infrastructure, together with an in-depth look at the provincial road networks of three provinces. The hazard exposure analysed covers: flash flooding, river flooding, landslide susceptibility and typhoon flooding. This is mapped against transport flows and the possibility, and costs, of rerouting. The economic impacts of possible disruptions are calculated, along with the costs of adaptation. A methodological framework is developed to determine the prioritization of investments through an analysis of the costs of infrastructure adaptation and the probability and costs of failure. (Jung Eun Oh, et al. 2019).

UK Aid has financed a range of research into how climate change will affect the viability of transport infrastructure and what measures need to be taken to build in resilience. An example is a study by the World Bank, funded by DFID and other donors, "Enhancing the Climate Resilience of Africa's Infrastructure: The Roads and Bridges Sector" by Cervigni et al, (2017). The study considers a number of aspects including the vulnerability of roads to climate change, integrating climate change into planning, whether there should be a reactive response or proactive adaptation, and what the risks of inaction are. Climate change projections are forecast across Sub-Saharan Africa and the issues are considered country by country. This study finds:

- Direct damages: tens of billions of dollars in damages to roads, which will require additional maintenance to preserve basic serviceability; preliminary estimation of damage to bridges suggests costs may be even higher (in the order of $30 billion, mean estimate).
- Substantial system disruption: apart from increasing maintenance costs, climate changes will cause the disruption of road links, interrupting the flow of goods and people, to the tune of 100 million days of disrupted road links by 2050, all of which has a substantial economic cost.

The study advocates that climate change needs to be incorporated into road asset management and that regular maintenance is a first key step towards increasing climate resilience of roads and bridges. It is also recommended that investing proactively in pavement improvements to withstand higher temperatures is economically justified under most climate projections. On the other hand, in the short term, proactive adaptation to precipitation and flooding events is unlikely to be justified.

Nevertheless, in the longer term (by mid-century) the costs and risks of inaction will grow over time and the case for adaptation will increase. Blanket prescriptions should be avoided and a case-by-case analysis (for example different countries are likely to be affected in very different ways) should be undertaken.

Other research into the need for climate adaptation has been carried out under the SEACAP, AFCAP and RECAP rural transport programmes these include:

- Road embankment and protection in Mekong flood plains (Howell, 2008)
- Effects of climate change on roads and rural communities in Ethiopia (Hearn, 2014)
- The vulnerability to rural access of climate change in different regions of Mozambique (Le Roux et al. 2016)
- The climate resilience and adaptation of roads in Ethiopia, Mozambique and Ghana (Paige-Green, et al. 2016)
- The identification of high-risk areas to climate change and prioritisation for climate resilient road construction in Ethiopia (Arnold et al. 2018)

15. Conclusions and recommendations for further work

The report has shown that although the road planning models HDM-4 and RED are widely used, particularly for the appraisal of interurban roads and the heavier trafficked rural roads, the focus of attention of both the Multilateral Development Banks and the planning community has moved away from cost benefit analysis and towards environmental and social concerns. The trend towards 'sustainable urban transport' also reflects this.

To capture a wider perspective of the issues there has been increasing interest in the use of multi-criteria analysis. The use of wider economic impact approaches for transport planning in high income countries also reflects a dissatisfaction with the limitations of the conventional transport user cost savings approach.

However outstanding issues remain with all the key appraisal approaches. There is no internationally agreed approach for wider economic impacts. The use of multi-criteria analysis for transport planning has fluctuated in countries such as the UK and France, and amongst the MDBs. Major challenges remain with implementing the sustainable urban transport approach and major issues remain with modelling transport costs.

Recommendations for further research are given below. Overall, there is a need to properly understand both how markets work, and what people want from their transport systems. In the analysis of transport costs, we cannot assume perfect competition.

The Need for a Comprehensive Look at Current Transport Appraisal Practises

It would be useful to do a systematic study of current transport appraisal documents. Although post-evaluations are widely published, the initial planning and appraisal documents that are usually prepared by consultants are not made available online. It would be useful to know what processes were involved in selecting the options that were chosen, and what assumption went into the models used.

The Use of Multi-Criteria Analysis (MCA) and Multi-Criteria Decision Analysis (MCDA)

The are good grounds believe that MCA and MCDA could be particularly useful in urban and rural transport where environmental and social welfare issues are relatively important. However, consultation is likely to be key to the successful use of these approaches. We need to understand what data is required, along with the most appropriate framework of questions, for decision makers to feel comfortable in making judgements within an MCA/MCDA exercise. The exact technical specification for coming to conclusions and deriving weights for MCDA (i.e. such as the Analytical Hierarchy Process, Multi-Attribute Utility Theory, Likert Scale etc) is likely to be of secondary importance.

Among the issues to consider are:

a) Should cost benefit analysis be included with the MCA framework?

b) Should a poverty/distribution of income analysis be included, and if so, how?

c) What environmental indicators should be included?

The Wider Economic Impacts (WEI/WEB) of Road Investment

Over time, there are grounds to believe that within road appraisals within LMICs there will be a gradual shift in the composition of transport benefits away from road roughness reduction (particularly with the introduction of electric vehicles) towards WEI. Wider economic impacts are built on the assumption of imperfect competition, hence there is need to properly understand how local markets work in different countries.

However, the current UK DfT approach to WEIs looks complex and very demanding of detailed local data. To be widely used in LMICs, in conjunction with tools such as HrDM5, then simplified approaches, involving the need for less local data, are likely to be preferred.

Planning Sustainable Urban Transport

There are clearly going to be major challenges in trying to introduce restrictions on the use of private cars in countries that have a rapidly growing car fleet. Similarly, the introduction of high-density public transport options such as bus rapid transport, urban rail, and metros, are likely to face affordability issues in the poorest countries.

Although there are a range of relatively easy traffic management measures that can be implemented, World Bank staff have reported that politically difficult decisions still have to be made, including reducing incentives for car purchases, increasing fuel prices, rationing private vehicle traffic in congested areas and substantially increasing mass transit capacity (IEG World Bank, 2017). As part of the planning process, we need to fully understand what people want.

To implement sustainable solutions, we may need to support the sensitization of political leaders and the wider public of the benefits of sustainable urban transport. One way of achieving this would be to quantify the benefits from real life case studies of different measures. There is also a need to help increase in local capacity to plan and implement urban transport initiatives.

Information from appraisal and post evaluations suggest that development banks have, in recent years, tried to provide better accessibility and mobility for the urban poor, however more needs to be done to assist people with disabilities and provide safe spaces for women and girls (IEG World Bank 2017).

Planning Rural Roads

There is a need to reconcile the limited predicted benefits from the current road appraisal models with the apparently large impacts found in some rural road studies. There is evidence that wider impacts are sensitive to the local road density with the highest impacts where road density is lowest. Further work on wider eonomic impacts, in a rural context, may help to fill the gap.

Because transport cost models cannot capture the social and economic costs of disruption, they are not really suitable for roads that are likely to be impassable for more than a few hours. In this case cost-effective analysis, or MCA approaches to establish year-round ‘basic minimum access’ are likely to be more appropriate. This issue needs to be further explored.

Modelling Vehicle Operating Costs, electric vehicles and transport tariffs

To fully understand how road infrastructure affects vehicle operating costs and the wider economy we need to have a deeper understanding of how the market for vehicles, maintenance practises and freight transport markets work. In addition, the introduction of electric vehicles will also have a profound effect on long term operating costs.   Critical issues are listed below.

a) Vehicle age structure and import of used-vehicles

b) Adoption of different vehicle lifetime maintenance strategies

c) Variability in utilisation, including impact of restrictive practises, vehicle queuing systems and cross border delays

d) The need to reconcile predicted operating costs and freight tariffs

e) vehicle operating costs of electric vehicles

f) EV emissions

g) The effect of heavy electric trucks/buses on road pavements

h) The changing fleet composition, with introduction of EVs, and growth of private transport

Incorporating Climate Emissions and Climate Resilience into Transport Planning

Although onstruction emission models have been available for some years, there appears to be a lack of information on the extent to which they are being used within transport appraisals. This needs further investigation.

Similarly, there has been a useful range of research on incorporating climate resilience into infrastructure planning. It would be useful to know the extent to which this work has had an impact on infrastructure engineering design, and whether there are outstanding issues that still need to be addressed.

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APPENDIX A: Project TORS

The The TORs for this work are as follows:

Scope of work

Deliverables: The project has been structured into a set of deliverables as listed below. The supplier is required to submit a Proposal that outlines how they will address and deliver on the core scope of the ToR.

The deliverables are as follows:

1. Produce an inception report, reviewing the literature and detailing what will be possible to cover in the overall report, with options outlined that can be discussed with HVT and HVT stakeholders.

2. Report taking the form of a 'State of Knowledge Report'.

The report should be of sufficient quality that can be shared with the chief economists of FCDO and ADB, and include:

- a comprehensive analysis of current approach on transport economic assessment and how these can be enhanced.
- assess leadership in this area and compare this with current approaches in LMICs across Asia and Africa.
- suggestions on how to improve the current approach on transport economic assessments, as well as on what a broader, multi-criteria approach would look like to ensure the role of transport in traditional and emerging areas of interest on the global stage.
- an assessment of data and data requirements to ensure the practicalities of any such approach are fully understood and potential barriers to uptake are well documented.

The work should outline suggestions for improvements, type of data used and an approach toolkit for its application in infrastructure assessment and policy development. It should combine a literature review with the research supplier's own analysis.

The work will cover rural and interurban roads, as well as some consideration of urban road appraisal. NB a consultant from ADB may be able to assist with data on the latter. More specifically, the work will also cover:

- The use of economic appraisal for road planning and road management, including one-off projects and road networks, and the interests and concerns of different parties
- Modelling transport costs within HDM4
- Rural road impacts and wider economic benefits from main roads
- Social benefits and environmental issues
- Incorporation of multi-criteria analysis within rural road appraisal -including a case study from Ghana
- Analysis of the UK Department of Transport Approach
- Incorporating climate objectives in appraisal, including carbon pricing, the introduction of EVs, carbon emissions from vehicles and construction, the effect of climate on road design."

APPENDIX B: The use of Multi-Criteria Analysis (MCA) for rural road planning

MCA is often advocated for rural road planning. Six papers relating to the use of MCA for rural roads in LMICs were identified and key characteristics relating to each approach are included in the Table below.

Lead Author	Hasan	Bhandari	Akpan	Cheonklang	Shankar	Misra
Country	Bangladesh	Nepal	Nigeria	Thailand	India	India
Year	2022	2016	2022	2016	2019	2018
Use of CBA, and HDM4	YES	YES			YES	
Approaches used for selection and factor weighting	AHP, RMMTPM	Likert scale	MAUT, AHP	AHP	HDM-4, MPI, AHP, Likert scale, DT	AHP
Application results to road network?	NO	NO	YES	YES	YES	NO
MCA Factors:						
Maintenance Costs		YES			YES	
Construction Costs		YES	YES		YES	
Road Surface Type	YES					
Road condition					YES	YES
VOCs/ travel time costs		YES			YES	
Traffic	YES			YES		
Access to Markets/ Economic facilities	YES		YES	YES		
Access to Health facilities	YES		YES			
Access to Education	YES	YES	YES		YES	
Population		YES	YES		YES	
Environmental Issues		YES		YES	YES	
Connectivity	YES			YES	YES	
Safety/ Accidents	YES	YES		YES	YES	

Local Priority	YES	YES				
Other Factors:	Bus Route	Impact on historical/ cultural sites	No. of polling units	No of: provinces Districts Sub districts	Pollution cost	Straight, Curve, Intersection Conditions for:-
	Social centre	Possibility of landslide/ Erosion/ flooding		Shorts cuts/by pass traffic congestion, landmarks, road density Tourist attractions	Submergence, landslides flooding	Geometrics, shoulder, drainage Street lights Road marking Road signs
				Rural area access, agricultural area	pavement condition	
				Engineering difficulty		
				Consistent strategies		

Abbreviations: AHP- Analytical Hierarchy Process, CBA -Cost Benefit Analysis, DT -Delphi Technique, HDM-4 Highway Development and Management (Model 4) MPI Maintenance Priority Index, MAUT -Muti-Attribute Utility Theory, RMMTPM- Reed-Muench Median Threshold Population Method, VOCs -Vehicle Operating Costs

The six approaches use MCA to help prioritise the maintenance and investment in the road network. Five of the papers take into account the social and economic need for access, however Mishra (2018) just considers the engineering conditions as an indicator for the need for improvement.

In identifying the different factors to take into account and weighting their attributes five papers use the Analytical Hierarchy Process[16] (AHP) as one of the procedures they employ. Other approaches are also used such as Likert Scale and the Delphi Technique. All of the papers weight the factors to help come to a final prioritisation. The Department of Communities Report (2009) on MCA/MCDA approaches discusses the relative merits of different mathematical approaches to derive choices such as AHP and the Multi-Attribute Utility Theory.

It is interesting to note that three of the papers use conventional CBA as part of their prioritisation procedure. So, MCA is not seen as a pure alternative to CBA. Also, the HDM4 model is explicitly used as a way of calculating vehicle operating cost savings, travel time savings and accident cost savings by Shankar in India.

Each paper is considered in more detail below.

Hasan, M.U. et al. (2022) A Methodology for Planning and Prioritisation of Rural Roads in Bangladesh. Sustainability 2022, 14, 2337

This study proposes a Rural Road Planning and Prioritisation Model (RPPM). It consists of two major components: (i) developing a core network in participation with local stakeholders and (ii) prioritisation of roads based on Cost-Benefit Analysis (CBA) and Multi-Criteria Analysis (MCA).

Ten criteria were suggested for the MCA approach (see the Table above), and weights were calculated using the Analytical Hierarchy Process (AHP) and the Reed-Muench Median Threshold Population

[16] Analytic hierarchy process - Wikipedia

Method. The proposed approach was piloted in one district, and a web-based software is also developed for practical implementation by the Local Government Engineering Department (LGED), Bangladesh. It is suggested that for Maintenance that MCA is used. While both CBA and MCA can be used for Improvement.

Bhandari, S.B., P.B. Shahi and R.N. Shrestha. (2016) Ranking Rural Road Projects: Weighting Different Evaluation Criteria with a Focus on the Case of Nepal. International Journal of Engineering Research and Science and Technology. ISSN:2319-5991, Vol. 5, No.1 Feb 2016

The paper reviews the differences and the suitability of Cost Benefit Analyses and Multi-Criteria Analyses for rural road projects. It then reviews the literature and characterizes a set of criteria that may be used for and ranking such projects by applying an MCA to Nepal. Thirteen criteria were selected and their individual importance was determined by submitting a questionnaire based on eleven points Likert scales to rural road experts from Nepal and other 22 countries.

Weights for criteria were determined from a direct evaluation of criteria by the by the Nepali and foreign experts The sum of the total weights of the six Economic criteria [Road construction costs (7.05) , Road maintenance costs (7.9), Vehicle Operating Costs (6.58), Travel time costs (7.04), Accident costs (8.23) and Pollution costs (6.2)] were greater than the sum of the Social criteria weights [Population served per km (9.28), Access to education services (8.27), Access to other services (9.14) and Road as a community priority 8.57)] or the sum of the weights for Environmental factors (Impact of natural systems (8.73), Encroachment on sensitive or protected areas (8.19) and Possibility of landslides/erosion/flooding (8.92)}.

However, when the three sustainability pillars were considered together Social Aspects (8.79) had a higher weighting than Economic Criteria (8.66) or Environmental Aspects (7.83) with population served per km to having the highest individual weighting. The figures in brackets represent the geometrical mean of the weights. The highest individual weighting was for Population Served per km.

Akpan, U. and R. Morimoto (2022) An application of Multi-Attribute Utility Theory (MAUT) to the prioritization of rural roads to improve rural accessibility in Nigeria. Socio-Economic Planning Sciences 82 (2022) 101256

This study uses Multi-Attribute Utility Theory (MAUT) to examine how rural roads in Akwa Ibom State, Nigeria may be prioritized for upgrade to maximize access to key socio-economic facilities. In the analysis, a Multi-Criteria Decision Analysis is used to prioritize ten rural roads in Akwa Ibom State in South East Nigeria. Using spatial location data the decision criteria chosen are:

- the Cost of road upgrade,
- the number of Agro-processing facilities,
- the number of markets,
- the number of health facilities
- the number of primary schools
- the number of secondary schools
- the number of people within a 100m x 100m area
- the number of polling units

To identify weights the Analytic Hierarchical Process (AHP) was used which included a pair-wise matrix with a 9-point scale. The respondents chosen were staff from the Ministry of works, staff from donor funded projects and development experts in academia. A series of scenarios to meet key criteria were developed and weights were derived. Marginal utility functions were developed. The analysis was applied to 59 rural roads and 10 roads were identified to be prioritized. These roads have the highest average utility scores across different scenarios implying they had the highest net socio-economic benefit if upgraded.

Cheonklang, P. I. Phummiphan, S. Horpibulsuk, and M. Hoy. (2016) Prioritizing rural roads projects in north-eastern Thailand by analytical hierarchy process (AHP). Lowland Technology International date; 20 (2): 197-204. International Association of Lowland Technology (IALT): ISSN 1344-9656 Special Issue on: Green Technology for Sustainable Infrastructure Development

order to prepare a rural road development plan for the Bureau of Roads (5) in North East Thailand a prioritization procedure was developed using the Analytical Hierarchy Process (AHP), a multi-criteria decision-making method. Five key objectives were considered, Tourism, Logistics, Traffic Congestion Reduction, Rural Area Access and the Country's Border Security.

To meet objectives three main factors, and 17 minor factors, were identified. See Table Below.

Factors to be Considered in the Planning Process			
Main Factor:	1.Transport and Traffic Engineering	2. Accessibility	3. Other
Minor Factors:	1.1 Travel Demand	2.1 Number of landmarks	3.1 Environment
	1.2 Connection to the main highway	2.2 Densit of roads in study area	3.2 Difficulty in Engineering
	1.3 Number of Provinces	2.3 Number of stores	3.3 Accidents and safety
	1.4 Number of Districts	2.4 Number of businesses and ports	3.4 consistent with strategies
	1.5 Number of Sub-Districts	2.5 Number of tourist attractions	
	1.6 Shortcut, bypass and traffic congestion reduction	2.6 Agrcultural area	
	1.7 Support multi-modal transport		

Under the supervision and guidance of an expert panel Staff from the Rural Road Bureau determined the weights of the different factors using the AHP method. The routes of the rural road network were analysed and prioritised. The identified priorities were the used to prepare the road development plan, which also took into account the continuation of the development of the road network and the allocation of the budget to urgent projects in proportion to the population of each province.

Shankar, S., and B. Paneendra. (2019). A Multi-Criteria Evaluation Approach for Prioritization of Low-Volume Roads for Maintenance and Improvement. 12th International Conference on Low-Volume Roads, Kalispell, Montana, September 2019

The objective of the study was to find the most suitable criteria system and their weights of prioritising LVRs for maintenance and improvement. This was then applied to an existing LVR network.

The initial list of potential criteria was selected based on a literature review and surveys with local people, field engineers and transportation experts. The first-round survey was prepared by using a Likert scale and the scale adopted is from "not important" to "very important." In the second-round survey for finding the weights, two methods were used. A pairwise comparison method was used for finding weights of main criteria, and a ranking method was used for finding sub-criteria weights.

In total 19 criteria were adopted, including 6 social, 4 pavement condition, 6 economic and 3 environmental criteria. Most of these are shown in table above. (Pavement condition includes the distress index, roughness index, skid resistant index and structural capacity index). However, after reviewing the data it was realised the economic parameters depended on pavement condition and it was felt that it was not possible to combine both sets of parameters in a single criterion and it was proposed to have two alternative criteria. So, Criteria A includes social, pavement condition and environmental parameters while Criteria B includes, social, economic and environmental parameters.

Two further rounds of surveys were carried out to reduce differences among group members, with a facilitator presenting panel members with a comparison with average group response asking whether the members are willing to revise their response or not. After analysing the total results, the facilitator finalised the final weights of each criterion.

The multi-criteria approach then was applied to eight roads in Warangal District. This was based on a range of data from the local district, for the social data, and from the local engineer on road condition. While the economic data on VOCs, travel time savings, and accident costs came from the HDM-4 model. Pollution costs were calculated from external costs of transport in Delhi.

The two sets of criteria gave different rankings of the 8 roads. Overall, it was felt that Criteria A was most suited where there were no budget constraints, and there was less time available for planning. While the economic analysis in Criteria B demands more data and is more suitable for budget constraints.

Misra, J. and A. Swaroop. (2018) Prioritization of Road Networks for Rural Road Improvement with Analytical Hierarchy Process. International Journal for Innovative Research in Science & Technology| Volume 4 | Issue 8 | January 2018 ISSN (online): 2349-6010

A procedure is developed to prioritise rural roads for improvement based on engineering characteristics. Roads are divided up into sections: straight, curved and intersection. For the sections seven conditions are identified namely for geometric, surface, shoulder, drainage, street light, road marking and road sign. Using the Analytic Hierarchy Process (AHP) weights were estimated for the twenty-one different factors.

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