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Development of the Highways Maintenance Economic Assessment (HMEA) Model

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Executive Summary

The benefits of highway maintenance have been assessed for many years by comparing the forecasts of the future costs of maintenance arising under different maintenance strategies. These analyses have recognised that spending money earlier can often reduce the future needs for maintenance and therefore the costs over a long analysis period. Some analyses included the costs of disruption to road users caused by the maintenance work and the changes in costs to road users as the condition of the network changes but have not considered other wider benefits provided by the road network.

Earlier TRL studies for the Department for Transport and Transport Scotland included literature reviews for the impacts on road users that can only be described qualitatively due to the lack of relationships suitable for inclusion in quantified analyses. These reviews have been updated as part of this project for the UK Roads Liaison Group (UKRLG) Asset Management Board, to capture studies that have been reported since those earlier reviews. The review also confirmed the approaches used in earlier studies for assessing the impacts of the road network remained appropriate and the Highway Maintenance Economic Assessment (HMEA) model has built on those earlier developments. The results of the new literature review are summarised in this report.

The Highway Maintenance Assessment Tool (HMAT) was developed to assess some of the wider impacts of road maintenance and included the principal quantifiable impacts of road condition and maintenance on road users. The initial version of HMAT relied on the HMEP Life-cycle Planning Toolkit for the forecast of network condition and maintenance need. The outputs from the HMEP Toolkit were used in the assessment of the indirect costs of the condition and maintenance over the analysis period. In HMAT, the effects of network condition, traffic growth and vehicle speed are used in the calculation of user costs associated with journey times and vehicle operating costs while also taking into account the costs to users due to the future maintenance on the network. The effects of vehicle emissions during normal use and at roadworks are included with the costs of carbon embodied in the materials used in maintenance works. Estimates are made of the changes in the number and costs of accidents on the network as the condition and amount of maintenance changes.

The HMEA model has been developed to extend the analyses included in HMAT but also modifying HMAT to allow the results from stand-alone analyses of the future network condition and maintenance to be used if results from HMEP analyses within HMAT are not available.

HMAT is a Microsoft Excel spreadsheet and that spreadsheet has been fully integrated in the Microsoft Excel spreadsheet for the HMEA model. An HMEA analysis is for one network and

one maintenance scenario but the associated HMEA Collator combines the results from up to five HMEA analyses and the impacts shown in those analyses compared by nominating one option as the base case.

It was recognised that the condition of the network can impact the prosperity and economy of an area and the HMEA model has been developed to quantify that benefit by considering the impact of network condition on aGVA, tax from income, VAT and NIC over the specified analysis period. It also considers the changes in employment in the area served by the road network if the network condition changes.

Another earlier study for Transport Scotland assessed the value of the Trunk Road Network in Scotland and the approach adopted for that assessment has also been included in HMEA to assess the value of the network used in the HMEA analysis. In that approach the costs of the traffic on the analysed network using an alternative network are estimated by considering the different traffic behaviour on the alternative network. The assessment does not take account of increased congestion on the alternative network but is aimed to represent the benefit of the availability of the analysed network.

It was also recognised that highway authorities may have other income from use of the network and tolls. A simplified representation of these charging mechanisms has been included in HMEA, allowing the income to be modified if the network condition attracts or deters the use of the network.

HMEA uses published datasets not usually employed in highway authorities and the report includes a list of potential sources for the data needed in the model. Where data is available from other sources that can be used but the aim was to provide users with a starting point in the collection of economic data suitable for the analysis of the specified road network.

To represent the economy of the area served by the road network, the main economic sectors of the economy are identified and the data for those sectors found using the Standard Industrial Classification (SIC) categories associated with the key sectors, taking into account the proportion of the economy that is dependent on the road network.

This report describes the HMEA model, the data needed in the model and the use of the results from HMAT analyses with the economic impacts from HMEA to show the economic impact of the road network. The analysed network can be split into sub-networks to reflect the different conditions and maintenance of parts of the overall network.

A simple example analysis using HMEA is described together with guidance on how to use the model. The benefits identified by HMEA analyses vary with the size and standard of the road network and the maintenance scenarios analysed. The model allows the impacts of alternative assumptions for the data in the model to be considered to identify the key aspects of the network that affect the economy.

1 Introduction

The aim of this project was to develop and use a model to assess the benefits of a road network to society and the economy served by the road network. The Highway Maintenance Economic Assessment (HMEA) model was developed to be suitable for the analysis of the Wales Strategic Road Network (WSRN) and local road networks (e.g. for a Local Authority). Where the value of the benefits can be quantified the model enables investigation of how those benefits change with the level of carriageway maintenance spend.

1.1 Background

The benefits of highway maintenance have been assessed for many years by comparing the forecasts of the future costs of maintenance arising under different maintenance strategies. These analyses have recognised that spending money earlier can often reduce the future needs for maintenance and therefore the costs over a long analysis period. Some of the analyses included the costs of disruption to road users caused by the maintenance work and the changes in costs to road users as the condition of the network changed.

In 2012, in a study for the Scotland National Maintenance Review, Parkman et al (2012, 2012a and 2012b) showed how the benefits of maintenance changed by including wider aspects of maintenance and in 2013, the RAC Foundation and ADEPT considered how the same approach could be adopted for England (Gould E, Parkman C and Buckland T, 2013.) Following the work in Scotland and England, in 2015 TRL developed the Highway Maintenance Assessment Tool (HMAT) for the Department for Transport and Local Authorities (Buckland et al, 2015).

HMAT included the principal quantifiable impacts of road maintenance on road users. The model predicts the quantifiable impacts of levels of road maintenance but recognised that there were constraints, due to existing knowledge, on how far some impacts may be quantified. The model included the effects of network condition, traffic growth and vehicle speed on user costs associated with journey times and vehicle operating costs while also taking into account the costs of the future maintenance on the network, the costs of carbon embodied in the materials used in maintenance works and the changes in the number and costs of accidents on the network as the condition and amount of maintenance changed. The study also described the impacts that could only be described qualitatively due to the lack of relationships suitable for inclusion in the quantified impacts.

In 2016, Transport Scotland showed the contribution made by the Trunk Road Network in Scotland to the economy of Scotland (Peeling et al, 2016). This was an analysis for a single year and did not take account of the changes that may occur if the condition of the network changed.

This project takes that work further by developing the Highway Maintenance Economic Assessment (HMEA) model that combines the indirect benefits from road maintenance derived in HMAT with the changes to the contribution of the road network to the economy as future network condition changes. This study also updated the literature studies on quantitative and qualitative approaches to the assessment of the benefits of road maintenance undertaken in previous studies.

In addition to developing the HMEA model to assess the benefits of maintenance of the road network, as part of this project the model was used to estimate the quantifiable benefits of the Wales Strategic Road Network (WSRN) and demonstrate the change in benefits with the level of carriageway maintenance on the WSRN. The aim of those case studies was to demonstrate the use of the model, show possible sources for the data needed in the model and show the results available from HMEA analyses.

The road network facilitates employment and supports economic activities by providing direct access to jobs, education, healthcare, retail opportunities, and social activities. Investment in the road network improves communities' access to these opportunities, especially those in remote rural areas. The network enables the freight and distribution sector to operate and provide through routes for individuals and businesses across the country.

The road network is used to transport fresh and high quality products around the country, which can then be sold throughout the UK and in global markets. This enables the development of efficient delivery patterns reducing the number of goods vehicles required as well as providing improved operation of freight depots and distribution centres.

For the tourism industry, the road network supports competition with international suppliers and attracts worldwide visitors, by offering safe and efficient access throughout the country, including remote tourist destinations.

Investment in the road network leads to economic benefits to the wider economy such as agglomeration externalities – the benefits that firms obtain by locating near each other, greater competition and increased employment in other parts of the economy as well as productivity gains. The network helps people to enter the labour market by reducing travel times and for employers, it provides access to a wider range of potential employees.

Increased connectivity delivered by the road network positively impacts on rural and remote communities and reduces regional inequalities in accessibility, benefiting regional cohesion. It promotes inclusive growth through:

- Lifeline transport links: Connecting communities and providing lifeline transport links in remote areas. A well maintained road network is essential as poor road transport links can leave areas isolated.
- Access to education, jobs and services for all. The road network is used by buses, the prime mode of transport for many excluded and/or low income groups, including the elderly, job-seekers and people with disabilities.

HMEA enables the effects on the wider economic benefits from the road network resulting from different maintenance strategies to be examined.

1.2 Structure of this report

This report describes the analysis details for HMEA and the results of the literature review that updates the literature reviews undertaken in earlier studies that include the initial development of HMAT (Buckland T, Parkman C, Booth C and Abell R, 2015), studies for Transport Scotland (Parkman C, Abell R, Bradbury T and Peeling D, 2012b and Peeling J, Palmer D, Booth C, Abell R, 2016) and for the RAC Foundation and ADEPT (Gould E, Parkman C and Buckland T, 2013).

Section 3 describes the findings from the literature with detailed source information in Appendix A, Appendix B and Appendix C.

Section 4 describes the HMEA model and Section 5 describes how an HMEA analysis is undertaken, including the data to be input, running the analysis and the results obtained.

Section 6 works through an analysis of a simple road network. The data used for the example does not represent an actual network but is data that may be found for networks suitable for HMEA analyses. The example uses forecasts of network condition and future maintenance produced outside HMAT and does not describe the process used to generate those forecasts.

HMEA and, to a lesser extent, HMAT require data inputs not commonly used in the assessment of maintenance assessment programmes. Section 7 and Appendix E provide data links that will help identify data for use in HMEA.

Interpretation of the results from an HMEA analysis is specific to the analysis undertaken but Section 8 gives some information that may help better understand the implications of initial results and point to where further analyses could provide further insight into the benefits of alternative maintenance scenarios.

The report also contains a list of abbreviations used throughout the report (see Section 9) and references to background reports and information sources not included in the literature review (see Section 10).

1.3 Additional information

In addition to this document and the HMEA User Guide (Brittain S and Abell R, 2020), supporting information on how to use the HMEA model can be found on the Introduction tab of the HMEA workbook and via the help buttons. The version number of the model can be found on all work sheets in the workbook and a version history can be found on the "Introduction" tab of the workbook.

2 Objectives

The aim of this study was to address the gap in the evidence base on the societal and economic value of the road network. The project had the following objectives:

1) To update earlier literature reviews of UK and international evidence for the assessment of the wider benefits of road maintenance
2) To develop a model to estimate the economic benefits of road maintenance, use the model to undertake example economic analyses of the impacts of road maintenance spend on the WSRN and show how the model could be used with other road networks (e.g. Local Authority networks).

This report describes the results of the literature review, the methodology used for the development of the model for the economic analyses and an example of the use of the model.

3 Literature review

Following the literature review carried out for work to assess the study on the value of the trunk road network to society and the economy in Scotland (Peeling J, Palmer D, Booth C and R Abell, 2016), this review was of currently published works for the period since that review published in 2016. The review for Transport Scotland considered:

- The societal and economic impact of the Trunk Road Network in Scotland
- Possible methodologies for quantifying the contributions of the Trunk Road Network to Scotland's economy and, where possible, the societal impacts.

The literature review in this project, to update the results from the Scotland study, reviewed recent articles, conference papers and published reports from across the world using web and electronic databases available to TRL and helped inform the development of the model for local roads and trunk roads in England and Wales.

This review considered the qualitative benefits of road maintenance that build on the observations in the Transport Scotland review and the main areas of impact included in quantitative analyses.

The purpose of the literature review was to:

- Review relevant literature on calculating the economic value of investing in road maintenance and report on estimates of contribution to macro-economic measures and multiplier for every pound invested.
- Review potential methodologies for calculating the economic value of investing in highway maintenance, with specific reference to the WSRN.

Economic assessment is a component of public management. It is concerned with the *ex-ante* appraisal of proposed highway maintenance projects prior to their implementation. Economic assessment is a tool that calculates the potential costs and assigns values to the anticipated benefits of a proposed project. It helps to identify the economic trade-offs between different alternatives and to select the best and most appropriate projects.

Good economic assessment demands a clear understanding of the direct, and indirect, impacts of proposed projects and thus, where possible, includes environmental costs and benefits and is further linked to broader health/livelihood effects of highway maintenance. Economic assessments can also identify external impacts and equity (i.e. who pays and who reaps the benefits) as well as efficiency.

Economic assessments need to follow a systematic and step by step methodology. In designing and performing the economic analysis special attention should be given to appropriately defining the geographic unit of analysis, properly assessing the time and duration of the maintenance project, and objectively evaluating the key outputs by using recognised discount rates for future costs and benefits. One of the common challenges of making good economic assessments is to measure the specific impacts of costs that are difficult to monetise. Consulting with local stakeholders provides support in estimating most accurately the economic value of impacts from the road network.

An economic impact analysis typically measures or estimates the change in economic activity between two scenarios, one assuming the economic event occurs, and one assuming it does not occur (which is referred to as the counterfactual case). For HMEA it is more appropriate to compare the impacts of alternative maintenance strategies.

3.1 Quantifiable economic assessment methods

A range of economic appraisal and assessment methods can be applied in different circumstances. These methods include Cost-Benefit Analysis (CBA), Cost-Effectiveness Analysis (CEA), PESTLE analysis (political, economic, social, technological, legal and environmental), Gross Value Added (GVA), Harmonised European Approaches for Transport Costing and Project Assessment (HEAT), Multi-Criteria Analysis (MCA), Web-based Transport Analysis Guidance (WebTAG), Highway Development and Maintenance model (HDM-4), Road Deterioration and Works Effects (RDWE) Adjustment Factors, Roads Economic Decision Model (RED), and the Highways Maintenance Efficiency Programme (HMEP) Lifecycle Planning Toolkit.

When used consistently, economic assessments provide an objective way of recommending the most suitable option from the available alternatives. Depending on the type of assessment, results are expressed as the discounted cost (i.e. Net Present Value (NPV)[1] or Internal Rate of Return (IRR)[2]). Financial analysis only considers the costs and benefits that are directly carried by the highway authority. Economic analyses aim to consider the costs and benefits of a project or intervention for the economy as a whole.

Appendix A describes alternative assessment methods that can be used for the assessment of road maintenance options.

The data to be assembled for quantification of the contribution of investment in highway maintenance will depend on the assessment methodology selected for the analysis. CBA, MCA or a combination of the two are the most frequently used methods. The distinction between the two approaches is sometimes unclear but a definition of CBA is where:

(i) The analyst allocates weights (represented by a monetary accounting unit) and sums them up, whilst with MCA

[1] Net Present Value (NPV) is the summation of the current value of a series of present and future cash flows. NPV accounts for the time value of money and provides a method for evaluating and comparing cash flows spread over many years.

[2] IRR is the discount rate at which benefits and costs are equalised

(ii) The analyst does so in conjunction with decision-makers, stakeholders and other concerned users in a more 'participatory' approach.

In cases where agreed monetary values are available for the majority of impacts, CBA has a relative advantage over MCA but it's the other way round in cases where monetary values are not available.

In most instances a hybrid of CBA and MCA is employed that overcomes the inherent disadvantages of either approach. The development of HMEA is based on WebTAG since this is sufficiently flexible to accommodate a range of different metrics and indicators. It also includes the most relevant parts of CBA where appropriate.

The assessment framework to be used with HMEA therefore comprises two main elements:

- The spreadsheet model into which baseline and other option data is entered to demonstrate the impacts of the investment in highway maintenance
- Guidance for policy makers, road providers, and managers of transport infrastructure to provide detailed information on the spreadsheet model describing what the tool is useful for, how it should be used, how to provide the input data, the assumptions on which the outputs are based and how the outputs should be interpreted.

3.2 Economic and societal impact (Qualitative Aspects)

This Section provides a review of recent evidential research that either supports the findings of the review carried out for Transport Scotland in 2016 or adds to the research by identifying evidence of further developments. The areas identified in the review were:

- Welfare - health and environment, including safety, green infrastructure, air quality, noise and vibration.
- Importance of road transport - providing connection and economic growth
- Inclusive growth including accessibility - equity and culture
- Food, tourism and employment - changing industry and employment patterns
- Land use – access to land for companies and households

This literature review has updated the earlier review of economic and societal impacts (qualitative aspects) and considers how the economic success of businesses is reliant on good transport networks and, in particular, an accessible and well-maintained road network. The categorisation established during the earlier review remains suitable for this review which identified 30 further references, provided in Appendix B. Research entries highlighted in Green in the Appendix show the research that has added to this review.

Appendix C summarises the areas of qualitative impacts associated with alternative maintenance strategies.

There is a much divergent research on the important attributes that should be considered for economic assessment of new and existing road networks. The literature review has highlighted some of the trending research and identified that much of the research has identified the drawbacks to the current economic appraisal methods but has not yet identified robust and compelling evidence for adopting alternative methodologies.

4 HMEA description

The Highways Maintenance Economic Assessment (HMEA) model and HMEA Collator, are used to process and assess the economic impacts of different road network maintenance treatment scenarios over a specified analysis period. HMEA includes the impacts on aGVA (approximate Gross Value Added[3], an estimate of the total output of an economy), Value Added Tax (VAT), Tax from Income, National Insurance Contributions (NIC) and employment caused by the different condition and maintenance of the network. These impacts are combined with the impacts to road users caused by the change in condition of the network and the maintenance carried out on the network. Figure 4-1 shows the structure of an HMEA analysis.

HMEA also includes the option to calculate the benefit of the network (i.e. the impact on accidents, travel time and CO_2) shown by the change in behaviour, and therefore the change in cost, if that traffic was using an alternative network (e.g. traffic on the trunk road network moved to the local road network). This does not take into account the increased traffic on the alternative network but models the change in costs resulting from the use of the different road types.

A further option in HMEA allows the increased income from tolls and road charging to be included in the analysis.

[3] aGVA (approximate Gross Value Added) is the value generated by any unit engaged in the production and the contribution of individual sectors or industries to a country's Gross Domestic Product (GDP). It represents the direct economic benefits of economic activity, whereas welfare involves wider components. Many welfare gains from transport schemes are themselves recorded as increases in GDP, for example the economic benefits of increased employment and productivity, but some are not. It is possible that some impacts on GDP do not reflect increases in welfare. Wider economic benefits that are missing from conventional appraisal methods reflect the main market imperfections, including agglomeration externalities and imperfect competition.

Values of aGVA impacts from HMEA when combined with the outputs from HMAT could result in double counting of certain elements of value added. This may result only from overlaps between vehicle operating costs and costs attributed to travel time as safety, environmental impacts and non-business costs/benefits are not part of aGVA. The overlap would only relate to business trips but as the values of time and vehicle costs are averages for all uses, no allowance for the possible overlap is made in HMEA analyses.

HMEA uses aGVA for one of the measures of the impact of road network condition on the economy. aGVA is measured for the national economy but data is available for regional parts of the country (e.g. for individual or groups of Local Authorities).

The pre-existing Highways Maintenance Assessment Tool (HMAT) is used as part of the HMEA analysis process and provides the assessment of the indirect impacts on road users and society from the condition and maintenance of the road network. The HMAT analysis is separate from HMEA and HMEA automatically accesses the results from the analyses in the HMAT files.

An HMEA analysis is for a single road network but that network may comprise up to 6 sub-networks with network condition and impacts on road users analysed separately in HMAT for each sub-network, prior to the HMEA analysis for all the network.

HMAT provides an estimate of the treatment and condition impacts on road users from a specified maintenance scenario for a road network. The impacts from the condition of the network included in the analysis are the changes in vehicle operating costs, travel time and accidents along with changes in carbon in vehicle emissions due to use of the network.

The impacts on road users caused by the maintenance of the network are shown by the delays and the change in vehicle emissions and the changes in the numbers of accidents at roadworks sites. The treatment impacts also include the change in the carbon emissions resulting from the amount of maintenance work carried out. Further guidance on the use HMAT is published separately.

HMAT incorporates the Highways Maintenance Efficiency Programme (HMEP) Carriageway Life-cycle Planning Toolkit. HMEP uses the current condition of each road type and the adopted maintenance strategy to forecast the condition of each road type for each year of the analysis period, the cost of the maintenance carried out on each road type in each year of the analysis period and the amount of maintenance work carried out on each road type in each year.

As part of the HMEA development, HMAT has been updated to Version 2 to enable the network condition and maintenance forecasts used by HMAT (i.e. the condition, maintenance costs and amount of maintenance work calculated by HMEP) to be calculated in another separate tool and the results from those analyses loaded into HMAT for the calculation of the indirect costs.

On the HMAT opening screen the user chooses to use or not use the HMEP carriageway analysis tool in the HMAT analysis. If the HMEP Toolkit built into HMAT is not used, some of the data that would be provided in HMEP for use in the analysis of future network condition and maintenance is input into HMAT.

HMAT analyses include a simple analysis of the effect of the amount of maintenance on the levels of employment and aGVA resulting from that maintenance work. If the HMEP Life-Cycle Toolkit is used in an HMAT analysis, the results of the employment analysis are shown in HMAT but are not used in HMEA. If the HMEP Life-Cycle Toolkit is not used in the HMAT analysis (i.e. external forecasts of network condition and maintenance are used in HMAT) then the results of the analyses of employment and aGVA are not shown in HMAT. The employment and aGVA analyses in HMEA are more comprehensive than the analyses of these aspects in HMAT.

An HMEA analysis for a maintenance scenario uses the HMAT files for each sub-network making up the network with the economic data for the road network. The change in network condition can be used to modify the expected traffic and economic growth rates during the analysis period. This enables HMEA to show the consequences of poorer network condition reducing traffic flows or improved network condition increasing the traffic and economic growth rates.

The results from the HMEA analyses of different maintenance scenarios on the road network can be loaded into the HMEA Collator to show the difference in the impacts caused by the different maintenance scenarios. In the Collator, one of the scenarios is nominated as the base case and the comparisons are made between the base case and each alternative maintenance scenario examined for the road network.

The HMEA model is based on a set of worksheets in the spreadsheet and combines the results from separate analyses in HMAT that represent the indirect impacts on road users of the network condition and maintenance, with the economic impacts calculated in HMEA.

The HMEA model uses six worksheets for an analysis:

Worksheet Tab	**Description**
Introduction	This describes the HMEA worksheets and the colour coding of the worksheet tabs and cells
Economic data	Describe the economy for the analysed network
Network benefits	Benefits from the availability of the analysed road network
Public Income	Other income from the road network
Name and Filepaths	Specify the filenames of the HMAT data to import and run the HMEA analysis
Advanced settings	Describes the effects of network condition on economic and traffic growth rates

Two worksheets reproduce summary data from the HMAT analyses to show:

Worksheet Tab	**Description**
Network Details	Shows details of the road network analysed in HMAT and to be analysed in HMEA
Condition&Maint Data	Summarises the analysis parameters used in HMAT and to be used in HMEA

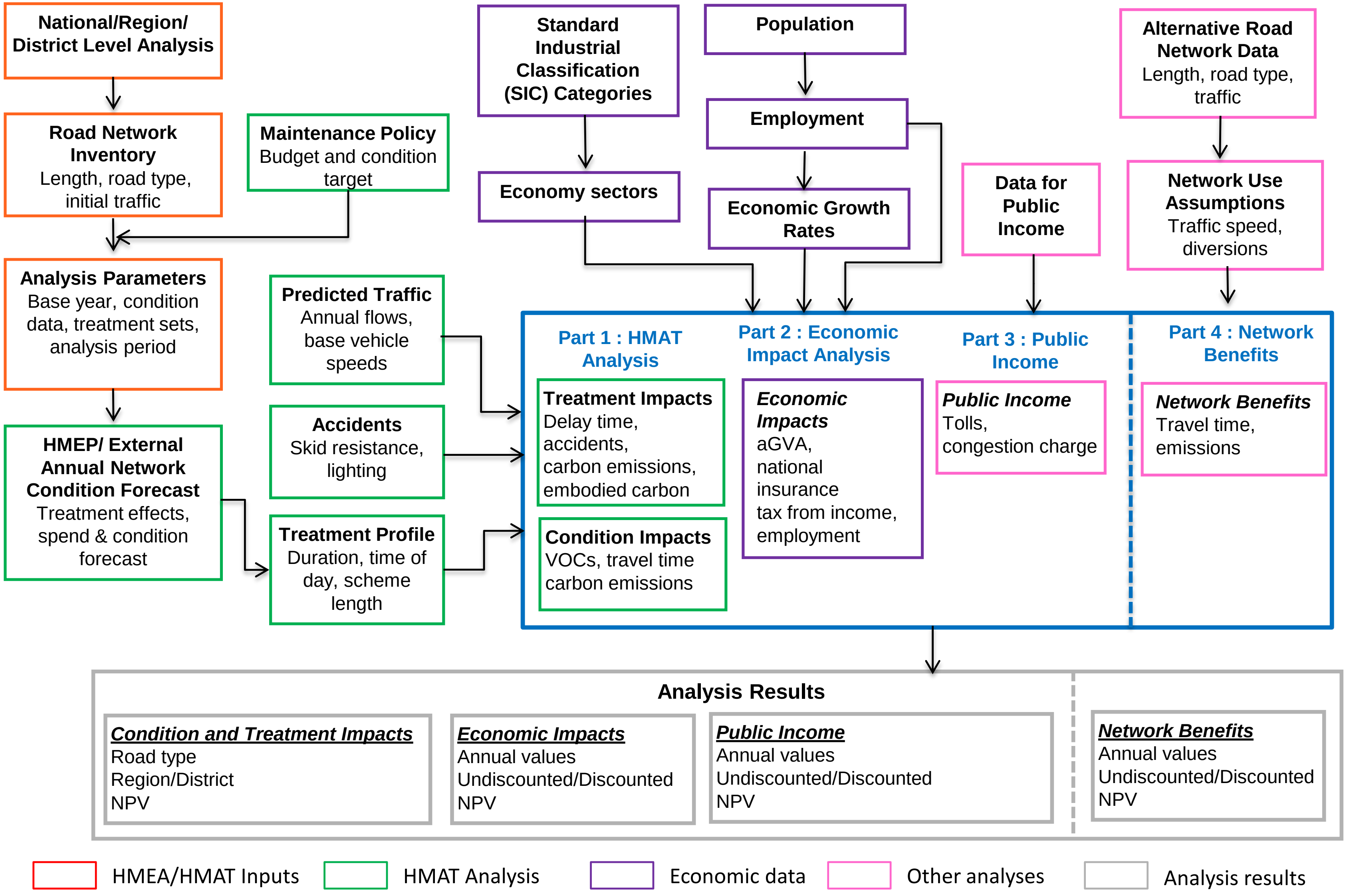

Figure 4-1 Structure of an HMEA analysis

When the HMEA analysis has run, two worksheets show the results:

Worksheet Tab	Description
Future Projections	Shows the annual discounted and undiscounted values for the costs calculated in HMAT and HMEA for the network and each sub-network
Summary (Life analysis)	Summary table of the discounted and undiscounted total HMAT and HMEA costs over the analysis period for the network and each sub-network

There are also hidden worksheets in HMEA used to hold background data and as temporary stores for analysis results as the analysis progresses.

There are three stages in the HMEA analysis and where the same parameters are used in more than one stage it is important that the same values are used in the different stages as the key data items must be consistent across the analysis. Similarly, parameters for analyses that are to be compared (e.g. different maintenance scenarios) must also be consistent. The following parameters used in HMAT and HMEA are specified only in HMAT:

- Base year for the analysis
- Analysis period length
- Network description

Where an external analysis is used to provide the forecasts of future condition and maintenance work for use in HMAT, the analysis parameters (e.g. initial network condition, treatment types) for the external analysis, as well as those for the HMEA/HMAT analysis must also be consistent across all stages of the analyses that are to be compared.

4.1 Road Network Condition and Maintenance

For an analysis, the road network in HMEA can be described at two levels. The first is when the network is modelled as a single network and the second is when the network is represented by a number (up to 10) of sub-networks. When sub-networks are used, an HMAT analysis is needed for each sub-network.

The first stage in the HMEA analysis is the prediction of the future network condition and maintenance treatments during the analysis period. This may be undertaken as part of the HMAT analysis using the the Highway Maintenance Efficiency Programme (HMEP) Lifecycle Planning Toolkit built into HMAT. Alternatively, external analyses may be used and the results imported into HMAT in the tabular format shown in the HMAT worksheets.

Network condition is described by between 3 and 10 condition bands. The same number of bands is used for all road types. The HMAT input data includes the initial condition of the network (i.e. the percentage of each road type in each condition band in the base year) and the future condition is predicted using the HMEP Toolkit or the external analysis. Details of the maintenance treatments are also specified in HMAT.

An example of the input data required for HMAT when the HMEP Toolkit in HMAT is not used, is given in Appendix D.

The outputs required from the condition and maintenance analyses, in terms of network condition, budget forecast, and treatments undertaken are used to assess the impacts of the road network in HMAT.

If traffic data is also required for the external analysis of the future condition and maintenance of the network, then the traffic level used should be the same as used in HMAT. HMAT uses the initial traffic flow (by road type and vehicle type) with annual growth rates to forecast the annual traffic flows on the network. The result of the traffic forecast in HMAT is available in the Projected Traffic worksheet in HMAT. Using the produces Three datasets are needed in HMAT from using the HMEP Toolkit in HMAT, or an external analysis:

- Annual network condition forecast given by the percentage of each road type in each condition band.
- Amount of maintenance undertaken each year on each road type using each treatment.
- Annual maintenance spend for the network by road type for each maintenance treatment

The maintenance expenditure shows how much is spent to achieve the forecast indirect costs in HMAT and the economic benefits in HMEA. The amount of maintenance and the future condition ais used to estimate the indirect costs in HMAT.

The condition of the network can also be used to modify the annual economic and traffic growth rates in HMEA. For each year, the weighted average of the condition of each road type in the network is used to modify the traffic growth rates in HMAT. The condition of each road type is used to modify the annual traffic growth rates for each road type in HMEA.

4.2 Traffic

Traffic data is input in HMAT and comprises the flow by vehicle type in the base year on each road type. The annual growth rates for each vehicle type may be assumed to be the same for all road types, or different rates may be used for each road type.

Traffic carried on the network is required at various places in the HMAT and HMEA analyses:

Condition and maintenance forecast

The forecast traffic flows are used to calculate the indirect costs associated with the maintenance scenario using the traffic for the sub-network in the analysis. Deterioration of the network does not use the traffic data, the traffic flow is used only to estimate the impacts on road users.

Condition and maintenance impacts

Using the outputs from each network condition and maintenance analysis (i.e. for each sub-network) the model assesses the indirect impacts of the road network. These costs are added to the maintenance costs to show the costs and impacts on road users. These analyses are undertaken in the Highway Maintenance Appraisal Tool (HMAT) model to calculate the consequences of the road condition and maintenance in terms of:

- Vehicle Operating Costs – changes due to road condition.
- Travel time – changes due to pavement condition.
- CO_2 emissions – from vehicles using the network (separately at roadworks and during normal operation).
- Accidents at roadworks – increases in the number of traffic collisions at roadworks.
- Delays at roadworks – time delays at maintenance sites.

The other impacts calculated in HMAT (i.e. accidents due to changes in skid resistance and street lighting and the costs of carbon embodied in the materials used in the predicted maintenance works) do not use traffic in the calculation of the costs.

Network benefits

Where this is included in the analysis, traffic data (by vehicle type) is needed for both the network analysed and the alternative network that represents the roads the traffic on the analysed network is assumed to use if the analysed network is not available (e.g. the alternative network for the Trunk Road network could be all or part of the local road network).

Traffic for the analysed network is taken from the forecasts in HMAT. The traffic data for the alternative network is specified by the million vehicle kilometres, split by road type ('A' roads (urban and rural), 'B' roads (urban and rural), 'C' roads (urban and rural) and 'U' roads (urban and rural). Traffic for the base year is split by vehicle type (e.g. Cars and Taxis, motorbikes, Light Vans, Goods Vehicles and Buses and coaches). Fixed annual growth rates are used for each vehicle type through the analysis period.

The traffic levels are used in the calculations of network condition and maintenance impacts, network benefits (i.e. accidents, travel time and CO_2 emissions) and public income (but this traffic dataset is different to the data used in the other model components).

Public income

The traffic flow for the congestion charge and toll charge are different to the flows specified for the analysed network. For the congestion charge, the daily flows, by vehicle type, in the base year are specified by the user for each sub-network of the analysis. Not all vehicles on the analysed network may be included in the congestion charge analysis.

For tolls, again, not all the traffic on the analysed network may be included in the tolls charge analysis. The daily flow, by vehicle type, subject to toll charges in the base year and the annual growth rate for the number of vehicles is input to HMEA for each sub-network.

4.3 Impacts from network condition and maintenance

Using the outputs from each network condition and maintenance analysis (i.e. for each sub-network) the Highway Maintenance Appraisal Tool (HMAT) is used to assess the indirect impacts on the road network. These costs are added to the maintenance costs to show the costs and impacts on the highway authority and road users. The analyses calculate the consequences of the road condition and maintenance in terms of:

- Vehicle Operating Costs – changes due to road condition.
- Travel time – changes due to pavement condition.
- CO_2 emissions – from vehicles using the network (separately at roadworks and during normal operation).
- Accidents at roadworks – increases in the number of traffic collisions at roadworks.
- Delays at roadworks – time delays at maintenance sites.
- Accidents – numbers of collisions due to levels of skid resistance and lighting.
- CO_2 emissions – from production of the road materials used in the forecast maintenance treatments.

Data that is common to HMEA and HMAT (e.g. network description, analysis period) is input in HMAT and read into HMEA when the results of the HMAT analyses are loaded into HMEA. A full description of HMAT is given by Buckland et al (2015) with user guidance for running HMAT is described by Buckland (2015).

HMAT contains the HMEP Life-cycle Planning Toolkit to provide forecasts of network condition and the future maintenance requirements. HMAT has been updated to include the new version of the HMEP Life-cycle Planning Toolkit (UKRLG Asset Management Board, 2019) and to be able to run HMAT without the HMEP Toolkit. When the HMEP Toolkit, in HMAT, is not used for an HMAT analysis, the results of another external analysis can be copied into HMAT to calculate the indirect impacts of the forecast network condition and maintenance. Three sets of data are needed for input into the appropriate worksheets in HMAT:

- Condition of the network for each road type, condition band and year of the analysis period (i.e. percentage in each condition band for each road type for each year).
    - This is Tab “2 - Condition by Year” in HMAT.
- Maintenance work quantity for each year of the analysis period
    - For each road type and each treatment type, the area* treated
    - This is Tab “3 – Work Quantity” in HMAT

* Note: If Length is available rather than Area, the Length data can be used with the carriageway widths (input to HMAT) to manually create the Area table.

- Expenditure by treatment for each year of the analysis period
    - For each road type and each treatment type, the maintenance expenditure in each year of the analysis period
    - This is Tab ”4. - Exp by Treatment” in HMAT

When HMAT analyses of each sub-network have been run, the files can be saved ready for loading into HMEA for the Economic Impacts, Network Benefits and Public Income to be added to the analysis for the whole network.

4.4 Economic impacts

The economic impacts of the road network are measured by three separate aspects of costs and the level of employment. The following costs are considered:

- aGVA (approximate Gross Value Added) of the defined economic sectors.
- Per Capita aGVA for the defined economic sectors.
- Tax receipts from the defined economic sectors (i.e. Tax Receipts from Income, Value Added Tax and National Insurance Contributions).

Assumed annual growth rates for each aspect of cost are used to forecast the change in costs during the analysis period assuming the network condition in the base year (in terms of the percentage of the network in the bottom two condition bands) is retained over the analysis period.

To attribute the economic impacts of the road network some data is only available at the national level. These costs (and the base year for the costs) are therefore specified for National Insurance Contributions (NIC) and Value Added Tax (VAT) together with the national population.

Tax receipts from Income are available locally and are specified for each subnetwork together with the population of the sub-network and the base year for the data.

HMEA enables the importance of the highway network to the economic well-being of the area served by the road network to be assessed. The economic impacts are derived from descriptions of the economy given by economic sectors represented by the Standard Industrial Classification (SIC) categories (Office for National Statistics, 2009). An HMEA analysis can include up to six economic sectors defined as part of the user input[4]. Where the selected sectors represent a large share of the whole economy, it may be sufficient to use those sectors. However, if the sectors represent only a part of the economy, one sector, defined as 'Other', can be used to represent the sum of the remaining parts of the economy, not explicitly included in the named sectors.

The aGVA associated with each sector is specified for each sub-network using the SIC categories for each sector and the total for all sectors. If the specified sectors represent all the economy, the sum of the aGVA values specified for each of the sectors is close to the aGVA for all the economy. The base year of the aGVA data is specified to enable the data from different sources to be normalised. Where the input data is for a year before the base year of the analysis, the annual growth rate for the parameter is used to update the input data to the base year of the analysis.

The SIC categories to describe the economic sectors are specified together with the percentage of that part of the economy derived from the use of the analysed road network. Data does not exist for the contributions the road network makes to the various sectors but

[4] If more than six sectors are needed to describe the economy, multiple runs of HMEA can be undertaken and the results combined externally

for some sectors (e.g. Transport), the network makes large contribution while for others (e.g. Public Administration) the contribution is small. Where there is uncertainty in the contribution made to a sector, sensitivity tests can be used to show the importance of the assumed contributions to the results of alternative analyses.

Per Capita aGVA values based both on levels of employment and population enable the calculation of the Per Capita aGVA for each sector. The total tax receipts from employees and companies involved in the provision and use of the road network are calculated for each sector. Tax receipts are considered in terms of Tax Receipts from Income, Value Added Tax and National Insurance Contributions.

Assumed annual growth rates for each aspect of cost are used to forecast the change in costs during the analysis period assuming the network condition in the base year (in terms of the percentage of the network in the bottom two condition bands) is retained over the analysis period.

The number of people employed in the area supported by each sub-network is entered in the same way as for aGVA. The share of the employment in each economic sector that results from the associated SIC categories for each sector is input with the number employed in each SIC category and for all the sub-network. In the same way as for aGVA, if the selected sectors do not represent a sufficiently high percentage of the total then 'Other' can be used as the last sector, to represent those employed in all sectors not explicitly included.

The base date and the annual growth rate for employment are used in the same way as the growth rates for the other economic parameters, to normalise the employment data to the base year of the analysis and to forecast the changes in employment over the analysis period.

Where the forecast network condition changes from the base year condition, user defined factors can be used in the model to modify the annual economic growth rates (see Section 4.7). The impact of change in condition is based on the weighted aggregated condition of all road types.

To enable future costs to be aggregated over the analysis period, up to two annual discount rates are specified for the duration of the analysis period.

4.5 Network benefits

In HMEA, this part of the analysis can be included/excluded by the user on the "Network Benefits" worksheet.

This part of the HMEA analysis is different to the others in that it shows a value of the analysed network rather than the economic contribution made by the network. The value is shown by assuming the traffic carried by the analysed network is carried by an alternative network. The alternative network generally comprises lower hierarchy roads than the analysed network.

The benefit of the analysed network in the HMEA analysis is potentially more relevant to Strategic Road Networks (SRNs) where the benefits of the SRN are shown by estimating the effects of the traffic that is using the SRN, operating on an alternative network (e.g. local road network if the SRN was not present). This is not to represent the increased congestion on the alternative network, it is to represent the different operating conditions on the alternative network, compared to the analysis network. For local road networks, the analysis may show the benefits of the higher road hierarchy by considering that traffic using lower hierarchy roads.

The details of the alternative road network are used to calculate the impact on the total value of accidents, travel time costs and CO_2 emissions if the analysed network was not present (and the traffic used roads of the type described for the alternative network). The results from this analysis are included in the overall benefits of the analysed road network. Each component of the Network Benefits analysis is shown in the results table for an HMEA analysis.

The percentage of traffic flow on each road type in the analysed network that is assumed to use the road types on the alternative network is input for each road type in both the analysed network and the alternative network. The same percentages are used for all vehicle types, for each year of the analysis period. The percentage of the traffic on the analysed network that is assumed to move to the alternative network does not need to sum to 100% as it may be assumed if the analysed network was not available, there would be lower traffic levels on the alternative network (i.e. some people would be deterred from travelling).

Accidents

Accident data for the analysed network and the alternative network is used to assess the difference in the costs if the traffic on the analysed network is redistributed to the alternative network. The values of an accident (fatal accidents and serious accidents specified separately) on the alternative network are input with the base year for the data.

The traffic flow (and base year) on the alternative network is used with the annual traffic growth rates to forecast the traffic on the alternative network in each year of the analysis period. Where the option to enable the change in network condition to affect economic and traffic growth has been selected in HMEA (see Section 4.7), changes are made each year to the traffic growth rate for the analysed network. The annual traffic growth rates on the alternative network are not changed. The numbers of accidents with the total traffic flow gives the number of accidents per vehicle per year. The rate of increase in traffic flow each year is applied to the rate of accidents so the number of accidents increases with the increase in traffic. The current accident rate for the alternative network is applied to the number of vehicles assumed to transfer from the analysed network. The benefit is then the difference in accident costs for the traffic on the analysed network and the accidents that would have occurred on the alternative network.

The costs of accidents on the analysed network and the alternative network are calculated by:

$$\text{Total cost of accidents by road type per million vehicle km} = \frac{\text{No. of accidents (by type)} * \text{Cost of accident (by type)}}{\text{Traffic (by road type)}}$$

The difference in the costs of the accidents on each road type on the analysed network and the alternative network before and after redistributing the traffic to the alternative network show the benefits of the analysed road network.

Travel time

HMAT uses vehicle speed for the travel time costs for the analysed network. The average vehicle speeds (by vehicle type and road type) are given for the alternative network and are used to show the difference in costs for the traffic using the analysed network if it is redistributed to the alternative network. The traffic flows and network length for the analysed network are used for the travel time costs.

The cost of travel time by vehicle type is:

Total delay time	=	Total journey time of redistributed traffic from analysed network - Total journey time of current use of analysed network
Travel time cost	=	Delay time (by vehicle type) * Value of time (by vehicle type)

The difference in the costs of the travel time on each road type before and after redistributing the traffic to the alternative network shows the benefits of the analysed road network.

CO_2 emissions

The cost of CO_2 emissions is based on the difference between the costs of the emissions from the traffic on the analysed network compared to the same traffic using the alternative network. The same traffic flow data for the network analysed is used for the impact analyses and the network benefits.

The ratio of the vehicle emissions on the alternative network compared with the analysed network is specified separately in HMEA for urban and rural roads. The difference in the emissions for the analysed network traffic (split by urban and rural road types) is calculated by the difference between the cost of emissions for traffic on the analysed network and the cost of emissions on the alternative network:

Alternative network (urban or rural) emissions	=	Analysed network emissions * Ratio of analysed network emissions over alternative network emissions

4.6 Public Income

Public income is calculated for income from:

- Tolls
- Congestion charge

The traffic flows used for both the congestion charge and tolls calculated in the public income worksheet are each separate from the traffic used in HMAT and the network benefits analysis. If the annual traffic growth rates in the other parts of the HMEA analysis are changed by the level of poor condition on the network, the traffic growth rates for public income are also changed by the same factors as the growth rates used in the condition and maintenance and economic impacts (see Sections 4.3 and 4.7).

The congestion charge income is based on:

- No of vehicles per day (by vehicle type) in the base year. If the parameters for all vehicle types are the same, then only one vehicle type need be used in the analysis.
- Annual growth in the number of vehicles per day (by vehicle type) over the analysis period. The base rate is user defined and used for all years of the analysis period unless it is modified by network condition (Sections 4.3 and 4.7).
- Charge per vehicle (by vehicle type) per day in the base year
- The increase in charge per vehicle over the analysis period (the rate of increase is specified for each vehicle type). The base growth rate is user defined.
- The congestion charge may not apply on all days of the week so the number of days per week is specified for use through the analysis period. There is no variation in daily traffic flow for days of the week.

Income from tolls is based on:

- No of vehicles per day (by vehicle type) in base year. If the parameters for all vehicle types are the same, then only one vehicle type need be used in the analysis.
- Annual growth in the number of vehicles per day (by vehicle type) over the analysis period. The base rate is user defined and used for all years of the analysis period unless it is modified by network condition (Sections 4.3 and 4.7).
- Charge per vehicle (by vehicle type) is a fixed fee per day (rather than per km) in the base year.
- The increase in charge per vehicle over the analysis period (the rate of increase is specified for each vehicle type). The base growth rate is user defined.
- Tolls apply every day of the week.

4.7 Other settings

HMAT increases the base year traffic flow by the annual growth rates input for the base year. HMEA uses forecast growth rates for the economic parameters (e.g. aGVA, VAT etc). In HMEA the user can choose whether to modify the forecast traffic from HMAT, the economic growth in the economic impacts and the traffic in the network benefits and public income analyses based on the condition of the network or to use the growth rates specified in the input data. If the growth rates vary with the condition of the network, the growth rates input for the base year are applied for all years where the condition of the network is the same as in the base year (i.e. condition at the start of the analysis period). If the condition improves or worsens in a year during the analysis period, the growth rates for that year are increased or decreased to reflect the change caused by the difference in network condition from the base year. If the condition is better than the start condition, then the growth rates, and hence the traffic flow and economic growth, are increased from the base rates and the growth rates are decreased from the base rates if the condition is worse than the condition at the start of the analysis period.

The percentage of poor condition is used to determine the change in the growth rates. Poor condition is defined by the number of condition bands. For the analysis of the indirect impacts in HMAT, the traffic growth rates are modified by the condition (i.e. percent in poor condition) of each road type. In HMEA, the growth rates for the economic impacts and traffic in the network benefits and public income analyses are modified by the weighted average of the condition of all road types.

The condition of the network is defined by condition bands (up to 10 bands can be used in HMAT and the HMEP Life-cycle Toolkit). The percentage in poor condition used to assess the effect on the growth rates varies with the number of condition bands used in the analysis:

- 3 or 4 condition bands, poor condition is the percentage in the bottom condition band
- 5, 6 or 7 condition bands, poor condition is the percentage in the bottom two condition bands
- 8, 9 or 10 condition bands, poor condition is the percentage in the bottom three condition bands

If network condition is assumed to affect the annual growth rates, the growth rates for year i are changed by a factor determined by the rules shown in Figure 4-2. The maximum change in condition, B%, that will impact the growth rates is assumed to impact the growth rates by A% (the change in condition is an absolute change).

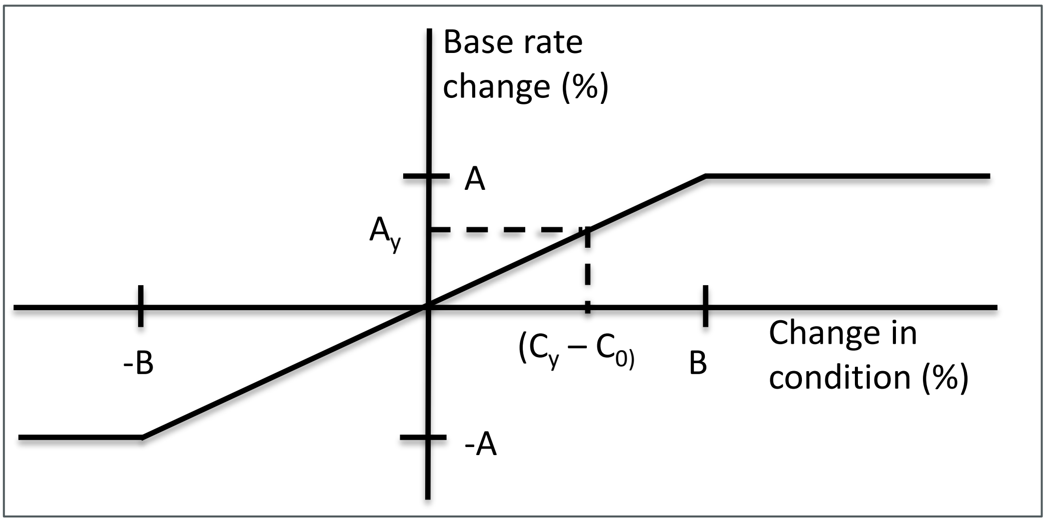

Figure 4-2 Modifying traffic and economic growth rates by network condition

If the network condition in the base year is Co% not in poor condition and in year, y, Cy% is not in poor condition. This represents a difference of (Cy – Co)% from the condition in the base year and the impact on the growth rate in year, y is Ay%:

Ay = A x (Cy-Co) / B

If the base data growth rate in year, y, is Gy% then that rate is modified to:

[Gy x (100 + Ay) / 100]

The change in condition from the base year may be an increase or decrease in the percentage not in poor condition and the effect on the annual growth rate of worsening condition is equal to the opposite effect of the same improvement in condition.

5 HMEA analysis process

This Section describes the stages in running an HMEA analysis and the data required for an analysis.

5.1 Network definition

The first stage is the selection of the network and the breakdown of the network into sub-networks for the HMEA and HMAT analyses (e.g. as sub-networks in a geographic area making up the overall network analysed). This involves checks on the data available for the sub-networks. Section 7 describes some potential data sources for the economic data and data that may not be immediately available in the highway authority. In addition to the suggested data sources, other departments in the highway authority may have local data that is appropriate for the analyses.

An HMAT analysis is needed for each sub-network and each maintenance scenario combination.

5.2 Maintenance scenarios

The HMEA analyses enable the wider benefits of maintenance scenarios to be examined using the HMEP Toolkit within HMAT, a stand-alone version of the HMEP Toolkit or another external network condition and future maintenance forecasting tool. Where an external model is used (including a stand-alone version of the HMEP Toolkit) it is important to ensure that any network, traffic and maintenance data used in the analyses are consistent. If the HMEP Toolkit built into HMAT is used, the data consistency is automatically provided. An HMEA analysis can compare the effects of different maintenance scenarios (e.g. do minimum, steady state etc.) on the sub-networks and the overall network.

Figure 5-1 shows how, on the opening HMAT screen, the use of the HMEP Toolkit is selected or disabled for the HMAT analysis. The button “HMEP condition analysis – disabled” switches between enabling and disabling the HMEP Toolkit in HMAT.

For each selected maintenance scenario it is necessary to run the HMAT model for each sub-network (e.g. if there are three sub-networks and four scenarios then this would require 12 HMAT analyses and will result in in 4 HMEA analyses, one per scenario). The process to generate the results for one scenario (and three sub-networks) is illustrated in Figure 5-2.

5.3 HMAT analyses

Details for the sub-network to be analysed in HMAT and then HMEA are specified in HMAT and automatically read into HMEA as part of the loading of the HMAT analysis results. For each HMAT analysis, the following data is required:

Worksheet Tab	Data description
Standard Inputs	Base year of the analysis and the length of the analysis period
	Analysis name
	Select road types to describe the sub-network[5] analysed
	Set the number of condition bands and the name of each band
	Set the number of and names of the maintenance treatments
	Carbon embodied in each maintenance treatment (asPECT, 2014)
	Average maintenance scheme length on each road type

[5] It is recognised that the road types will not necessarily be the same for all sub-networks in the network to be analysed in HMEA. HMEA will use all the road types defined in the HMAT analyses for the sub-networks.

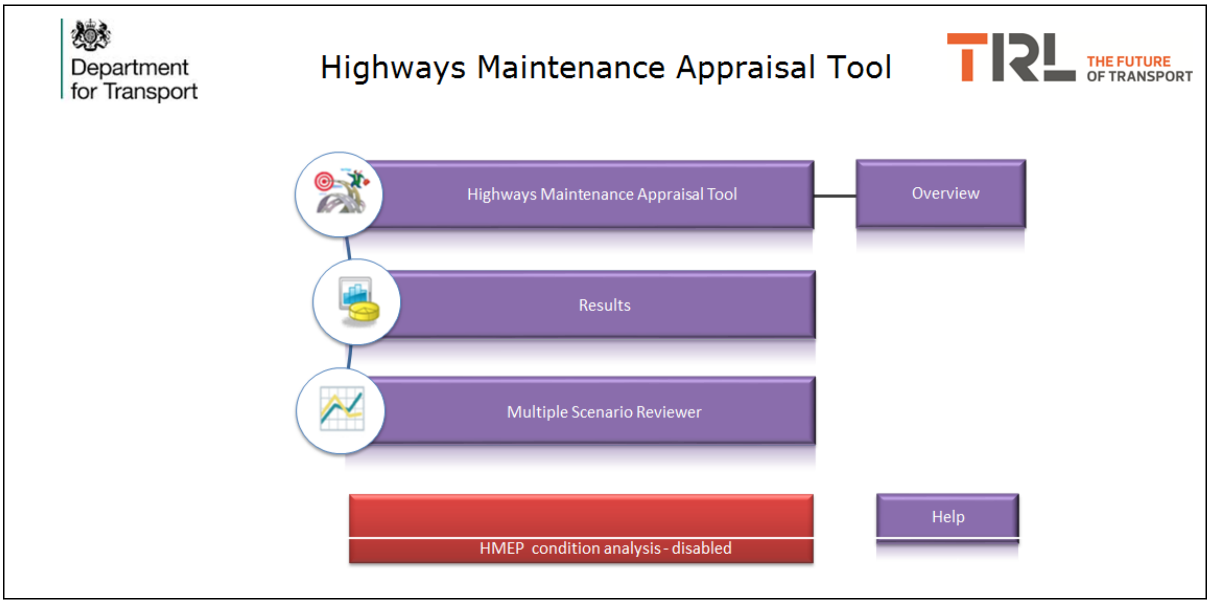

Figure 5-1 Modified HMAT opening screen

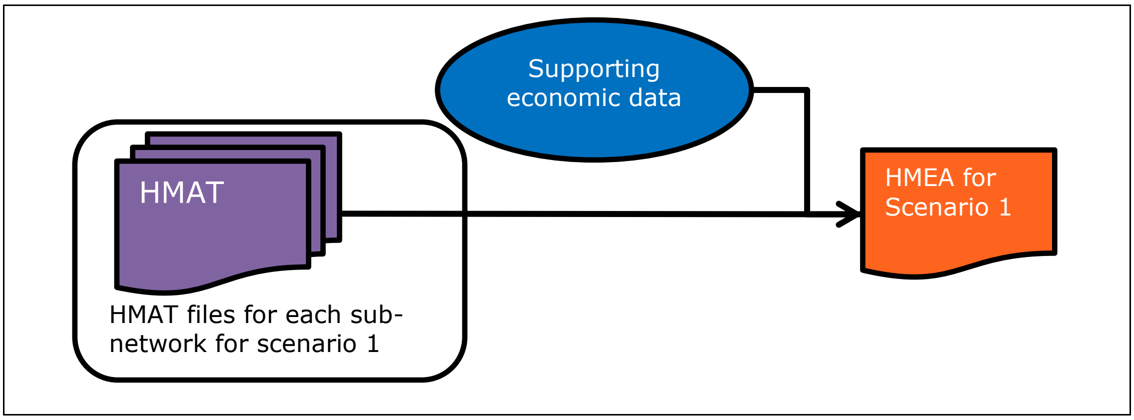

Figure 5-2 HMEA analysis for one scenario

Network size Carriageway length and width for each road type

Note: If the HMEP Toolkit in HMAT is enabled this data is not required but the initial network condition must also be input in HMEP.

Traffic Select vehicle types to be used

Annual flow of each vehicle type on each road type in the base year

Annual growth rate for each vehicle type

Condition by year Percentage of each road type in each condition band in each year

Note. This is only required if a standalone HMEP analysis or an external model has been used to forecast the network condition and maintenance. See example data in Appendix D.

Work quantity	Area treated by each treatment type for each road type and year Note. This is only required if a standalone HMEP analysis or an external model has been used to forecast the network condition and maintenance. See example data in Appendix D.
Exp by treatment	Maintenance expenditure by each treatment in each year on each road type Note. This is only required if a standalone HMEP analysis or an external model has been used to forecast the network condition and maintenance. See example data in Appendix D.
Lighting and skid budgets	Lighting budget[6] for each year Skid resistance maintenance budget for each year
Treatment impacts	Road closure patterns for maintenance on each road type Work output rates for each treatment type on each road type Level of carbon costs to use (High, Central or Low)
Condition impacts	CO_2 per litre of petrol, diesel, electric (default values available) Note. IRI tables and the default vehicle speeds can also be edited but default values are available
Accidents	Annual lighting budget Number of slight, serious and fatal lighting accidents resulting from the specified budget Breakdown of each accident type into daylight/night etc Skid resistance maintenance budget and percentage of the network with skid resistance below the Investigatory Level Two percentage changes in skid resistance maintenance budget and the resulting percentage of the network with skid resistance below the Investigatory Level

[6] The lighting (and skidding) accidents are calculated for each year by considering the budget in comparison with the budget for the accident data provided. There is no cumulative effect with increasing time, nor any increase in lighting related accidents or change in predicted speeds due to carriageway maintenance on the network.

A specified percentage reduction in the lighting budget translates to the same percentage reduction in the amount of available lighting on the network. Studies have shown that the number of accidents increases as lighting is dimmed or removed. The budget used in HMAT therefore relates to the money spent on lighting. For the existing lighting, this comprises the maintenance of the lighting infrastructure and the operating energy (electricity) costs to power the lighting. Where the maintenance of the lighting infrastructure is not available, the cost of the lighting energy (electricity) is used as it is that money that is saved if the level of lighting is reduced.

Condition bands to IRI	The tables need to match the number of road types and condition bands in the analysis (Default data available)
Base vehicle speeds	For each road type and vehicle type (Default data available)

If the HMEP Toolkit in HMAT is used then two other Tabs enable the overall maintenance budget to be broken down into carriageway maintenance and the carriageway maintenance budget input into the HMEP Toolkit.

Further details on the data needed in HMAT is given in the HMAT User Guide (Buckland, 2015).

Where multiple sub-networks are used in an HMEA analysis, it is important that the HMAT files are structured in the same way and the same parameters used for:

- Base year of the analysis and length of analysis period
- Number of road types and road type names
- Number of condition bands (and structured in order of Good to Poor condition)
- Number and types of maintenance treatments but the details of the treatments, such as cost and rate of working, can be different on each sub-network.

5.4 HMEA analysis

When the HMAT analyses are complete for a scenario, the HMEA analysis can be carried out. The economic data used is for the network for all the sub-networks to be analysed and is entered on worksheets within HMEA.

Worksheet Tab	**Data description**
Economic Data	Network name
	National VAT, NIC and population values with the year of the data
	Names of the sub-networks (see the “Name and Filepaths” worksheet). Note: sub-networks must be named before loading HMAT analyses.
	Population, Tax from Income and the base year for the data, for each sub-network
	Annual growth rates for aGVA, Tax from Income, VAT, NIC and employment
	Discount rates for the analysis
	Industry sectors to represent the economy
	SIC categories to represent each industry sector representing the economy
	Percentage of economy enabled by the road network for each SIC category/economy sector combination
	aGVA base year

	aGVA for each SIC category and each sub-network Total aGVA for each sub-network Percentage of employment enabled by the road network for each SIC category/economy sector combination Employment base year Employment for each SIC category and each sub-network Total employment for each sub-network Below the data input tables, the worksheet shows the allocation made in HMEA of aGVA and employment to each economic sector and sub-network.
Name and Filepaths	Analysis name Folders holding the HMAT analysis files Allocation of the HMAT files to the sub-network names specified on the “Economic Data” worksheet Specify if network condition is to be used to modify the traffic and economic growth rates (this must be selected before running HMEA) Extract HMAT data and run HMEA Existing HMEA data can be cleared using the box on this worksheet
Advanced settings	Set the limits of the effect on the traffic and economic growth rates caused by changes in network condition. The maximum change in each growth rate and the change in condition causing the maximum change in each growth rate
Network benefits	Select if this analysis is to be included. If not enabled, no other data is input on this worksheet. Costs of fatal and serious accidents on the analysed network and the base year of the data Annual growth rate for the costs of accidents Alternative network – traffic and accidents: Traffic data base year, select traffic data format, annual traffic flow by vehicle type and road type, numbers of fatal and serious accidents, annual traffic growth rates by vehicle type Redistribution of traffic: Percentages of traffic to be moved from the analysed network to the alternative network by road type Vehicle speeds on the alternative network by vehicle type and road type Ratio of CO_2 emissions on the alternative network to the analysed network

Public income	Select if this analysis is to be included. If not enabled, no other data is input on this worksheet. Select traffic data format Congestion charge: Base year of the data, days/week to apply the charges, number of vehicles/day and the annual growth rate for each vehicle type to be charged on each sub-network, charge/vehicle for each vehicle type and the annual growth rate in the charge/vehicle for each vehicle type Tolls: Base year of the data, number of vehicles/day and the annual growth rate for each vehicle type to be charged on each sub-network, charge/vehicle for each vehicle type and the annual growth rate in the charge/vehicle for each vehicle type
Network Size	HMEA shows a summary of the network by sub-network and road type
Condition&Maint Data	HMEA shows a summary of the data for the analysis period, condition bands and the treatment types
Future Projections	HMEA shows the analysis name and the undiscounted and discounted values[7] calculated in HMAT and HMEA for each year and over the analysis period for the analysed network and each sub-network. In addition to the costs, the forecast levels of employment are shown for each year of the analysis period. The level of employment and the Per capita aGVA are not summed over the analysis period but the value for the end of the analysis period is shown in the last year of the analysis period.
Summary (Life analysis)	HMEA shows the analysis period, base year and analysis name HMEA shows the total undiscounted and discounted costs over the analysis period for the breakdown shown on the “Future Projections” worksheet (except all tax receipts are aggregated) over the analysis period for the analysed network and each sub-network

When this process is replicated for more scenarios, the economic data input into HMEA is mostly unchanged (i.e. the economic impacts of the different scenarios use the same HMEA base data). Therefore, to run the other scenarios, copies of the HMEA model used for the first scenario can be used with different HMAT files for the other scenarios. However, it is not a requirement that the same economic data is used for each scenario.

[7] Annual values are shown for maintenance expenditure, percentage of the network in poor condition, Total HMAT costs (split by vehicle operating costs, travel time, carbon (vehicle fuel), roadworks accidents, carbon (vehicles in roadworks), roadworks time delays, accidents, carbon (embodied in materials)).

5.5 Comparing HMEA analyses

When HMEA has been run (and saved) for each scenario the analysis results can be collected and assessed using the HMEA Collator as illustrated in Figure 5-3. The Collator can compare the results from up to five HMEA analyses.

The HMEA Collator comprises two worksheets. The first loads the results of the HMEA analyses and the second shows the results from the analyses.

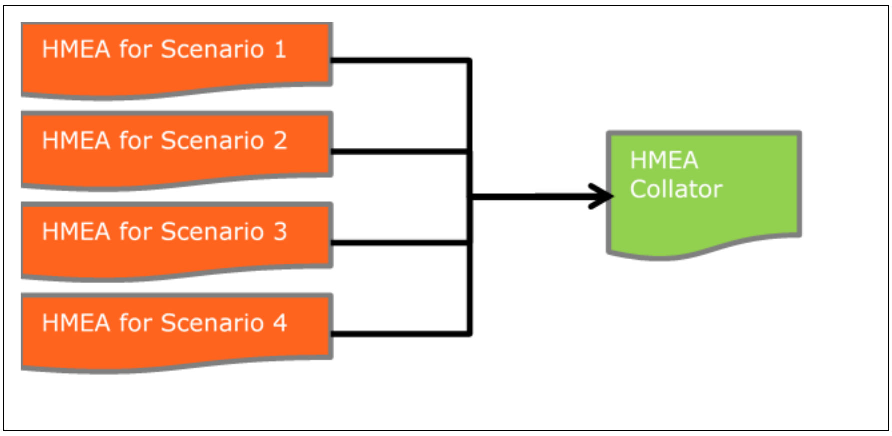

Figure 5-3 Comparing HMEA analyses

Worksheet Tab	**Data description**
Import Data	HMEA analysis files must be in a single folder with no other files. Up to 5 HMEA files can be imported when the folder has been selected. "Extract HMEA data" imports the data into the "Summary" worksheet. Old HMEA data can also be cleared using the "Clear extracted data" button.
Summary	The worksheet shows a summary of the HMEA results with each analysis identified by the analysis name. The undiscounted and discounted costs are shown for the direct maintenance costs, the HMAT indirect costs, network benefits, public income and the economic impacts. The total carbon costs extracted from the other summary costs are also shown. Select the base case to compare against the other HMEA analyses.

The results in the Collator are shown by the relative economic contributions made by each scenario (i.e. an HMEA analysis) compared to the base case scenario. The economic contribution of a scenario is derived by the change (from the base case) in indirect costs and economic impacts achieved by the change (from the base case) in direct maintenance costs.

Various measures of contribution are shown in the Collator with each measure including different components of the HMEA analysis.

The economic contribution cells in the Collator are coloured green or red depending on the comparison between the alternative scenario and the scenario selected as the base case.

- The cells are coloured green if:
    - There is an increased contribution and the direct maintenance cost for the alternative scenario is greater than the base case
    - The contribution is reduced and the direct cost for the alternative scenario is lower than the base case
- The cells are coloured red if:
    - The economic contribution is increased and the direct cost for the scenario is lower than the base case (i.e. if the direct cost for the scenario is lower than the base case and there is an increased contribution then the benefits of the alternative scenario are lower than the benefits of the base case. As the benefits of the alternative scenario are lower, this is shown as red.
    - The economic contribution is reduced and the direct cost for the scenario is greater than the base case

The Collator summarises the costs (undiscounted costs and discounted costs are shown in separate tables):

(1) Direct cost of maintenance

(2) HMAT analysis indirect costs

(3) Network benefits

(4) Public income

(5) Economic impacts

The economic contribution measures shown in the results are derived from these costs:

- Overall Economic Contribution (EC) = [(2) + (3) + (4) + (5)] / (1)
- EC: HMAT + HMEA (Economic) = [(2) + (5)] / (1)
- EC: HMEA (Excluding Economic) = [(2) + (3) + (4)] / (1)
- EC: HMEA (Excluding HMAT) = [(3) + (4) + (5)] / (1)
- EC: HMEA (Network Benefit + Public Income) = [(3) + (4) + (5)] / (1)
- EC: HMEA (Economic) = (5) / (1)
- EC: HMAT = (2) / (1)
- EC: HMEA (Network Benefit) = (3) / (1)
- EC: HMEA (Public Income) = (4) / (1)

The benefits in terms of changes in level of employment and per capita aGVA are not shown in the Collator as they are not summed over the analysis period. The in-year values are useful measures to consider but cannot be presented in the same way as the economic contribution.

6 Example HMEA analysis

This is an example analysis using data that is typical of road networks but is not for a specific existing network. The types of data used in the example are the same as would be used in an analysis for an actual network with realistic values but the values have not been taken from a real network.

Possible sources for the types of economic data used in HMEA are given in Section 7. The economic data used in the example analysis is described below.

For this example, the HMEA analysis compared the impacts of two maintenance scenarios over a 30 years analysis period. The first scenario retains the current level of maintenance funding but this is not sufficient to improve, or retain, the condition at the start of the analysis period. The second scenario uses increased funding to remove the poor condition on the network (i.e. remove the maintenance backlog) early in the analysis period and prevent the poor condition recurring during the analysis period.

The analysed network comprised two regions, R1 (total length ~497km) and R2 (total length ~264km). Each region has six road types: Motorway (Rural and Urban), Dual carriageway (Rural and Urban) and Single Carriageway (Rural and Urban). In region R1, the network is mainly Single carriageway (length ~321km) and Dual Carriageway (length ~80km) and in R2 the network is mainly Motorway (length ~90km) and Dual Carriageway (length ~ 115km). The condition of the networks is represented by three condition bands (Green-good, Amber-Fair and Red-Poor) and two maintenance treatments T1 and T2 are used to maintain the network.

Separate analyses have calculated the length to be maintained each year on each road type, the condition of each road type and the cost of the maintenance over the analysis period, for each scenario. Figure 6-1 and Figure 6-2 show examples of the change in condition of Dual Carriageway A-roads over the analysis period for the two scenarios. The results of the condition and maintenance analyses were used in HMAT as the first stage of the HMEA analyses. The results of the condition and maintenance analyses used in HMAT are shown in Appendix D.

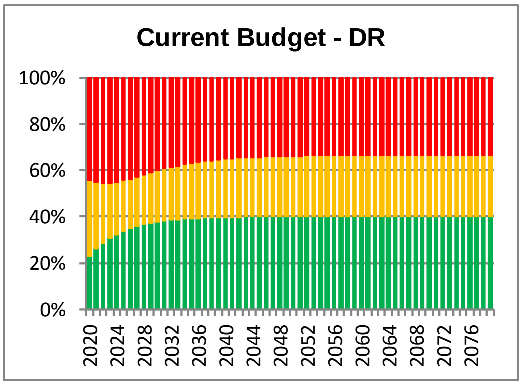

Figure 6-1 Condition of Dual Carriageway Rural roads in region R1 for the current budget scenario

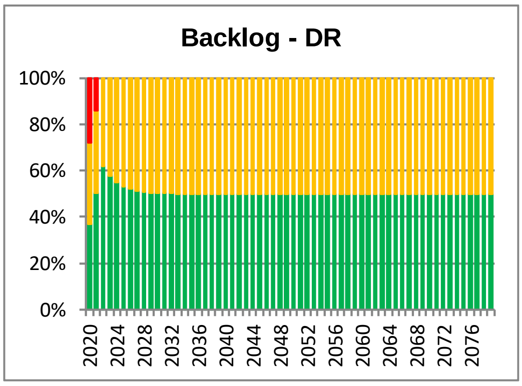

Figure 6-2 Condition of Dual Carriageway Rural roads in region R1 for the backlog scenario

Note. The condition of each road type is described by the percentage in each of three condition bands (Good – green, Fair – amber and Poor – red).

6.1 Economic data

In HMEA the economic data (e.g. aGVA, employment, VAT, NIC, Tax from income) is split into the sub-networks and economic sectors selected to represent the economy in the area analysed. Where the data is not available for those sub-networks and sectors it must be derived from national or local area data.

6.1.1 VAT and NIC data

Data for Value Added Tax (VAT) and National Insurance Contributions (NIC) is available only at the national level. HMEA then allocates the national values between the two regions. The base years for the values are also used to normalise the data to a common start year for the analysis. Table 6-1 shows the data used for this example.

Table 6-1. National VAT and NIC data

	Unit	Total	Base year
National Insurance (NIC)	£ million	2,732	2018
Value Added Tax (VAT)	£ million	3,146	2018

6.1.2 Tax from income

Allocation of the total tax to regions is based on the numbers employed in each region with the base year of the data. Table 6-2 shows the data used for this example.

Table 6-2. Tax from income

Network	Tax receipts from Income 2017 (£ million)
R1	679
R2	800
All the area	1479

6.1.3 Population

Population is needed for each region with the base year of the data (see Table 6-3).

Table 6-3. Population data

Network	Number
R1	419,021
R2	544,460
Total	963,482
Base year	2018

6.1.4 Annual growth rates

Growth rates for the economic data are specified for each region but for this example, the same values have been used for both regions (see Table 6-4).

Published data may give nominal growth rates but for the analyses, real growth rates should be used for a combination with the results from the HMAT analyses which use growth rates from the real growth rates given in WebTag.

Table 6-4. Forecast annual growth rates for model parameters

Network	aGVA	Tax receipts from Income	VAT	NIC	Employment
R1	1.4%	1.4%	1.4%	1.4%	0.9%
R2	1.4%	1.4%	1.4%	1.4%	0.9%

6.1.5 Discount rates

The annual discount rate for the analysis is 3.5%

6.1.6 Industry sectors and SIC Codes

The economy for the area is represented by the industry sectors shown in Table 6-5 with the corresponding Standard Industrial Classification (SIC) codes. There are 5 specific sectors with the sixth sector representing the rest of the economy.

Table 6-5 Industry sectors and SIC Codes for the economy

Industry Sector	SIC Code
Manufacturing	C - Manufacturing
Construction	F - Construction
Human health and social work activities	Q - Human health and social work activities
Agriculture	A - Agriculture, Forestry and Fishing
Public administration	O - Public administration
Other service activities	Remaining sectors not explicitly included

6.1.7 aGVA

The economic sectors are allocated to Standard Industrial Classification (SIC) categories to describe the contribution to the economy made by each sector. In the example, the allocation of each sector requires only one SIC category. aGVA data is given for each SIC code with the total for all the economy in each region. As the six sectors used describe the whole of the economy, the total for the six sectors is the same as the total for all the economy in each Region (see Table 6-5 and Table 6-6).

An estimate of the percentage of the aGVA for a sector that can be attributed to the road sector is needed. For the example analysis, the assumed share of each SIC category is shown in Table 6-7. For example, 70% of the aGVA for manufacturing in each region is assumed to be generated because of the road network. There is no published data for this so it is an area of assumption and the effect of the assumption can be tested as part of sensitivity analyses for the network.

Table 6-6. Sector aGVA allocation to SIC codes

SIC code	Manufacture	Construction	Human health and social work activities	Agriculture	Public administration.	Other service activities
C	70%					
Q			80%			
O					25%	
A				70%		
F		70%				
Other						40%

In the example, the five sectors selected to represent the main components of the economy account for approximately 90% of the total economy. To account for the missing 10%, the 'Other' sector is the difference between the total economy and the sum of the sectors defined explicitly in the analysis (i.e. Total aGVA – Sum of aGVA for the specified sectors). The percentage of the aGVA for this sector generated by the road network is also shown in Table 6-6. The base year for the data is 2017.

Table 6-7. aGVA for each SIC Category

SIC code	R1	R2	All Network
C	1,122	1,324	2,446
Q	785	926	1,711
O	671	791	1,463
A	637	751	1,389
F	486	573	1,059
Other	450	531	981
Total (Example)	4,152	4,897	9,049

6.1.8 Employment

Employment is modelled in a similar way to aGVA. The economic sectors are also allocated to Standard Industrial Classification (SIC) categories to show the employment for each sector. In the example, the allocation of each sector required only one SIC category but, as with aGVA, sectors may use more than one category.

Employment data is needed for each SIC code in the analysis and the total for all the economy in each region. However, the road network does not lead to all the employment for a sector and an estimate is needed for the percentage of the employment for the sector that is assumed to be dependent on the road network. The assumed share of each SIC category that is dependent on the road network in the example is shown in Table 6-8.

Table 6-8. Sector employment allocation to SIC codes

SIC code	Manufacture	Construction	Human health and social work activities	Agriculture	Public administration.	Other service activities
C	60%					
Q			30%			
O					70%	
A				65%		
F		30%				
Other						70%

The sectors selected to represent the main components of the economy account for approximately 85% of the total employment for the area. To account for the missing 15%, the ‘Other’ sector is used to show the difference between the total employment and the sum of the employment in the sectors defined explicitly in the analysis (i.e. Total employment – Sum of employment for the specified sectors). The percentage of this sector affected by the road network is more difficult to estimate but the allocation used in the example is also shown in Table 6-8. Table 6-9 shows the employment for each of the SIC categories considered in the example in the base year of 2019.

Table 6-9. Employment split by SIC code

SIC code	R1	R2	All Area
C	17,280	13,240	30,520
Q	1,560	1,960	3,520
O	19,720	24,120	43,840
A	15,920	19,600	35,520
F	7,720	11,200	18,920
Other	9,960	13,320	23,280
Total (All economy)	72,160	83,440	155,600

6.2 Network Benefits

In this example the network benefits analysis has been enabled and costs calculated. Data is needed to describe the alternative network (i.e. the network to which the traffic on the analysed base network is assumed to transfer to). The accident data (for 2019) used in the example analysis is shown in Table 6-10.

Table 6-10. Cost of accidents

Cost of a fatal accident on all roads	£1,745,879
Cost of a serious accident on all roads	£199,614

In HMEA, a single growth rate for the increase in the costs of accidents is used for all years of the analysis period (e.g. based on an average over the Analysis Period). An annual rate of 1.8% has been used for the example analysis.

Traffic for the alternative network in 2018 is shown in Table 6-11 and annual growth rates shown in Table 6-12. The same growth rates are used for all the road types on the alternative network and the same rates apply for all years of the analysis period.

Accidents on the alternative network in 2018 are shown in Table 6-13.

Table 6-11. Base year traffic on the alternative network

Road Type	Unit	Cars and Taxis	Motor Bikes	Light Vans	Goods Vehicles	Buses and Coaches	All motor vehicles
A Roads - Urban	Million vehicle km	1136	52	178	263	10	1639
A Roads - Rural	Million vehicle km	2489	210	447	94	21	3261
B Roads - Urban	Million vehicle km	384	105	94	5	5	593
B Roads - Rural	Million vehicle km	942	210	226	15	10	1403

Table 6-12. Annual traffic growth rates (%) for the alternative network

	Cars and Taxis	Motor Bikes	Light Vans	Goods Vehicles	Buses and Coaches
Growth rates	1.2	1.2	1.9	0.1	0.3

Table 6-13. No. of accidents on the alternative network in the base year

No. of fatal accidents on the alternative network	28
No. of serious accidents on the alternative network	322

Traffic on the analysed network is redistributed to different road types on the alternative network. In the example, the percentages for the redistribution of traffic to the roads in the alternative network are shown in Table 6-14.

Table 6-14. Redistribution of traffic from the base network to the alternative network

Base Network	Unit	Alternative network								
		A roads - Urban	A roads - Rural	B roads - Urban	B roads - Rural	C roads - Urban	C roads - Rural	U roads - Urban	U roads - Rural	Total
Motorway Urban	%	70		30						100%
Motorway Rural	%		70		30					100%
A roads - Urban	%	30		40		30				100%
A roads - Rural	%		30		50		20			100%

The speeds of traffic on the alternative network in the base year without any redistribution of traffic from the analysed network are shown in Table 6-15.

Table 6-15. Base traffic speeds on the alternative network

Alternative network	Unit	Cars	LGV	OGV1	OGV2	PSV
A roads - Urban	km/h	48	48	40	40	40
A roads - Rural	km/h	80	48	48	48	48
B roads - Urban	km/h	48	48	48	48	32
B roads - Rural	km/h	64	64	48	48	48
C roads - Urban	km/h	48	48	32	32	32
C roads - Rural	km/h	48	48	48	48	32
U roads - Urban	km/h	48	48	32	32	32
U roads - Rural	km/h	48	48	48	48	32

The ratio of the rate of carbon emissions on the alternative network compared to the analysed network is shown in Table 6-16.

Table 6-16. Ratio of vehicle emissions on the alternative network to the emissions on the base analysis network

Ratio of emissions between alternative network and base network - Urban	2.0
Ratio of emissions between alternative network and base network - Rural	2.0

6.3 Public Income

In this example the public income analysis has been enabled and costs are calculated for:

- Congestion charge
- Tolls

6.3.1 Congestion charge

In the example, the data is for 2019 and the congestion charge is applied for 5 days per week in both regions. For this example, the annual rate of growth of the number of vehicles is the same for all vehicle types in both regions. The charges per vehicle and the annual rate of growth in the charge per vehicle are also the same for all vehicle types in both regions. The data used in the example is shown in Table 6-17 and Table 6-18.

6.3.2 Tolls

The toll data describes the number of vehicles subjected to tolls in the base year (2019), the annual growth rate for the number of vehicles, the charge per vehicle (by vehicle type) and the annual increase in the charges are also specified. The data used in the example analysis is shown in Table 6-19.

Table 6-17. Congestion charges (No. of vehicles in the base year and annual growth rates)

Vehicle Type	Base year count and annua growth rate	Unit	R1	R2
Cars	Count	No/Day	12,000	15,000
	Count Growth rate (%)	%	1.0%	1.0%
LGV	Count	No/Day	4,500	5,000
	Count Growth rate (%)	%	1.0%	1.0%
OGV1	Count	No/Day	2,000	2,200
	Count Growth rate (%)	%	1.0%	1.0%
OGV2	Count	No/Day	750	780
	Count Growth rate (%)	%	1.0%	1.0%
PSV	Count	No/Day	1	1
	Count Growth rate (%)	%	1.0%	1.0%

Table 6-18. Charge per vehicle and annual rate of charge increase

	Unit	Cars	LGV	OGV1	OGV2	PSV
Charge per vehicle	£	11.50	11.50	11.50	11.50	11.50
Growth rate	%	2.0%	2.0%	2.0%	2.0%	2.0%

Table 6-19. Toll data for each vehicle type in each Region

Vehicle Type	Toll data	Unit	R1	R2
Cars	Count	No/Day	8,793	3,216
	Count Growth rate (%)	%	1.7%	1.7%
	Charge per vehicle	£	£1.50	£1.50
	Charge Growth rate (%)	%	1.5%	1.5%
LGV	Count	No/Day	355	427
	Count Growth rate (%)	%	1.7%	1.7%
	Charge per vehicle	£	£1.50	£1.50
	Charge Growth rate (%)	%	1.5%	1.5%
OGV1	Count	No/Day	1,777	2,011
	Count Growth rate (%)	%	2.7%	2.7%
	Charge per vehicle	£	£4.00	£4.00
	Charge Growth rate (%)	%	1.5%	1.5%
OGV2	Count	No/Day	1,244	1,389
	Count Growth rate (%)	%	1.1%	1.1%
	Charge per vehicle	£	£12.00	£12.00
	Charge Growth rate (%)	%	1.5%	1.5%
PSV	Count	No/Day	122	235
	Count Growth rate (%)	%	1.0%	1.0%
	Charge per vehicle	£	£20.00	£20.00
	Charge Growth rate (%)	%	1.5%	1.5%

6.4 Advanced settings data

In the example analysis the change in network condition impacts the economic and traffic growth rates through the analysis period. The size of the impact is determined by the change in the percentage of the network in poor condition (for each road type for the economic growth rates and for all road types on the network combined for traffic growth).

In the example, a maximum 10% change in the percentage in poor condition will also change the traffic and economic growth rates by 10%. No bigger changes are applied and less than 10% changes are applied pro rata.

6.5 Analysis results

It is emphasised that this is not a real example and the results are shown here as an example of how analysis results that may be obtained from real analyses.

HMEA outputs results as undiscounted and discounted costs using the discount rates specified as part of the input data. The results from the example analysis described in this Section are all given as costs discounted to the base year of the analysis. Costs are output from HMEA and HMAT in thousands of pounds and are shown in the same format in the results from the example analysis. Conversion to millions of pounds may present a more realistic level of reliability.

Table 6-20 shows the results from HMAT and HMEA for the example analysis. Removing the backlog and retaining the improved condition through the analysis period has increased the direct maintenance costs from the Current Budget scenario by more than three times. The increases are more than five times in region R1 and double in R2. However, the improved condition has also resulted in higher vehicle speeds that have increased the vehicle operating costs for the Backlog scenario and that has been the main driver in the increase in the indirect costs shown from HMAT. The higher speeds also resulted in lower travel time costs but higher vehicle emissions costs. With the increased maintenance, each of the costs associated with roadworks were increased for the Backlog scenario but with no change to the skidding and lighting accidents budgets, those costs were unchanged for the two scenarios. The changes in each of the regions were in the same direction (i.e. increases and decreases) but were bigger in region R1 than in R2.

For Network Benefits, the improved condition with the Backlog scenario resulted in higher traffic and economic growth rates which but with higher vehicle speeds. The effect was to reduce the change in accident costs compared to the alternative network but the increases in benefits from travel time and vehicle emissions costs, the overall network benefit was increased for the Backlog scenario.

The improved condition with the Backlog scenario increased the traffic growth rates and higher income from both the congestion and toll charges.

The improved condition generated improvements to the economy in terms of aGVA and tax receipts as the improved condition generated higher annual economic growth rates than when the network condition was at the level of condition in the base year of the analysis.

The HMEA Collator summarises the results of the example analyses shown in Table 6-20 and calculates the resulting measures of economic contribution.

Table 6-21 shows the results from the Collator that represent the two maintenance scenarios for all the network but the results for each region could be used in the Collator or the same calculations can be undertaken outside the Collator for each Region if required.

In the example, the Backlog maintenance scenario costs an extra £248,707k (discounted cost) over the analysis period, compared to the Current Budget scenario. The improved condition of the network for the Backlog scenario, that results in higher indirect costs for the network of £6,033,353k (from the HMAT analyses) which includes higher carbon costs of £403,921k. The improved condition, and the resulting higher growth rates, however more than offset the increase in indirect costs for the Backlog scenario to result in an overall Economic Benefit of £63.68 per one pound spent on the increased maintenance. The overall increase was not achieved by the increase in economic benefit from HMEA on its own but including the improved Network Benefits and income from the congestion and toll charges provided the overall benefit from the Backlog scenario.

The cells in the HMEA Collator showing the economic contributions resulting from the increased maintenance costs of the Backlog scenario are coloured green where the benefits over the analysis period overcome the increased cost and red when the increased direct costs are bigger than the component of economic benefit.

The Overall Economic Contribution from adopting the Backlog scenario on the road network, including the network benefits is high at more than £90 for every extra £1 spent on maintenance. The higher costs resulting from the HMAT analyses show there is no benefit from reductions in the indirect costs from the higher backlog spend but this is more than overcome by the benefits elsewhere.

Table 6-20 HMEA results for the example analysis (discounted costs)

		Backlog	Current Budget	Backlog		Current Budget	
		Total	Total	Region R1	Region R2	Region R1	Region R2
Expenditure by Treatment	£ k	354,655	105,948	207,469	147,185	40,813	65,135
Vehicle Operating Costs	£ k	73,754,839	67,475,684	32,210,572	41,544,267	28,976,696	38,498,988
Travel Time	£ k	17,132,570	17,806,093	7,654,433	9,478,137	7,834,029	9,972,064
Carbon (vehicle fuel)	£ k	2,635,317	2,236,969	1,103,793	1,531,524	927,150	1,309,820
Roadworks Accidents	£ k	4,280	1,780	4,054	226	1,078	702
Carbon (vehicles in roadworks)	£ k	164	137	34	130	10	127
Roadworks time delays	£ k	84,609	63,309	5,556	79,053	1,399	61,910
Accidents	£ k	2,611,376	2,611,376	1,442,730	1,168,646	1,442,730	1,168,646
Carbon (Embodied in materials)	£ k	8,134	2,589	4,807	3,327	997	1,591
Total Scenario HMAT costs	£ k	96,231,290	90,197,937	42,425,978	53,805,311	39,184,088	51,013,849
Change in accident costs	£ k	-758,621	-799,006	-710,883	-47,738	-730,662	-68,344
Change in travel time costs	£ k	7,467,677	7,318,489	3,110,091	4,357,586	3,041,337	4,277,152
Change in cost of CO_2 emissions	£ k	2,031,240	1,724,056	774,478	1,256,762	650,661	1,073,395
Total Network Benefits	£ k	8,740,296	8,243,539	3,173,686	5,566,610	2,961,336	5,282,203
Congestion charge	£ k	20,105,546	1,654,086	9,056,741	11,048,805	612,506	1,041,580
Tolls	£ k	4,307,728	346,107	2,239,165	2,068,563	150,837	195,270
Total Public Income	£ k	24,413,273	2,000,193	11,295,906	13,117,368	763,343	1,236,850
aGVA	£ k	131,565,593	127,480,186	60,358,006	71,207,587	58,284,677	69,195,508
Per Capita aGVA	£	25,675	25,033	25,307	25,996	24,608	25,400
Tax receipts	£ k	28,161,420	27,286,404	13,008,292	15,153,128	12,561,451	14,724,953
Total Economic Impacts	£ k	159,727,013	154,766,590	73,366,298	86,360,715	70,846,128	83,920,462

Much of the benefit from this example HMEA analysis is from the extra income arising mainly from the assumed toll charges. Nevertheless, the economic impacts of aGVA and tax receipts show the benefit of the improved network condition.

Table 6-21 Comparison of the scenarios in the HMEA example analysis

	Cost #	Backlog	Current Budget Base Case
Direct Cost: Maintenance	**£k**	354,655	105,948
HMAT Indirect Costs	**£k**	102,231,649	90,197,937
Total Carbon costs	**£k**	2,643,616	2,239,695
Network benefits	**£k**	8,740,296	8,243,539
Public Income	**£k**	24,413,273	2,000,193
Economic Impacts	**£k**	159,727,013	154,766,590
Overall Economic Contribution (EC)		63.68	
EC: HMAT + HMEA (Economic)		-28.44	
EC: HMEA (Excluding Economic)		43.73	
EC: HMEA (Excluding HMAT)		112.06	
EC: HMEA (Net Ben + Public Inc.)		92.12	
EC: HMEA (Economic)		19.94	
EC: HMAT		-48.39	
EC: HMEA (Network Benefit)		2.00	
EC: HMEA (Public Income)		90.12	

Discounted costs

The forecast changes in employment levels and the per capita aGVA are not shown in the HMEA summary table or the Collator but the improved condition with the backlog scenario resulted an increase in employment more than 20% higher[8] than with the current budget scenario. Table 6-22 shows the forecast changes in employment levels for the network and each region over the analysis period. Table 6-23 shows the forecast changes in per capita aGVA for the network and each region over the analysis period.

For actual analyses, more interpretation could be made but the results from the example analysis show the potential for the use of the HMEA analyses.

[8] The increase in employment over the analysis period with the Current Budget scenario was 25,929 and 31,723 with the Backlog scenario.

Table 6-22 Forecast employment levels for the example analysis

		Backlog	Current Budget	Backlog		Current Budget	
		Total	Total	Region R1	Region R2	Region R1	Region R2
Year 1	No.	95,972	95,972	44,674	51,298	44,674	51,298
Year 30	No.	127,695	121,901	59,435	68,621	56,471	65,430
Increase	No.	31,723	25,929	14,761	17,323	11,797	14,132

Table 6-23 Change in per capita aGVA for the example analysis

		Backlog	Current Budget	Backlog		Current Budget	
		Total	Total	Region R1	Region R2	Region R1	Region R2
Year 1	£	59,485	59,485	58,635	60,225	58,635	60,225
Year 30 (Discounted)	£	25,675	25,033	25,307	25,996	24,608	25,400
Year 30 (Undiscounted)	£	68,629	67,887	68,630	70,498	66,733	68,882
Increase (Undiscounted)	£	9,144	8,402	9,995	10,273	8,098	8,657

7 Data sources for HMEA

HMEA requires access to various datasets for the analyses, including data for the HMAT analyses and the forecasts of future network condition and maintenance. The data for HMAT and forecasts of future network condition and maintenance using the HMEP Toolkit or a separate analysis is generally available within the highway authority and published data as part of WebTag (DfT, 2013b) but the data for the economic analyses in HMEA is less commonly used in a highway authority. This Section therefore identifies some possible data sources that may provide relevant data for HMEA but it is recommended that checks are made to make sure locally available data (i.e. within a local authority) is not available for use in HMEA.

In general, the data for HMEA analyses can be provided from four areas:

Published data	Office of National Statistics (ONS) (e.g. tax, GVA, employment, etc), Transport Statistics (e.g. traffic, accidents, etc), other sources (e.g. carbon emissions from materials)
WebTag	Fuel data, future traffic levels and vehicle types, vehicle emissions data
Highway Authority	Network and maintenance data, traffic speeds
Default data	HMEA holds default data to test the significance and benefit of obtaining more reliable data

Appendix E contains data sources that may help with the provision of economic data for use in HMEA. The data sources are listed under the different parts of the HMEA analyses. The data sources are regularly updated so more recent versions may be available but the more recent data can, generally, be accessed through the links listed.

Section 10 also contains references to documents that may lead to new data sources. The sources listed Appendix E refer to data available at the time of developing HMEA and other sources, as well as more recent data, may be available for use in HMEA.

For the economic impact analysis, where possible, published data is used. Where no data is available, assumptions can be made that specifically relates to the sectors or activities under consideration. Where data used in the model is derived from more than one economic sector then the derived data is referred to as "adjusted" values (e.g. adjusted employment). The adjusted data is shown in the economic impacts worksheet below the input data.

It is important that the base year for each dataset is provided as part of the data input so the analysis can normalise the timing of different datasets and the analysis results are aligned to the base year used for the condition and maintenance impacts analyses. If necessary, each cost component is aligned using the annual growth rate specified for each component.

8 HMEA results interpretation

HMEA can be applied to national or local road networks and estimates the based on the maintenance scenarios investigated. It is therefore not possible to set a firm expectation of the benefits likely to be seen from the possible analyses.

The early stages in the development of the HMAT model to assess the wider impacts of maintenance showed benefits of nearly £3 can be obtained for every extra £1 spent on maintenance (Buckland T, Parkman C, Booth C and Abell R, 2015). A later study for Transport Scotland, as part of the National Maintenance Review for Scotland, showed that maintenance spend on the road network (local roads and Trunk Roads) provides benefits of £1.50 for every extra £1. That analysis did not include all the benefits identified in HMAT or HMEA.

More recent studies for local roads in England using HMAT have shown for each additional £1 spent on carriageway maintenance to retain the Steady State condition gives a saving of £4.20 in the overall indirect costs.

Another study for Transport Scotland to assess the value of the Trunk Road network in Scotland (Peeling J, Palmer D, Booth C, Abell R, 2016) showed the road network contributes £1.38 billion in Approximate Gross Value Added (aGVA) each year (i.e. Per capita aGVA of £44k), generates £358 million in tax receipts and leads to employment for 31,000 people (1.2% of all Scotland). There were also benefits from reduced journey times, vehicle emissions and fewer accidents. Local Authority road networks will not generate the same value or impacts on the local economy but it is important that these wider benefits from the road network are taken into account when identifying the best maintenance scenarios to adopt.

These earlier studies did not include any other public income (e.g. the congestion charge and tolls included in HMEA) and took no account of changes in road condition impacts on expected traffic and economic growth rates.

A key part of the use of HMEA is assessing the sensitivity of the initial results from scenario comparisons to changes in key parameters. Finding how sensitive the results are to changes in the data shows the robustness of the benefits analyses and brings confidence to the strength of the benefits case for maintenance scenarios.

9 Abbreviations

ADEPT	Association of Directors of Environment, Economy, Planning & Transport
aGVA	Approximate Gross Value Added
AST	Appraisal Summary Table
BCR	Benefit-Cost Ratio
CBA	Cost Benefit Analysis
CEA	Cost-Effectiveness Analysis
DfT	Department for Transport
DPMTAG	Development Planning and Management Transport Appraisal Guidance
FYRR	First Year Rate of Return
GVA	Gross Value Added
HDM	Highway Development and Maintenance model
HEAT	Harmonised European Approaches for Transport costing and project assessment
HMAT	Highway Maintenance Appraisal Tool
HMEA	Highway Maintenance Economic Assessment
HMEP	Highways Maintenance Efficiency Programme
IRR	Internal Rate of Return
LATIS	Land-Use and Transport Integration in Scotland
MCA	Multi-Criteria Analysis
NIC	National Insurance Contributions
NPV	Net Present Value
PESTLE	Political, Economic, Social, Technological, Legal and Environmental
RED	Roads Economic Decision model
Scot-TAG	Scottish Transport Assessment Guidance
SIC	Standard Industrial Classification
STAG	Scottish Transport Assessment Guidance
TfL	Transport for London
VAT	Value Added Tax
VOC	Vehicle Operating Costs
VPD	Vehicles per Day
WebTAG	Web-based Transport Appraisal Guidance
WelTAG	Web-based Transport Appraisal Guidance (WebTAG)
WSRN	Wales Strategic Road Network

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Appendix A Quantitative economic analysis methods

A.1 Cost-Benefit Analysis (CBA)

Many quantitative transport economic assessment techniques are based on cost benefit analysis (CBA). CBA is a systematic process for calculating and comparing the benefits and costs of a proposed project or investment. CBA focuses primarily on quantifying the impact on economic welfare. It has two purposes:

1. To determine if a proposal is a sound investment/ decision (i.e. the justification for/ feasibility of the decision); and
2. To provide a basis for comparing projects. This involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much.

It is commonly applied to the *ex-ante* assessment of road investments, both of completely new highways as well as improvements to existing ones. It involves identifying all potential benefits and costs of a proposal and measuring these using monetary metrics. Furthermore, it is not always possible to monetise all impacts and therefore non-monetised variables can sometimes be presented separately to complement the BCR.

The benefit-cost ratio (BCR) summarises the overall value for money of an investment or proposal. The ratio is the benefits from the investment, expressed in monetary terms, relative to its costs (also expressed in monetary terms). The higher the BCR the better the return on the investment. However the BCR can be misleading as a small project may generate significant benefits so it has a very high BCR while a large project may generate a lot more benefits but since its cost is also very high its BCR may be relatively low.

A related concept is the Internal Rate of Return (IRR). This is a measure of an investment's rate of return. The term internal refers to the fact that the IRR excludes external factors, such as inflation, the cost of capital, or various financial risks.

Future costs and revenue streams can be discounted to the present day using a discount rate to ascertain the Net Present Value (NPV) of the investment. NPV represents the preference between the value of consumption today and consumption in the future (i.e. it is a social time preference rate or social discount rate. A higher discount rate suggests that impacts some years hence are not valued as highly as those in the near future.

A.2 Cost-effectiveness Analysis (CEA)

Cost-effectiveness analysis (CEA) compares the relative costs and outcomes (impacts) of different courses of action. CEA is distinct from CBA, which assigns a monetary value to the measure of an impact. CEA is often used in health studies, where it may be inappropriate to monetise the health effect. In health studies typically the CEA is expressed in terms of a ratio where the denominator is a gain in health from a measure (for example, years of life extended, premature births averted, and sight-years gained etc) and the numerator is the cost associated with that health benefit.

In CEA benefits are not monetised. However, specific benefits or beneficiary populations are identified and these are quantified using an appropriate metric. What cannot be done, especially in the case of some rural road projects or access roads which lack traffic upon which to base traditional calculations of benefits, is to express those benefits in monetary values.

Quantification of proxy benefit categories can be carried out (e.g. population in the road area of influence or costs/km).

CEA aims to select the cheapest (most cost-effective) method of attaining given objectives, while CBA selects the project with the highest ratio of benefits to costs or benefits surplus (difference between total gains and total expenditures). Unlike in CBA, a CEA index does not indicate an 'opportunity cost'[9], so that projects cannot be ranked confidently against other projects. Ranking can be undertaken but it requires a policy decision or 'judgement'.

Other ways to implement CEA with regard to roads is to link the cost to other performance criteria which are a proxy for benefits without resorting to estimating the benefits, especially on low traffic volume roads.

A.3 PESTLE analysis

PESTLE analysis (political, economic, social, technological, legal and environmental) gives an overview of the different macro factors to be taken into consideration in an investment decision. It is concerned with providing an ex ante overview of the likely impacts. A PESTLE analysis assesses the likely impact of possible measures and any constraints to their implementation. PESTLE analysis comprehensively and systematically reviews the impact of a strategy across six main areas of interest:

- **Political factors** relate to how the government intervenes in the economy – the areas in which politics has an impact. Political factors include decisions regarding infrastructure investments, tax policy, labour laws, environmental laws, tariffs, etc.
- **Economic factors** include economic growth, employment generation, finance, interest rates, income distribution, inflation rates etc. These factors greatly affect how businesses operate and make decisions.
- **Social factors** include health and education impacts, age distribution, safety impacts, poverty reduction etc. For example, an ageing population may imply a smaller and less-willing workforce (thus increasing the cost of labour).
- **Technological factors** include technological aspects like R&D activity, automation, technology incentives and the rate of technological change. These can determine barriers to entry, efficient production levels etc. Technological impacts affect costs, efficiency, quality, and innovation.

[9] The opportunity cost of making a particular choice is the value of the most valuable choice out of those that were not taken. When an option is chosen from two mutually exclusive alternatives, the opportunity cost is the "cost" incurred by not enjoying the benefit associated with the alternative choice.

- **Legal factors** include health and safety law, employment law, etc. These factors can affect costs, employment regulations etc.
- **Environmental factors** include ecological and environmental impacts such as climate change, landscape degradation which may especially affect industries such as tourism, farming, and insurance.

PESTLE may, but may not, include metrics to indicate the impact of a particular course of action. Often it involves a subjective assessment of the likely impact of a decision and may therefore not provide an independent or objective point of view. It could be applied to the *ex-ante* appraisal of road investments but may not provide a robust impact evaluation approach. Due to its high-level approach it is not suitable for highway maintenance expenditure.

A.4 Gross Value Added (GVA)

Gross Value Added (GVA) is defined as the value generated by any unit engaged in the production and the contribution of individual sectors or industries to GDP. GVA plus taxes (less subsidies) on products is equivalent to Gross Domestic Product (GDP). Regional estimates of GVA are usually measured using the income approach, summing income generated by resident individuals or corporations in the production of goods and services (ONS, 2016b). Total GVA estimates are divided by the resident population to calculate per capita GVA. This can be useful for comparing regions of different sizes, provided there are no large commuting flows into or out of the regions.

GVA can also be applied to understand the contribution of different economic sectors. Some components of GVA include Gross Trading Profits and Surplus, estimates of total Gross Operating Surplus and rental income (ONS, 2016a). GVA calculations are generally more appropriate for sectoral analysis (e.g. construction or freight distribution) or regional analysis. These components are summed to form estimates of GVA. Undertaking a full and complete GVA approach requires significant data input. Some of the data required is available in Wales and estimates of GVA are published (e.g. Wales Government, 2018).

The economic footprint of road investment involves two types of impact:

- Direct – measures the economic value of activities and outputs of road construction and maintenance (i.e. the resources used to deliver a new or improved road, including employment); and
- Indirect – measures the economic value of resources to the domestic supply chain (i.e. within Wales) used by the road sector to undertake its activities.

Wider economic benefits (e.g. economies of agglomeration [10], congestion reduction and modal shift to road from rail) can also be calculated.

[10] Economies of agglomeration are cost savings arising from urban agglomeration. One aspect of agglomeration is that firms are often located near to each other giving access to wider markets.

A.5 Harmonised European Approaches for Transport Costing and Project Assessment (HEAT)

Harmonised European Approaches for Transport Costing and Project Assessment (HEAT) is a set of harmonised guidelines for project assessment and transport costing on the EU level in the following areas:

- Value of time and congestion
- Value of accident risk reduction
- Costs from health impacts and of pollution and noise
- Wider economic effects (i.e. indirect effects, infrastructure costs)
- General CBA aspects (e.g. inter- and intra-generational distribution, risk and uncertainty)

HEAT is based on a review of appraisal methods internationally. It involves undertaking surveys for selected impacts but is based on CBA. It includes a variety of data: construction related costs such as the disruption from construction, system operating costs and maintenance, user benefits and vehicle operating costs, the value of travel time savings, reliability, congestion and service quality, user charges and revenues, safety impacts, many of which are monetised impacts. Environmental impacts such as noise impacts are also included.

A particular feature is the concept that an appraisal methodology should provide a level playing field for appraisal work which takes place at a decentralised level and across transport modes and location types. An appraisal methodology will be relatively highly codified while the decisions themselves are more judgement based.

The international review of appraisal method concluded that WebTAG (see below) remains the leading model of open documentation of appraisal guidance and is frequently used as a benchmark by different countries (Mackie and Worsley, 2013).

A.6 Multi-Criteria Analysis (MCA)

For most projects the use of single criterion for evaluation is insufficient since it is difficult to capture all benefits and costs, reduce them to monetary values and represent them by an indicator such as annual cost, NPV, IRR, etc. (These are all similar because they represent the maximisation of net benefits).

However, many of the items in a ‘social accounting balance sheet’ relate to non-measurable costs and benefits, requiring non-monetary metrics. These are either measured in physical or time units or, where they cannot be quantified in any way, are listed as intangibles. Often when several alternative public investments are under consideration each scheme can be ranked in terms of progress towards instrumental objectives [11] such as minimizing resettlement, maximizing school attendance, public health indicators etc.

Quantifiable monetary costs and benefits can be easily incorporated into economic analyses but to account objectively for those policy objectives that cannot, a Multi-Criteria Analysis (MCA) is often employed. A MCA takes into account both the effects that are valued in monetary terms and other effects that are not.

Since the monetary and non-monetary effects of a project cannot be added together directly (because of a lack of a common metric), MCA usually places a weighting factor on the individual effects. If, for example, such a list were to include ‘reductions in accidents’ and ‘scenic beauty’ and if the former were deemed more important than the latter, then they would be weighted with a higher factor so that the allocated ‘score’ would count for more in the final summing up. Thus, the various benefits/ impacts are summed up in their ‘weighted’ form. The aggregate number of points that each project receives is computed by simply adding the ‘weighted’ points allocated per objective.

A.7 Web-based Transport Appraisal Guidance (WebTAG)

The Web-based Transport Analysis Guidance (WebTAG) is the UK Department for Transport’s (DfT) transport appraisal guidance and toolkit (Department for Transport, 2013b). It consists of software tools and guidance on transport modelling and appraisal methods that are applicable for highway interventions. These facilitate the appraisal and development of interventions, enabling analysts to build evidence to support the business case development, to inform investment funding decisions. WebTAG is one form of MCA.

Development of analysis using WebTAG guidance is a requirement for all interventions that require UK government approval or finance. The transport appraisal process is about options generation, development and the evaluation of intervention impacts.

WebTAG is developed based on the HMTreasury Green Book (HM Treasury, 2011) that sets out the framework for appraisal and evaluation for all policies, programmes and projects. This constitutes binding guidance on all UK Government departments and executive agencies. This ensures that interventions from different departments are directly comparable, even if the detail of the analytical techniques used to estimate impacts varies.

The business case approach applied in WebTAG shows if schemes:

- Are supported by a robust case for change that fits with wider public policy objectives – the ‘strategic case’
- Demonstrate value for money – the ‘economic case’
- Are commercially viable – the ‘commercial case’
- Are financially affordable – the ‘financial case’

[11] Instrumental objectives should include both (a) the kind of behavioural outcomes expected and (b) the content. http://www.yourarticlelibrary.com/statistics-2/stating-instrumental-objectives-10-main-principles/92643

- Are achievable (i.e. deliverable) – the ‘management case’

To ensure that decision-makers are always presented with a full account of the impacts, all the impacts (monetised, quantified and qualitative wherever feasible) are summarised and presented (Department for Transport, 2013) in the form of an Appraisal Summary Table (AST). WebTAG gives advice on the appraisal of the social impacts and distributional impacts of transport interventions. Reliability impacts on commuters and other users, access to services, severance, and affordability are also addressed. WebTAG therefore covers a wide range of impacts, not only the economic effects.

To assess value for money, the monetised impacts are summed to establish an initial benefit-cost ratio, which implies an initial value for money band (i.e. poor, low, medium, high, or very high). This band is then adjusted to account for impacts where qualitative or quantitative, but not monetised, information is available. This ensures that the value for money assessment of a proposal considers all its impacts, not just those which are monetised.

In the UK context a wide range of impacts are considered, as shown in Table A7-1.

A.7.1 Welsh Transport Appraisal Guidance (WelTAG)

The Welsh Transport Appraisal Guidance (WelTAG) (Wales Government, 2017a) is based on WebTAG and provides a framework for proposed changes to the transport system. It contains best practice for the development, appraisal and evaluation of proposed transport interventions in Wales. It was developed by the Wales Government to ensure that public funds are invested in a way that ensures they maximise contribution to the well-being of Wales. The guidance is intended to be applied to all transport strategies being promoted/ requiring funding from the Wales Government. WelTAG replaced the interim guidance STAG (Scottish Transport Appraisal Guidance) (see below), that was the practice in Wales. Prior to NATA (New Approach to transport Appraisal), appraisal of proposals was largely an economic exercise based on monetised benefits and costs, notably within a cost-benefit analysis framework.

It focusses on sustainable development which is a fundamental part of how public bodies must operate. All transport interventions in Wales must consider the needs of future generations as well as the present. The principle of sustainable development is made up of five ways of working that public bodies are required to follow:

- Looking to the long term so that we do not compromise the ability of future generations to meet their own needs
- Understanding the root causes of issues to prevent them from occurring or getting worse
- Taking an integrated approach so that public bodies look at all the well-being goals in deciding on their well-being objectives
- Involving a diversity of the population in the decisions that affect the
- Working with others in a collaborative way to find shared sustainable solutions

Table A7-1 Impacts included in WebTAG

Category	Impacts
Economy	Business users & transport providers
	Reliability impact on Business users
	Regeneration
	Wider Impacts
Environmental	Noise
	Air Quality
	Greenhouse gases
	Landscape
	Townscape
	Historic Environment
	Biodiversity
	Water Environment
Social	Commuting and Other users
	Reliability impact on Commuting and Other users
	Physical activity
	Journey quality
	Accidents
	Security
	Access to services
	Affordability
	Severance
	Option and non-use values
Public Accounts	Cost to Broad Transport Budget
	Indirect Tax Revenues

WelTAG fits with the HM Treasury Green Book and the five case model for better business cases as set out in WebTAG. WelTAG is applicable to all transport interventions, regardless of the transport modes affected and links to mode-specific transport guidance, such as the Design Manual for Roads and Bridges (DMRB) guidance for highway schemes. It comprises five stages:

1. Strategic Outline Case
2. Outline Business Case
3. Full Business Case

4. Implementation
5. Post Implementation

The transport case is an evidence based assessment of:

- What the impacts will be
- The scale of those impacts
- Where and when the impacts will occur
- Who/what will experience the impacts

A WelTAG appraisal should consider the wide range of current impacts caused by the intervention under examination, the likely impacts into the future if no action is taken, the difference that the proposed intervention would make now and in the long term, and any other impacts that are likely to result from the implementation of the proposed solution.

The significance and scale of the impacts of each option should be presented using a seven-point scale, as follows:

- Large beneficial (+++)
- Moderate beneficial (++)
- Slight beneficial (+)
- Neutral (0)
- Slight adverse (-)
- Moderate adverse (- -)
- Large adverse (- - -)

The detailed evidence, data and analysis underlying the statements made in the WelTAG Stage reports are presented in a separate document known as the WelTAG Impact Assessment Report (IAR).

A.7.2 Scottish Transport Assessment Guidance (Scot-TAG)

STAG is part of Scottish Transport Analysis Guide (Scot-TAG) (Transport Scotland, 2008) which is based on WebTAG and provides transport practitioners working on Scottish-based transport projects, with access to the latest information and guidance that they will need when developing and assessing transport schemes and strategies.

Scot-TAG serves as the gateway to:

- Land-Use and Transport Integration in Scotland (LATIS) (Transport Scotland, 2017)
- Scottish Transport Appraisal Guidance (STAG) (Transport Scotland, 2008)
- Development Planning and Management Transport Appraisal Guidance (DPMTAG) (Transport Scotland, 2009)

STAG sets out a structure and methodology drawn from UK and European sources and is supported by a Technical Database which provides detailed advice on the application of the individual elements of STAG. STAG involves the appraisal of generated options which could potentially address identified problems and opportunities against a range of criteria, including value for money. STAG ensures that potential options to address evidenced-based transport problems or opportunities are identified and appraised in a consistent manner.

STAG is objective-led rather than solution-led which avoids pre-conceived solutions being brought forward without considering other options which may meet the identified problem or opportunities. It provides best practice transport appraisal guidance to be used to find transport solutions to identified or perceived transport problems and opportunities using an evidence base.

The STAG criteria are:

- Environment
- Safety
- Economy
- Integration
- Accessibility and Social Inclusion

The STAG Criteria provide a framework to ensure all impacts are considered, and practitioners should not begin the process of formulating Transport Planning Objectives by considering only the national objectives. This could dilute the importance of local objectives or the inclusion of issues which, for the transport planning context in question, are not relevant. The Appraisal requires a summary of the following:

- Geographical Context – a general statement describing the geographic area likely to be affected by the option
- Social Context – a summary of the social makeup of the area likely to be affected by the option
- Economic Context – a description of the principal sectors and industries within the study area as well as a summary of factors affecting performance

The appraisal must also assess the feasibility, affordability and public acceptability of each option. Practitioners must consider:

- **Feasibility** – a preliminary assessment of the feasibility of construction or implementation and operation (if relevant) of an option and the status of its technology (e.g. proven, prototype, in development, etc.) as well as any cost, timescale or deliverability risks associated with the construction or operation of the option, including consideration of the need for any departure from design standards that may be required
- **Affordability** – the scale of the financing burden on the promoting authority and other possible funding organisations and the risks associated with these should be considered together with the level of risk associated with an option’s on-going operating or maintenance costs and its likely operating revenues (if applicable)

- **Public Acceptability** - the likely public response is of importance at this initial appraisal phase and reference to supporting evidence, for example results from a consultation exercise must be provided where appropriate

The information gathered forms an Appraisal Summary Table (AST). As part of a STAG study an Evaluation Plan should be developed to outline how Evaluation will be undertaken following implementation. It is expected the Evaluation Plan would consider the following:

- **Process Evaluation** - this is conducted at an early stage in the existence of a project and which is primarily concerned with how well the project has been implemented, this is also known as formative Evaluation
- **Outcome Evaluation** - this is conducted once the project has been in existence for a sufficient period to enable an examination to be undertaken of actual performance against identified targets

The outcome evaluation should look for clear and measurable outcomes from the project. The timing of an outcome evaluation needs to be carefully programmed. If undertaken too soon, final impacts may not have had time to 'work through', but if undertaken too late, resources will be wasted if the project is not efficient or effective.

Outcome evaluations are intended to answer questions such as 'what is the extent of the identified outcomes, and what were the costs of achieving this?' and, where comparisons can be made with similar projects, 'do these resources and outcomes together represent value for money?'.

The process used in an outcome evaluation may be set out as a series of sequential steps:

- Definition of scope and purpose
- Project rationale
- Aims and objectives
- Measures and indicators
- Base case for comparison
- Analysis and interpretation
- Reporting and recommendations

A.8 Highway Development and Maintenance model (HDM-4)

The Highway Development and Maintenance (HDM-4) (HDM Global, 2004) is a software system for evaluating options for investing in road transport infrastructure. Created by the Word Bank, the HDM-4 model is most commonly used as a basis for feasibility studies, in which a road project is evaluated in terms of its economic viability. The main purpose of the HDM-4 model is to provide a consistent framework for analysis of road investments and maintenance strategies at planning, programming and more detailed project preparation stages.

In a conventional economic analysis of potential road investments, such as that performed by HDM-4, streams of combined road works (or ‘agency’) costs and road user costs (RUC) are compared for two or more alternative investment strategies. The potential savings in road user costs may be regarded as the 'benefits' of a superior strategy to be set against the (additional) 'costs' of required works, compared with an alternative (base) strategy. The HDM-4 model is typically used in developing countries and can be applied in a range of circumstances:

(1) Upgrading from earth or gravel surfaces to paved road.

(2) Alignment and other improvements, including widening, to paved roads.

(3) Rehabilitation of road pavements.

(4) Upgrading (typically dualling) of major roads - e.g. from 2 to 4 lanes.

(5) Low cost improvements to minor rural roads with low volumes.

(6) New bypasses or relief roads in or around major urban areas.

(7) Periodic maintenance and rolling programmes on paved road networks.

(8) Strategic analysis for complete networks to support budgeting and policy

Since the model simulates future changes to the road system from current conditions, the reliability of the results is dependent upon two primary considerations:

(i) How well the data in the model represents the reality of current conditions and influencing factors, in the terms understood by the model; and,

(ii) How well the predictions of the model fit the real behaviour and the interactions between various factors for the variety of conditions to which it is applied.

Application of the model thus involves two important steps:

- Data input – A correct interpretation of the data input requirements, and achieving a quality of input data that is appropriate to the desired reliability of the results; and,
- Calibration of outputs – Adjusting the model parameters to enhance how well the forecast and outputs represent the changes and influences over time and under various interventions.

Calibration of the HDM-4 model focuses on the two primary components that determine the physical quantities, costs and benefits predicted for the analysis, namely:

- Road Deterioration and Works Effects (RDWE) (see below) – comprised of the deterioration of the pavement and the impact of maintenance activities on pavement condition and the future rate of pavement deterioration; and,
- Road User Effects (RUE) – comprising vehicle operating costs (VOC[12]), travel time, safety and emissions.

There are three levels of calibration for HDM, which involve low, moderate and major levels of effort and resources, as follows:

[12] VOC refers to changes in the costs of owning and operating vehicles and are counted as benefits or disbenefits.

(i) Level 1 – Basic Application: This determines the values for basic input parameters, adopts many default values, and calibrates the most sensitive parameters with best estimates, desk studies or minimal field surveys.

(ii) Level 2 – Calibration: This requires measurement of additional input parameters and moderate field surveys to calibrate key predictive relationships to local conditions. This level may entail slight modification of the model source code.

(iii) Level 3 – Adaptation: This undertakes major field surveys and controlled experiments to enhance the existing predictive relationships or to develop new and locally specific relationships for substitution in the source code of the model.

A.9 Road Deterioration and Works Effects (RDWE) Adjustment Factors

The HDM-4 flexible pavement Road Deterioration and Works Effects (RDWE) models have six deterioration adjustment factors. The list below gives the impact elasticity[13] class, typical ranges of values and the net impact for each of the six factors.

Criteria:

1. Amount of cracking
2. Rut depth
3. Roughness
4. IRR for patching
5. IRR for reseal
6. IRR for overlay

Impact sensitivity:

A = S-I (High impact, S > 0.5)

B = S-II (Moderate impact, 0.2 – 0.5)

C = S-III (Low impact, 0.05 – 0.2)

D = S-IV (Negligible impact, < 0.05)

The roughness-environment factor is the most important, due to the wider range of its values, followed by the cracking initiation and progression factors. The general roughness progression factor has low priority, despite its moderate sensitivity, because its range is small based on many inter-country validation studies. These adjustments can be grouped into two classes:

- High impact
- Low impact

[13] Elasticity: Measurement of how an economic variable responds to a change in another (i.e. the responsiveness).

It is recommended that at least the high impact factors require calibration to the local conditions on priority. HDM-4 V2 (HDM Global, 2004) models allow more specific adaptation based on local materials and condition by increasing the number of calibration factors for model adjustments from 6 to 20.

The Guideline recommends the adoption of HDM-4 default values except for parameters which are considered to be "sensitive" and are included in Level 1 calibration.

A.10 Roads Economic Decision Model (RED)

The RED model (World Bank, 2009) is a consumer surplus[14] (CS) model to help evaluate investments in roads with traffic volumes between 50 and 200 vehicles per day. The model estimates vehicle operating costs and speeds, performs economic comparison of the alternatives, and compares some maintenance options, calculates switch values, and finally (if desired) performs a stochastic risk analysis.

RED was designed as a simplified economic evaluation model alternative to HDM-4, with only few input parameters that are not considered demanding to collect, to assist agencies in planning and programming of works for low-volume roads. RED provides an approach for progressing the decision-making process with regard to the improvement, development and maintenance of low-volume roads.

The model carries out comparisons of alternative investment and maintenance options once basic VOC and road agency cost data has been input. It is a static model in the sense that traffic does not interact with initial road conditions and vice versa. Since traffic volumes are low and often study budgets are small using the full HDM-4 model would be inefficient.

RED calculates a whole range of decision criteria such as NPV, IRR, BCR, FYRR[15], etc. In addition, since with low volume roads some variables can greatly affect the outcome there is a built-in ability to carry out sensitivity analysis, switching value analysis[16] and stochastic risk analysis[17] whereby a range of outcomes is computed.

RED is a simplified version of HDM-4 but it still carries out sophisticated economic evaluation but at the same time addresses some concerns that were evident with HDM-4 in relation to low volume roads.

The specific advantages of RED are:

a) Reduces the input/data requirements

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[14] Consumer surplus is the difference between the maximum price a consumer is willing to pay and the actual price they do pay. If a consumer would be willing to pay more than the current asking price, then they are getting more benefit from the purchase than they initially paid.

[15] First Year Rate of Return

[16] Switching value is the value of the variable at which the project investment decision is changed. Usually it is defined as the percentage change from the base case.

[17] Stochastic risk analysis is used for estimating errors and small probabilities when the observables are averages of a large quantity of independently acting agents or extremes of observations.

b) Takes into account the higher uncertainty related to inputs especially when traffic is low

c) Computes generated traffic based on a defined price elasticity of demand to which induced traffic can also be added – that is private trips are separated from additional traffic due to some agricultural or industrial process

d) Can use vehicle speeds as a surrogate parameter for road roughness to define the level-of-service of low-volume roads

e) Makes provision for road accident reduction benefits

f) Makes provision for the inclusion of other cost and/or benefit categories especially for non-motorised traffic, social services, environmental impacts, etc.

g) Provides an extensive provision for rapid sensitivity, switching value and risk analysis

Like HDM-4 RED is best used for road investment appraisal when base year traffic is between 50-200 vpd[18]. Induced agricultural producer surplus can be evaluated as an 'add-on' benefit if necessary. This can be done by examining additional value in percentage terms e.g. 0.5%, 1%, 2% etc and evaluating the likelihood given the value of current output.

Instead of in-built predictions for annual road condition as in HDM-4, the RED model uses the concept of average levels of service for low volume roads because:

1. Convenience in defining levels of service for low-volume roads with parameters other than average annual roughness and gravel thickness
2. Difficulty in measuring or estimating the roughness of unpaved roads and determining the grading frequency to be applied to unpaved roads
3. Seasonal change in road condition and pass ability
4. Cyclical nature of the road deterioration under a full-scale maintenance policy. Also, other benefits such as those related to non-motorized traffic, social service delivery, and environmental impacts, can be included in the analysis.

The RED Risk Analysis Module (RAM) performs a risk analysis based on triangular probability distributions for the main input parameters. Model users define the estimate of an input variable and some measure of the likelihood of occurrence for that estimate, taking the form of a triangular probability distribution.

The risk analysis module analyses every possible outcome, by executing many "what-if" scenarios. The user may specify how many scenarios. In each scenario random inputs following the defined probability distributions are generated, and the frequency distributions are presented in a graph, together with statistics for the outputs (e.g. minimum, maximum, average, standard deviation and the median rate of return). It also generates the:

- Rate of return percentile for three percentile options; and the
- Probability that the rate of return is less than or greater than a certain value.

[18] Vehicles per day

This is intended to address the fairly high level of uncertainty which is often present in economic analysis of low-volume roads. RED is particularly used in developing countries but does not have the capability to input a wide range of maintenance options.

HDM-4 is much more refined (although more demanding in user time). With HDM-4 a series of different maintenance options, with a wide range of values for interventions (either fixed time intervals, or responsive – triggered by different condition parameters) can be input, and then results examined. More detailed unit costs can also be input.

Additionally, the RED model has no prediction equations for road deterioration (with motor traffic and weather) over time. The user makes an exogenous assumption on the average level of service for a given period in the future. With HDM-4 the need to make possibly assumptions about future levels of roughness (or other road distress conditions) is avoided. A series of refined deterioration models, for unpaved, asphalt and concrete roads, in a wide variety of climates, are built into HDM-4, and it is preferable when possible to make use of these.

A.11 Highways Maintenance Efficiency Programme (HMEP) Lifecycle Planning Toolkit

A Framework for Highway Infrastructure Asset Management (HMEP) has been introduced setting out the activities that support asset management:

- Context of asset management
- Asset management planning process
- Enablers to support implementation of asset management

Guidance supports local highway authorities in the development and implementation of highway infrastructure asset management, in order to deliver the potential benefits, including efficiencies that can be gained by taking a long term view. The purpose of the Guidance is to:

- Establish a framework to enable development of asset management
- Provide advice for authorities to interpret the requirements of asset management
- Promote good practice through a common framework for highway infrastructure asset management
- Support efficiency in the delivery of highway maintenance
- Embed the learning from practical application of asset management
- Enable quick and consistent progress to be made

The Guidance covers all highway infrastructure assets in the ownership of local highway authorities. There will be assets that some authorities consider appropriate to include as highway infrastructure assets, whilst others may consider them as part of other management arrangements, for example, public rights of way.

Asset management comprises the whole lifecycle of an asset from construction, through maintenance, to disposal. This Guidance concentrates on the management and maintenance aspects of highway asset management since these are generally the most relevant aspects for authorities.

Some infrastructure assets connected with the highway may be managed by other authorities, depending on the local government arrangements in place in the area. For example, in two tier authorities, street furniture could be the responsibility of the District Council, whilst the County Council is responsible for the highway. It is for individual authorities to determine how they manage their assets, but the approach in the Guidance can be applied to a wide range of assets.

HMEP is a sector-led transformation programme to maximise returns from investment in highways and deliver efficient and effective highway maintenance services.

HMEP includes:

- Lifecycle planning toolkit
- Support and training for the implementation of lifecycle planning
- Deterioration model for bituminous carriageways
- Guidance on drainage asset management
- Collaboration toolkit
- Shared services toolkit

Appendix B Results of the literature search

B.1 Previous review results

The previous literature review (for Transport Scotland) has been updated and below are the results that were considered relevant to the development of HMEA. The references highlighted in Green are the principal research studies that have added to the discussion in Section 3 of the report. The numbers refer to the reference in the report for Transport Scotland (Peeling J, Palmer D, Booth C, Abell R. 2016).

#	Author	Title	Year	Link
1	Transport Scotland	National Transport Strategy - January 2016	2016	https://www.transport.gov.scot/our-approach/strategy/national-transport-strategy/#
5	Litman, T.	Generated traffic and induced travel	2019	http://www.vtpi.org/gentraf.pdf
10	World Road Association	Preserve your country's roads to drive development	2016	http://www.piarc.org/en/order-library/24521-en-Preserve%20your%20Country-s%20roads%20to%20Drive%20Development.htm
17	National Assembly for Wales Public Accounts Committee	Value for money of motorway and trunk road investment	2015	http://www.assembly.wales/laid%20documents/cr-ld10271/cr-ld10271-e.pdf
31	Visit Scotland	Tourism development framework in Scotland - role of the planning system in delivering the visitor economy	2016	https://www.visitscotland.org/about-us/what-we-do/our-plans/tourism-development-framework
35	Parkman, C, Bradbury, T, Peeling, D, Booth, C.	Economic, Environmental and Social Impacts of Changes in Maintenance Spend on Local Roads in Scotland	2012	"The Value of the Trunk Road Network to Society and the Economy in Scotland", CPR2339, TRL, Wokingham, England. Prepared for Transport Scotland.
49	Welsh Assembly Government	Welsh Transport Planning and Appraisal Guideline	2017	https://gov.wales/welsh-transport-appraisal-guidance-weltag

B.2 Results for the HMEA review

New research articles found as part of the literature review for this project are shown below. The references highlighted in Green are the research that have been more significant in the discussion in Section 3 of the report.

#	Author	Title	Year	Link
1	Lyons,G	Handling uncertainty in transport planning and decision making - Report of a roundtable discussion held in London on 20 July 2018	2018	http://eprints.uwe.ac.uk/37926/
2	Frontier Economics Ltd	Assessing the productivity benefits of improving inter-city connectivity in Northern England	2016	https//www.nic.org.uk%2Fwp-content%2Fuploads%2FAssessing-the-productivity-benefits-of-improving-inter-city-connectivity-in-Norther-England.pdf&usg=AOvVaw0zTOyVMENEeUjnJ448PyYL
3	Kent Hymel	If you build it, they will drive: Measuring induced demand for vehicle travel in urban areas	2019	http://dx.doi.org/10.1016/j.tranpol.2018.12.006
4	Xu, Wangtu, Yang, Linchuan	Evaluation of transport policy packages in the excess commuting framework: The case of Xiamen, China	2019	https://www.sciencedirect.com/science/article/pii/S0264275118310813?via%3Dihub
5	Aldred, R, Croft, J	Evaluating Active Travel and Health Economic Impacts of Small Streetscape Schemes: An Exploratory Study in London	2019	http://dx.doi.org/10.1016/j.jth.2018.11.009
6	Guilbert, A, De Cremer, K, Heene, B, Demoury, C, Aerts, R, Declerck, P, Brasseur, O, Van Nieuwenhuyse, A.	Personal exposure to traffic-related air pollutants and relationships with respiratory symptoms and oxidative stress: A pilot cross-sectional study among urban green space workers	2018	https://www.sciencedirect.com/science/article/pii/S0048969718333096?via%3Dihub Only summary available – do green workers get high exposure? Dependent on smoking, no consecutively long periods of exposure recorded. Didn't seem to conclude anything particularly notable.
7	Wu, W, Wang, M, Zhang, F	Commuting behavior and congestion satisfaction: Evidence from Beijing, China	2018	https://www.sciencedirect.com/science/article/pii/S1361920918306795?via%3Dihub
8	Krueger, R; Rashidi, T H, Akshay, V	X vs Y: An Analysis of Inter-Generational Differences in Transport Mode Use Among Young Adults	2019	http://amonline.trb.org/
9	Wilmshurst, B, Wallis, I	Research Report 594 Demonstrating the benefit of network operation activities	2016	https://www.nzta.govt.nz/resources/research/reports/594/
10	Whitfield, GP, Meehan, LA, Maizlish, N, Wendel, A M.	The integrated transport and health impact modeling tool in Nashville, Tennessee, USA: Implementation steps and lessons learned	2017	https://www.sciencedirect.com/science/article/pii/S2214140516301876
11	Eppink, P; Awatere S,Frame, B, Whenua, M	Research Report 601 Understanding the value of transport investment in historic and cultural heritage	2016	https://www.nzta.govt.nz/resources/research/reports/601/?category=&subcategory=&audience=359&term=Benefits%2C+economics%2C
12	Halse, A H, Fridstrøm, L.	Explaining Low Economic Return on Norwegian Road Projects.	2018	https://trid.trb.org/view/1512660 Summary only available in English

#	Author	Title	Year	Link
13	Cohn, J, McAdam, T, Ridgway, M.	Case Studies in Realizing Co-Benefits of Multimodal Roadway Design and Gray and Green Infrastructure.	2018	https://trid.trb.org/view/1506290
14	Chacon-Hurtado, D, Yang, R, Gkritza, K, Fricker, J D.	Economic Development Impact of Corridor Improvements.	2018	https://trid.trb.org/view/1528718
15	Achebe, J C, TIGHE, S L.	Towards Developing Environmental Sustainability Performance Measures for Pavement Asset Management Practice	2018	https://trid.trb.org/view/1568403
16	Agarwal, P K, Khan, A B, Choudhary, S.	A Rational Strategy for Resource Allocation for Rural Road Maintenance.	2017	https://trid.trb.org/view/1470671
17	Liew, N, Chu, J.	How much is your daily commute? Developing a working model to estimate the total travel cost.	2016	https://trid.trb.org/view/1457904
18	Zavitsas, K, Sousa, H, Polak, J W, Chryssanthopoulos, M K.	An Integrated Optimisation Framework for Road Asset Management Decision Making Considering Travel Delay	2016	https://trid.trb.org/view/1392267
19	Grudgings, N, Hagen-Zanker, A, Hughes, S, Gatersleben, B, Woodall, M, Bryans, W	Why Don't More Women Cycle? An Analysis of Female and Male Commuter Cycling Mode-Share in England and Wales	2018	https://trid.trb.org/view/1531663
20	Apparicio, P, Gelb, J, Carrier, M, Mathieu, M, Kingham, S.	Exposure to noise and air pollution by mode of transportation during rush hours in Montreal	2018	https://trid.trb.org/view/1528140
21	Riley, E, Harris, P, Kent, J, Sainsbury, P, Lane, A, Baum, F.	Including Health in Environmental Assessments of Major Transport Infrastructure Projects: A Documentary Analysis	2018	https://trid.trb.org/view/1542487
22	Henning, T, Tighe, S, Greenwood, I, Bennett, C R.	Integrating Climate Change into Road Asset Management	2017	https://trid.trb.org/view/1509143
23	Ai, U.	Level of service requirements for freight on rural roads and refinement of heavy vehicle roughness band index	2018	https://trid.trb.org/view/1574966
24	Kırbaş, U, Karaşahin, M.	Investigation of ride comfort limits on urban asphalt concrete pavements.	2018	https://trid.trb.org/view/1531994
25	Tomiyama, K, Kawamura, A, Rossi, R, Gastaldi, M, Mulatti, C.	Contribution of physio-psychological measurements to improving ride experience of road users related to surfaces unevenness	2018	https://trid.trb.org/view/1538176
26	Department for Transport, England	DfT Transport Investment Strategy	2017	https://www.gov.uk/government/publications/transport-investment-strategy

#	Author	Title	Year	Link
27	Department for Transport, England	DfT The Inclusive Transport Strategy: Achieving Equal Access for Disabled People	2018	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/728547/inclusive-transport-strategy.pdf
28	Transport for North, England	Strategic Transport Plan	2018	https://transportforthenorth.com/onenorth/
29	Transport for South East, England	Economic Connectivity Review	2018	https://transportforthenorth.com/onenorth/
30	Welsh Government	Prosperity for All: Economic action plan	2017	https://gov.wales/prosperity-all-economic-action-plan

Appendix C Economic and societal impact (Qualitative Aspects)

The qualitative aspects that describe the economic and societal impacts of road maintenance have been grouped into five areas:

- Welfare
- Importance of road transport
- Inclusive growth including accessibility
- Food, tourism and employment
- Land use

C.1 Welfare

Research has identified core economic assumptions that are based on acceptance of the established concept of fear of scarcity of resources (Lietaer and Belgin, 2010). Economic welfare is therefore a concept that is balanced against other factors. The problem explored in New Zealand is through an international search for a definition of environmental value. There is no agreed system for measuring the level of welfare or the future value of the existing environment (Eppink et al, 2016).

The current UK cost benefit analysis system appraises development based on a monetary value for environment, economy, safety, accessibility and integration. Welfare has strict parameters based on measurable or estimated impacts such as journey time savings. Updated in July 2017 there are four aspects of well-being in the UK: economic, social, environmental and cultural, supported by seven goals. It is becoming increasingly more popular for highway authorities to set their goals and learn through collaboration as the economic response to change continues to break the rules in the perspective of being able to apply reasonably accurate future economic scenarios in appraisals.

C.1.1 Health

Health is an area that has received a considerable amount of attention in recent years. Riley et al (2018) interrogated four major road schemes to assess the consideration given to calculating a value concerning the health impacts within their respective environmental impact assessments. The findings were that health equity of a community largely went un-assessed, the consideration of distribution of health impacts across vulnerable and sensitive groups was insufficient, and that discussion of the possible interactions between project aspects, health determinants, health outcomes and health equity was also insufficient. Mitigation measures of impacts to air quality for the road projects were more detailed than those given for noise, vibration or property acquisition. The study concluded that health equity should be considered at a far earlier stage in the scheme development and should encompass a wider context. It also identified the difficulty that the selected schemes demonstrated in quantifying complex relationships between the different aspects of health (Eppink et al, 2016).

C.1.2 Differences in perception of safe environment

Research has demonstrated an increasing interest in establishing evidence on the differences found in statistics such as those between male and female perception of a safe environment and identifying the unrecognised impact of road schemes on society based inclusion (Grudgings, 2018). The quality of surrounding infrastructure has a higher impact on the likelihood of women deciding to cycle than for men. In improvement schemes examined, where the surrounding infrastructure is regarded as pleasant, the uptake of cycling is statistically closer and therefore suggests more equitable. The research did not provide a definitive calculation for what is pleasant, so it is fair to conclude that it is difficult to quantify this in an objective assessment.

C.1.3 Heritage

Heritage is part of the environmental considerations and has many intangible values that arise from an awareness and association with the past. In the experience of the Maori in New Zealand this is expressed as an ancestral connection and the inter-relatedness of knowledge to the lives and experiences of human communities (Eppink et al, 2016).

It was suggested that the varied approaches to heritage assessments of transport projects tend to reflect the mild regulatory obligations to consider such impacts. In project development, factors like travel times, traffic reliability and road safety are weighted more heavily than environmental or heritage benefits. Defining benefits that go beyond travel time and reliability and giving them a meaningful weight in the decision is still unfamiliar (Eppink, et al, 2016). Within the UK the heritage and value of the natural environment still remains largely unexplored.

Heritage is a complex and qualitative measure that is difficult to capture in economic value and there does not yet appear to be a meaningful formula for its inclusion in the valuation process.

C.1.4 Environmental sustainability

Road infrastructure is critical to quality of life. The road pavement provides mobility and access to various types of users. Construction and maintenance of road networks have undeniable impact on the biophysical environment, which sustains human and non-human lives, and supports their wellbeing. Further, road surface design and condition can influence vehicle fuel efficiency and thereby impact on greenhouse gas emissions. An assessment of five leading sustainability rating tools for road pavements identified a number of limitations to their design and performance. Likewise, current lifecycle assessment tools have differing levels of detail, both temporal and spatial, and the guiding ISO 14040 standards published in 2006 do not specify an exact approach. In consideration of how the various systems reported the environmental impact of an innovative hot-mix asphalt, research identified there is need for localised, region specific impact factors. The study concluded that identifying a process whereby environmental performance measures of pavement lifecycle integrated with optimised sustainable maintenance and rehabilitation policy has not yet been achieved (Achebe, J. C. et al, 2018).

C.2 Importance of road transport

The World Road Association (2016) identified that economic benefit has a range of welfare deliverables. It further identified the critical benefits for population and service movement through use of a wide variety of vehicle modes that are not easily modelled in benefit appraisal.

The research highlighted road maintenance as important for the preservation of network functionality.

C.2.1 Effects of poor road maintenance

There are some areas of research with little representation, and therefore only qualitative values are available at best, these are the effects of poor road maintenance on the economy. For instance, the effects of poor road surface can have an impact on physio-psychology and thereby an economic measurement of rideability of the highway has also been difficult to monetise (Tomiyama K, 2018). Further the effects of noise and vibration are not fully understood for either those using the network or those living alongside the network. The quantified impacts include the effect of variation in ride quality on road users but it is recognised that the relationships are founded on limited research.

C.2.2 Activities of highways maintenance operations

The operations activities of highways authorities include repair and improvement of the highway. Historically there has been limited requirement to carry out in-depth economic assessments of operations activities. The methodologies and approaches for carrying out benefit appraisal (Wilmshurst, B. 2016) of operations activities are not well established.

C.3 Inclusive growth

C.3.1 Accessibility

In the Scotland report it was determined that inclusive growth is recognised as reducing poverty and inequality, and benefits the most marginalised in society (CAFOD, 2014)

It was also found that road networks can alleviate poverty, enhance social cohesion and integrity, and promote inclusive growth by providing opportunities for social mobility.

In a Strategy for England and Wales it was identified that while Wales can lay claim to some economic successes in its recent past, the benefits of this have not been evenly distributed, and policy makers for Wales are increasingly interested in how to achieve 'inclusive' growth. The Welsh Government's Prosperity for All: Economic Action Plan, published in December 2017, put inclusive growth at the core of its vision, with several key action areas highlighted as priorities.

C.3.2 Reduction in commute time

In inclusive growth, reduction in commute time is seen as an economic advantage. In WebTAG calculations, it increases reliability and predictability of time taken to travel to work, ensuring the availability of the work force. In some of the more recent research this assertion is questioned in relation to equity. A more efficient highway with greater capacity actually encourages longer commute distances. The impact of this lifestyle choice on the health and wellbeing of road users is not well documented in transport and highway literature.

Further, it is argued that the widening and development of new networks does not benefit those at the less advantaged end of society. There are benefits to the middle and upper sectors of society. This is expressed in economic valuation as the ability to enhance trade.

C.3.3 Access to services for remote communities

In the previous literature review specific reference was made to Halcrow research into the characteristic of lifeline roads in Scotland and identified the fragile nature of remote communities in Scotland that have a significant constraint to ease of access to lifeline services such as health, education, retail etc. This is then further accentuated by lack of alternative routes when delays and closure occur.

The review for Scotland also identified the socio-economic impact of road improvement schemes from improved access to lifeline services, employment, and sustainability of the remote community.

In explaining the low economic return on Norwegian road projects compared to neighbouring countries, Halse et al (2018), suggested a number of drawbacks to the use of a Benefit-Cost Ratio (BCR) to compare the merits of road schemes. Such drawbacks include higher economic return is likely to outweigh higher construction costs and higher population density that is likely to outweigh higher kilometres travelled. These lead to the conclusion that different geographic characteristics can be detrimental to evaluating schemes based simply on economic return.

C.3.4 Younger generation movement away from car reliance

Recent research has identified changing trends where there is an emergence of changes in attitude towards travel. For example, younger members of society are statistically less interested in driving than previous generations and there is a progressively higher uptake in commuter cycling activities (e.g. increase of 25% shown by Lyons, 2018). However, these findings are not sufficient to inform existing economic models.

C.4 Food, tourism, and employment

It is recognised that the impact of the road network extends well beyond the actual road network, although this is difficult to quantify, there are combined direct, indirect and induced outputs from the road network in relation to the provision of food, tourism and employment. Recent research has confirmed the findings of the review in 2016 but has not advanced the ability to include this effect in economic models.

C.5 Land use and property values

Metsaranta et al (2014) concluded the benefits of road investment are an increased attractiveness of location for companies and households but noted it can also create pressures on land use because of the added attraction of the increased value of the land. Recent research has confirmed findings of previous reports but led to no new changes in understanding.

Appendix D Additional data required for HMAT when HMEP is disabled

If the HMEP Toolkit is disabled in HMAT (i.e. future network condition and maintenance need is forecast using a stand-alone HMEP Toolkit or another tool) then the data that the other tool generates will need to replicate the format of the HMAT results tables and entered into HMAT.

When assembling the data, (i.e. different types of data and the same condition data for the other case studies) the order of road types must be the same as in HMAT analyses as HMAT relies on the order to make sure the data is attached to the correct road type. Three sets of data need to be input in the appropriate worksheet:

- Condition of the network for each road type, condition band and year of the analysis period (i.e. percentage in each condition band fir each road type for each year)
- Maintenance work quantity for each year of the analysis period
    - For each road type and each treatment type, the area/length* treated
- Expenditure by treatment for each year of the analysis period
    - For each road type and each treatment type, the maintenance expenditure

* Note: If Length is available rather than Area, the Length data can be used with the carriageway widths to manually create the Area table.

Tables D-1 to D-3 show example data for the analysis of a road network using a short (10 years) analysis period with one road type in each of rural and urban environments, representing carriageway condition in four condition bands and using three maintenance treatments.

Table D-1. Condition for each road type

Road Type	Condition Band	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
A - DUAL(Rural)	VG	14.48%	6.27%	2.86%	5.51%	5.18%	15.73%	25.17%	25.31%	24.72%	29.45%	30.29%
A - DUAL(Rural)	G	62.33%	58.68%	8.19%	18.88%	13.46%	13.46%	0.00%	4.39%	2.22%	5.00%	4.16%
A - DUAL(Rural)	F	23.18%	35.05%	21.83%	68.80%	66.43%	61.65%	62.38%	44.97%	14.22%	4.87%	3.90%
A - DUAL(Rural)	P	0.00%	0.00%	0.06%	6.81%	14.93%	9.16%	12.45%	25.33%	58.83%	60.68%	61.65%
A - DUAL(Urban)	VG	3.21%	4.61%	0.74%	96.08%	96.08%	96.63%	93.62%	93.62%	68.49%	2.17%	3.57%
A - DUAL(Urban)	G	63.69%	63.69%	1.17%	3.37%	1.60%	0.00%	0.00%	3.01%	28.14%	94.47%	93.07%
A - DUAL(Urban)	F	33.09%	31.69%	0.71%	0.55%	1.77%	3.37%	6.38%	3.37%	1.60%	1.60%	0.00%
A - DUAL(Urban)	P	0.00%	0.00%	0.00%	0.00%	0.55%	0.00%	0.00%	0.00%	1.77%	1.77%	3.37%

Table D-2. Work quantity (m^2) for each road type

Road Type	Maintenance Treatment	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
A - DUAL(Rural)	T1	1142	31	38	38	38	38	38	38	38	38	38
A - DUAL(Rural)	T2	5459	140	183	183	183	183	183	183	183	183	183
A - DUAL(Rural)	T3	1100	2942	3694	3694	3694	3694	3694	3694	3694	3694	3694
A - DUAL(Urban)	T1	12	14	14	14	14	14	14	14	14	14	14
A - DUAL(Urban)	T2	52	68	68	68	68	68	68	68	68	68	68
A - DUAL(Urban)	T3	1093	1372	1372	1372	1372	1372	1372	1372	1372	1372	1372

Table D-3. Expenditure (£) by treatment type for each road type

Road Type	Maintenance Treatment	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
A - DUAL(Rural)	T1	47,073	58,155	58,155	58,155	58,155	58,155	58,155	58,155	58,155	58,155	58,155
A - DUAL(Rural)	T2	81,842	115,954	115,954	115,954	115,954	115,954	115,954	115,954	115,954	115,954	115,954
A - DUAL(Rural)	T3	585,363	725,151	725,151	725,151	725,151	725,151	725,151	725,151	725,151	725,151	725,151
A - DUAL(Urban)	T1	1,212	1,213	1,213	1,214	1,214	1,215	1,216	1,216	1,217	1,217	1,218
A - DUAL(Urban)	T2	25,890	31,985	31,985	31,985	31,985	31,985	31,985	31,985	31,985	31,985	31,985
A - DUAL(Urban)	T3	53,198	75,370	75,370	75,370	75,370	75,370	75,370	75,370	75,370	75,370	75,370

Appendix E Data links for HMEA and HMAT data

E.1 Data sources for data to be used in HMEA

VAT and NIC

National values are available from:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/833379/Aug19_Receipts_NS_Bulletin_Final.pdf

Tax from income

National values for 2017 and 2018 are available from:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/782862/NS_Table_3_11_1617.xlsx
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803473/Disaggregated_tax_and_NICs_receipts_-_statistics_table.pdf

aGVA

aGVA by industry sector is published information (e.g. at the following websites).

https://www.statista.com/statistics/285023/gross-value-added-gva-in-the-uk-by-sector/
Gross Value Added (Average) at basic prices: CP SA £m - Office for National Statistics (ons.gov.uk)

Population

Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland - Office for National Statistics (ons.gov.uk)

Annual growth rate - aGVA

The background growth (GDP deflator, as given in the WebTAG databook) would give the real terms aGVA growth per year.
https://www.gov.uk/guidance/transport-analysis-guidance-webtag

Annual growth rate - Tax from income, VAT, NIC

The Institute of Fiscal Studies (and others) suggest VAT, NIC and Tax from Income will each increase at a similar rate to aGVA (i.e. have only a small increase in the percent of GDP in the future).
Institute of Fiscal Studies. The UK's public finances in the long run: the IFS model. IFS Working Paper W13/29

Employment

Employment by industry sector is published information (e.g. at the following websites).

https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/employmentbyindustryemp13
https://statswales.gov.wales/Catalogue/Business-Economy-and-Labour-Market/People-and-Work/Employment/Jobs/Employees-Only/Business-Register-and-Employment-Survey-SIC2007/employeejobs-by-area-year

Annual growth rate - Employment
UK Economic Outlook March 2016 (later editions don't refer to employment) suggests employment to rise (in the UK) at 0.9% per year.
https://obr.uk/forecasts-in-depth/the-economy-forecast/labour-market/

Discount rate
Discount rates for transport analyses are part of the WebTAG guidance.

https://www.gov.uk/guidance/transport-analysis-guidance-webtag

Accidents

Accident data is available from the DfT Tag Data Book: Table A4.1.4 and Cobalt 2 worksheets.
https://www.gov.uk/guidance/transport-analysis-guidance-webtag

E.2 Data sources for the analysis of the Strategic Road Network in Wales

During development of HMEA, the model was demonstrated using analyses of the Wales Strategic Network (WSRN) and much of the data for use in those analyses was obtained from the sources listed below.

Tax receipts and National Insurance Contributions

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/833379/Aug19_Receipts_NS_Bulletin_Final.pdf

Population

https://statswales.gov.wales/Catalogue/Population-and-Migration/Population/Estimates/Local-Authority/populationestimates-by-localauthority-year

aGVA

https://statswales.gov.wales/Catalogue/Business-Economy-and-Labour-Market/Regional-Accounts/Gross-Value-Added-GDP/gvainwales-by-industry

Employment

https://statswales.gov.wales/Catalogue/Business-Economy-and-Labour-Market/People-and-Work/Employment/Jobs/Employees-Only/Business-Register-and-Employment-Survey-SIC2007/employeejobsinwales-by-industry-year

Road Lengths

https://statswales.gov.wales/Catalogue/Transport/Roads/Lengths-and-Conditions/roadlength-by-typeofroad-year

Traffic

https://statswales.gov.wales/Catalogue/Transport/Roads/Road-Traffic/volumeofroadtraffic-by-localauthority-roadclassification and

https://statswales.gov.wales/Catalogue/Transport/Roads/Road-Traffic/volumeofroadtraffic-by-roadclassification-typeofvehicle

Road Accidents

https://statswales.gov.wales/Catalogue/Transport/Roads/Road-Accidents/accidents/roadaccidents-by-severity-area

CO_2 emissions

https://www.ons.gov.uk/economy/grossvalueaddedgva/qmis/regionalgrossvalueaddedincomeapproachqmi

Development of the Highways Maintenance Economic Assessment (HMEA) Model

The condition of the road network can impact the prosperity and economy of an area and the Highway Maintenance Economic Assessment (HMEA) model has been developed to quantify that benefit by considering the impact of network condition on aGVA, tax from income, VAT and NIC over a specified analysis period. It also considers the changes in employment in the area served by the road network if the network condition changes.

This project for the UK Roads Liaison Group (UKRLG) Asset Management Board, extends the current Highway Maintenance Assessment Tool (HMAT), which incorporates the HMEP Life-cycle Planning Toolkit for the forecast of network condition and maintenance need.

HMEA represents the economy by the main economic sectors of the economy and the data for those sectors found using the Standard Industrial Classification (SIC) categories associated with the key sectors, taking into account the proportion of the economy that is dependent on the road network. The model also enables estimates of the value of the road network and includes other sources of income (e.g. congestion charging and tolls).

This report describes the HMEA model, the data needed in the model and the use of the results from HMAT analyses with the economic impacts from HMEA to show the economic impact of the road network. Potential data sources for HMEA are identified.

Earlier literature reviews have considered the impacts on road users that can only be described qualitatively. These reviews have been updated as part of this project to capture studies that have been reported since those earlier reviews.

Other titles from this subject area

CPR28833 Highways Maintenance Economic Assessment (HMEA) User Guide

CPR2136 Highways Maintenance Appraisal Tool (HMAT) User Guide

CPR2137 Valuing the Benefits of Road Maintenance

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