MAKING THE CASE FOR ROAD MAINTENANCE SPEND IN A COMPETITIVE BUDGET ENVIRONMENT

Karl Johnston
Transport Scotland
Chris Parkman, Richard Abell, Cathy Booth
TRL

1. INTRODUCTION

Maintaining Scotland's Roads (Audit Scotland, 2011) identified an overall maintenance backlog on roads in Scotland of £2.25 billion. Of this, £1.54 billion related to the maintenance backlog on Local Authority roads and £0.713 billion related to trunk roads, including bridges. The report included a central recommendation for the Scottish Government to take forward a national review of "how the road network is managed and maintained, with a view to stimulating service redesign and increasing the pace of examining the potential for shared services."

The Government accepted the central recommendations in the report and announced in early 2011 that a National Road Maintenance Review would be undertaken to look at how the road network in Scotland is managed and maintained.

The Review was taken forward by Transport Scotland in partnership with the Convention of Scottish Local Authorities (CoSLA), the Society of Local Authority Chief Executives (SOLACE), Society of Chief Officers of Transportation in Scotland (SCOTS) and the Scottish Road Works Commissioner under the guidance of a Steering Group. The Review reported to Ministers and Council Leaders in autumn 2011.

The Steering Group was supported by four Working Groups. One of the Working Groups was charged to address wider economic issues, impacts, costs and benefits of road maintenance. The Group commissioned a study to assess these aspects for both the local and trunk road networks, the results of which were presented in an overall Summary Report (Parkman, Abell, Bradbury, & Peeling, 2011), and more detailed separate reports for the trunk roads and local roads (Parkman & Bradbury, 2012), (Parkman C. , Bradbury, Peeling, & Booth, 2011).

This paper summarises the results of the study, in terms of both the qualitative and quantitative aspects. The primary focus of the paper is on the overall impacts. Details of the quantitative methodology and results are to be published elsewhere. It describes the overall approach and methodology, and then highlights key findings and conclusions from the study.

2. APPROACH AND OVERALL METHODOLOGY

The study assessed the impacts in accordance with the Scottish Transport Appraisal Guidance (STAG) criteria (Transport Scotland, 2011):

- Environmental impacts
- Safety impacts
- Economic impacts
- Integration impacts
- Accessibility and social inclusion impacts

The impacts were considered for three Scenarios over a 20 year analysis period:

- ***Scenario 1 (Base scenario).*** Maintain current (2010/11)[1] funding levels for 20 years
- ***Scenario 2[2].*** Reduce Scenario 1 funding levels by 20% for the first 10 years. Return to Scenario 1 spending levels uniformly over the following five year period, and further increase these by 2.5% per annum for the final five years of the analysis period
- ***Scenario 3.*** Reduce Scenario 1 funding levels by 40% for the first 10 years. Return to Scenario 1 spending levels uniformly over the following five year period, and further increase these by 2.5% per annum for the final five years of the analysis period

Both quantitative and qualitative impacts were considered for the Scenarios. Qualitative impacts were considered against each of the STAG criteria and for each criterion, specific sub-criteria were assessed, by undertaking a comprehensive literature review of evidence from elsewhere. The following impacts were quantified (at 2002 prices[3]):

- ***Vehicle operating costs.*** If road conditions deteriorate, there is an increased cost to road users (e.g. vehicles consume more fuel and may need more frequent repairs).
- ***Travel time costs.*** If road conditions deteriorate, vehicles generally travel slower but this effect is offset by fewer planned disruptions (due to less maintenance work being carried out if budgets are redcued) resulting in less delay at roadworks.
- ***Accident costs.*** If road conditions deteriorate, there is an increased risk of accidents due to lower skid resistance. Also, if street lighting is reduced there may be a consequential increase in traffic accidents.
- ***CO_2 emissions.*** Changes in CO_2 emissions related to the above impacts can be monetised.

Sensitivity testing was carried out on key aspects of the quantified analysis. The study identified numerous issues for consideration but the key conclusions were extracted and are reported in this paper.

3. KEY INFORMATION AND ASSUMPTIONS FOR ASSESSMENT

3.1 The Scottish Road Network

Local Authorities and Transport Scotland spent £654m on road maintenance in 2009/10 (Audit Scotland, 2011):

- Local Authorities spent £492m on local roads which represents a 12% increase on 2004/05 expenditure levels after taking into account general inflation.
- Transport Scotland spent £162m on trunk roads which represents a 12% decrease on 2004/05 after taking into account general inflation.

The road network is 56,000km in length of which 3,400km are trunk roads[4]. Trunk roads therefore receive approximately 5 times the expenditure per kilometre, demonstrating the difference in the asset value and strategic importance placed on the different networks.

Around 44 billion vehicle kilometres were travelled on the network in 2009, including around 17 billion travelled on the trunk road network.

These figures are examples of the significant differences between trunk and local roads which affect the type and level of the social, environmental and economic impacts of road maintenance. For example, impacts on pedestrians will be more significant on local roads than they are on trunk roads.

3.2 Funding Constraints in Practice

The nature and extent of the impacts of reductions in the total maintenance budget depend on how the reductions are allocated across maintenance activities. Pragmatic views were taken of the relative importance of each of the various activities in achieving typical road asset management objectives for a road agency. For example, safety related activities were given a higher priority and were protected when budgets were reduced for the scenario analyses. This stage of the assessment affected the outcome of the quantified analysis, the effects of which are only related to certain activities on the network (e.g. road carriageway maintenance).

3.3 Sampled Approach for Local Roads Analysis

There are 32 Scottish Local Authorities. For earlier studies SCOTS had assigned each Local Authority network into one of five categories (city, urban, semi-urban, rural and island). It was not possible to carry out a quantified analysis on each Authority, so a sampled approach was adopted which considered 8 authorities in detail, and scaled up the results from the analyses from the sample of Authorities to the full network based on consideration of the Authority types.

4. QUALITATIVE ANALYSIS AND SUMMARY OF EVIDENCE FROM ELSEWHERE

The overall assessment is summarised in Tables 1 to 5. Each table addresses one of the STAG criteria, assessing various sub-criteria within each of the criterion.

Evidence was collated from international published experience with a focus on those publications with more relevance to the Scottish context. The level of evidence for the impact of maintenance varied across the different criteria. Only some of the impacts could be quantified and those impacts are reported in more detail in Section 5. Also, some impacts relate more to one type of road network (e.g. urban, rural, trunk or local road) and comment has been made where appropriate and where the context is not clear.

The STAG criteria do not describe all of the impacts. One of the more significant issues excluded from the criteria is public satisfaction. Transport Scotland and Local Authorities undertake road user or public satisfaction surveys each year or biennially. Results of the surveys for Transport Scotland confirmed that vehicle users consider carriageway conditions important, and their dissatisfaction had increased in the last two surveys. Similar evidence was seen for Local Authorities. Although many Local Authority surveys are concerned mainly with general levels of service provided by the Authority (e.g. ease of access to the Authority) and do not address the details of road condition, answers to the general questions on road maintenance and state of the road network show clear increases in dissatisfaction. Some surveys show how the levels of service have deteriorated while some aspects have shown improvements (e.g. the level of satisfaction with street lighting has improved in one Authority since 2004 but the satisfaction with street cleaning in the same Authority has seen a bigger fall in satisfaction).

Table 1 Assessment of impacts on environmental criterion

Assessment of impacts on environmental criterion

Sub-criterion	Issue	Summary
Noise and vibration	New projects	New road projects adopt the latest standards and often provide noise mitigation measures (e.g. noise barriers in urban areas). Maintenance of noise barriers has not been considered in this study but it is likely that as maintenance budgets are reduced, the funding for the repair of existing barriers will be reduced. New surfaces, to current standards, lead to low levels of vibration in adjacent buildings but in the early life of some new surfaces there may still be high levels of noise from the interaction between vehicle tyres and the road surface. The amount of maintenance reduces with the funding reductions, so this effect is likely to be reduced.
	Road surfacings and traffic noise	The desire to minimise resurfacing costs will lead to increased lives of surfacings and a pressure to adopt cheaper surfacings. After an initial settling-in period, surfacings generally generate more noise with trafficking as they age (Abbott, Morgan, & McKell, 2010). Limited experience on Scottish local roads of potentially lower noise surfacings has been that they are of a similar final outturn cost but higher whole life cost as they do not last as long as other more traditional surfacings. The potential effect of changes in noise due to reduced maintenance expenditure is therefore considered neutral. The impact is more one of the lost opportunity to potentially invest in higher cost surfacings to reduce noise. There will only be a marginal effect due to ageing of existing road surfacings on the network. As surfaces deteriorate and funding for routine maintenance (e.g. patching) reduces, the likelihood for potholes and other sudden surface discontinuities increases. It is these sudden changes in ride quality that lead to increased vibrations and noise in near-by buildings which are likely to be a concern to local communities but these have not been quantified in this study. Increases in vibrations might also adversely affect vehicle users, particularly those who drive for long periods (e.g. truck drivers).
Global air quality	Vehicle use and road maintenance	Reduced maintenance funding leads to less works activity and therefore lower gas emissions from maintenance works. There are also fewer vehicles delayed through maintenance sites. However, as roads deteriorate, vehicle speeds reduce and fuel consumption and the levels of emissions change. The effect of all these aspects has been quantified in Section 5 and shows a marginal reduction in

Assessment of impacts on environmental criterion		
Sub-criterion	**Issue**	**Summary**
		CO_2 when maintenance budgets are reduced. It is important to note that there might also be an increase in unplanned reactive work as the network deteriorates leading to changes in levels of gas emissions but no quantification of this effect has been possible. As vehicle engine efficiency improves, the levels of emissions will be reduced for the same amount of travel and this helps to compensate for any adverse effects due to lower maintenance funding.
Local air quality	Vehicle use	Local air quality due to vehicle use will be proportional to the effects of global air quality noted above. Overall there will be a marginal reduction in amounts of NOx (nitric oxide and nitrogen dioxide) and Particulate Matter (PM10 and PM2.5) for both Scenarios (i.e. the 20% maintenance funding reduction and the 40% maintenance funding reduction). However these changes cannot be treated as indicative of changes in local air quality at specific sites.
	Maintenance activity	Reduced road maintenance will mean less planned maintenance work on the network. Particularly at major carriageway maintenance sites and for bridge or structures repairs, significant dust can be generated. With lower funding, the number of planned events may reduce and this may lead to better air quality, but this will be part offset by any increase in unplanned maintenance (e.g. more potholes and carriageway surface disintegration) and, potentially, other more significant and intrusive work (e.g. a weakened or collapsed structure requiring urgent repair).
	Street cleaning	Anecdotal evidence suggests that local air quality will deteriorate due to increased dust if streets are cleaned less but there is no quantified or reported evidence of this.
Water quality and drainage		The purpose of routine and planned drainage maintenance is to keep existing drainage functional. If such activities are reduced, the risk of local flooding will increase, deterioration of the road structure is likely to accelerate and outfall water quality will reduce if maintenance of any drainage pollution controls is delayed. There is evidence of increases in the number of flooding events in recent years

Assessment of impacts on environmental criterion		
Sub-criterion	**Issue**	**Summary**
		but there is no published evidence on the contribution of the effects of lower maintenance funding on these events.
Geology		This sub-criterion is assumed to be unaffected by any change in road maintenance funding.
Biodiversity and habitats	Street lighting	There is evidence that bats will not fly in directly illuminated areas so any reductions in street lighting due to lower funding may be beneficial to the bat population (Emery, 2008).
	Vegetation control	Roadside vegetation provides important grassland habitats and migration routes for many species. It has been found that a reduction in appropriate vegetation control leads to increases in noxious plants and a decline in species rich habitats. Reduced funding may therefore have a negative impact on biodiversity.
Landscape, visual amenity and cultural heritage	Customer satisfaction studies have shown the public has a clear impression of their local area and numerous studies support the 'broken windows' theory (i.e. poor amenity and appearance lead to an increased deterioration in the locality and the need for higher subsequent costs). Studies have also shown the public judge the need for maintenance on appearance. Studies by the Commission for Architecture and the Built Environment (CABE) since 2001 have promoted the higher quality of life provided by improved streets (CABE, 2007). A survey has shown 85% of the people felt the standard of public space and environment provided by improved maintenance (e.g. road condition, clear signing, street furniture) and non-maintenance related expenditure (e.g. pedestrianisation, CCTV and alcohol free zones) impacted directly on the quality of life. Studies have however also shown that priorities of local residents do not always match the priorities of planners and designers and may lead to lower cost options for maintenance and improvements. The Audit Commission (2007) showed carriageway and footway repair to be a high cause of concern for the public. At a workshop for experts and practitioners in this study, it was agreed that although quantified evidence of benefits from improved public realm is scarce, there is a strong case for improved amenity and cultural provision. It was also	

Assessment of impacts on environmental criterion		
Sub-criterion	**Issue**	**Summary**
	noted that standards for public amenity in Scotland are generally below those in other parts of Europe where more importance is given to achieving high standards of public realm.	
	Carriageways and footways	CABE (CABE, 2007) showed people value improvements to their streets. Studies by Transport for London have valued the increase in residential prices and retail rents achieved by roadspace improvements or close proximity to open space (e.g. parks). Transport for London has demonstrated benefit-cost ratios of between 2.5 and 5.5, without indirect benefits, from improvements in the public realm. Other studies have shown improvements to footfall for retailers after carriageway and footway improvements. As well as showing the benefits of maintenance and improvements these valuations provide measures to use in attracting private sector funding for maintenance and improvements in local areas. Poor walking environments and transport links can leave areas isolated and damage community cohesion (Social Exclusion Unit, 2003). Increases in cat and dog mess, litter, broken glass, vandalism and uneven footways all represent disincentives to the use of pedestrian footways and reduction in visual amenity. These negative impacts will be increased with reductions in maintenance funding for footways.
	Street cleaning	If street cleaning is reduced, the amenity and cultural heritage of an area will decrease and levels of crime may increase (DEFRA, 2006). Evidence suggests that the public places importance on a clean environment such that, for example, only partial graffiti removal would still impact negatively. However, studies in New York have shown the public believed the cost of maintaining cleaner streets to improve the public realm was too high. Experience from Perth and Kinross Council (Perth and Kinross Council , 2011) shows the severe impact on street cleaning costs from clearing the grit on footways used to reduce accidents during bad winter weather.

Assessment of impacts on environmental criterion		
Sub-criterion	**Issue**	**Summary**
	Street lighting	Better street lighting leads to improved perception of an area and an increase in commercial development.
Agriculture and soils		This sub-criterion has been assumed to be unaffected by the changes in the level of road maintenance funding considered in this study. (N.B. Winter maintenance is not included in this study).

Table 2 Assessment of impacts on safety criterion

Assessment of impacts on safety criterion		
Sub-criterion	**Issue**	**Summary**
Accidents	Carriageways	Road engineering is only one of the factors which might contribute to road accidents. For the reductions in maintenance funding considered, maintenance activities related directly to safety have been protected so the effects on accidents are minimised. Poor condition of the road surface can increase the risk of accidents due to skidding and also due to road users taking evasive action to avoid hazards (e.g. potholes). A majority of Scottish Local Authorities consider current levels of maintenance funding are a threat to road safety and that the threat has increased in the last year (Asphalt Industry Alliance, 2011). This view is likely to be exacerbated with the funding cuts considered in this study. On Scottish trunk roads, a skid resistance policy has been implemented. A review of condition and accident trends suggests accidents due to skidding could increase from their current levels of around 400 to around 450 per year for the 40% funding reduction Scenario and this effect is monetised in

Assessment of impacts on safety criterion		
Sub-criterion	**Issue**	**Summary**
		Section 5. Only three Scottish Local Authorities that have implemented a similar policy have been identified and there is not enough evidence to draw any conclusions on the impacts in these Authorities. International evidence suggests the risk of skidding will reduce with the introduction of skid resistance policies. Introduction of a skid policy might only reprioritise existing road surfacing funds and it will inevitably require start-up and monitoring investment which may be considered unaffordable if road maintenance funding is reduced. Funding reductions potentially represent a lost opportunity to reduce road accidents due to poor skid resistance on local roads.
	Structures	Failure of a structure can be catastrophic and make headline news (National Transport Safety Board, 2007). Whilst maintenance funding for road safety aspects has been protected in each of the funding reduction Scenarios in this study, there will almost inevitably be an increase in the risk of failures as budgets reduce. Infrastructure failures (e.g. failures of structures) potentially result in accidents for all types of road users. The likely costs of those accidents have not been estimated in this study.
	Street lighting	Historically, one of the justifications for the introduction of street lighting has been to reduce road accidents. With recent constrained funding and an aim to reduce the carbon footprint of road network operations, some UK Authorities (Institution of Lighting Engineers, 2010) have reduced the level of street lighting and reported no disbenefit, but the balance of evidence still suggests lighting reduces the risk of accidents (e.g. street lighting enables pedestrians to identify and avoid defects which could cause accidents). With selective (e.g. part of the night) reductions in street lighting (i.e. targeting low risk areas first), it might be possible to avoid significant increases in the risk of accidents but for the 40% funding reduction Scenario (which assumed a reduction of 23% in street lighting budgets) it is likely that safety risks will increase. For example, a coarse analysis quantified in Section 5 suggests accidents (all injuries) could increase by around 45 per year (from current levels of around 2000) on the local road network following a 40% reduction in maintenance funding.

Assessment of impacts on safety criterion		
Sub-criterion	**Issue**	**Summary**
	Footways and cycle-tracks	All evidence suggests increased deterioration of footways and cycle-tracks will cause an increased safety risk to pedestrians and cyclists but it has not been possible to quantify the impact for the Scenarios in this study. Over 10 years, one Scottish urban council paid out nearly 10 times more for claims due to footway incidents than claims due to car damage.
Security	Street lighting	Low levels of street lighting and poorly maintained street lighting furniture increase the public fear of crime (Institution of Lighting Engineers, 2010). Funding reductions that lead to lower levels of lighting will therefore reduce the use of streets for walking and cycling. Studies in Dudley, West Midlands and in Stoke-on-Trent found that improved levels of street lighting lead to reductions of more than 40% in recorded crime and that crime is not displaced.
	Street cleaning	This issue has been discussed under landscaping and amenity in Table 1.
	Footways	Reduced care of footways and roadside environments (e.g. fence repairs, surface repairs, vegetation control) increases the perceived risk of crime for the public and serves as a deterrent to use. This will lead to lower social interaction in neighbourhoods which increases the risks of crime. Funding reductions will exacerbate any such risks (perceived or real), especially among certain groups (e.g. the elderly).

Table 3 Assessment of impacts on economy criterion

Assessment of impacts on economy criterion

Sub-criterion	Item	Summary
Transport economic efficiency	Vehicle operating costs	Deterioration in road conditions will cause an increase in vehicle operating costs (e.g. fuel consumption, vehicle damage due to defects). The effect is quantified in Section 5. For all roads, the increased total undiscounted costs for the 40% funding reduction Scenario, compared with the base Scenario are incurred by cars (around 56%), trucks (around 20%) and vans and buses (around 24%). In the 40% funding reduction Scenario for local roads, in 2020 (i.e. before expenditure is assumed to increase), the undiscounted costs represent an annual additional 0.6 pence per vehicle km for cars, 1.3 pence per vehicle km for vans, 2.2 pence per vehicle km for buses and 3.6 pence per vehicle km for trucks at 2002 prices compared to the costs for the Scenario with no funding reductions. For trunk roads, the corresponding costs are lower at 0.2 pence per vehicle km for cars, 0.3 pence per vehicle km for vans, 1.6 pence per vehicle km for buses and 1.1 pence per vehicle km for trucks.
	Journey times	Deterioration in road conditions will cause increases in travel time as vehicle travel slower on roads in poorer condition. The effect is quantified in Section 5. In the 40% funding reduction Scenario, in 2020 before maintenance expenditure is assumed to increase, the longer journey times represent an annual additional 1,349,351 hours for cars, 239,629 hours for vans, 30,998 hours for buses and 186,980 hours for trucks on all (trunk and local) roads. This effect is, however, more than offset by less disruption to journeys due to reduced roadworks, which have also been quantified. The effects of increases in unplanned maintenance or route diversions that might occur with reduced planned maintenance were not assessed. Infrastructure failures are likely to increase journey times for all types of road users due to travel diversions. The possible effects on road user journey times from potential breaks in network links has been demonstrated in this study by relating the effects to the experience gained from the earthworks failure at Rest and Be Thankful on the A83 (Argyll and Bute). Although the effects are relatively small, they can cause significant local issues and affect economic activity (e.g. freight diversions and loss of passing trade).
	Journey	It was not possible to quantify the effects of decreased journey time reliability due to the potential

Assessment of impacts on economy criterion		
Sub-criterion	**Item**	**Summary**
	reliability	increase in risk of disruptions on the network (e.g. due to failure of signs, signals, structures or other assets). Analysis of data from the closure of the A83 at Rest and Be Thankful demonstrated that if the disruption is of short duration, the costs to road users of that disruption are unlikely to outweigh savings from reduced direct maintenance costs or the changes in road user costs that occur when maintenance budgets are reduced. Nevertheless, no matter how small, the effect still serves to increase costs to society.
	Journey quality	The journey quality for all users will deteriorate under all the funding Scenarios considered. Rougher roads are less comfortable to drive on, reduced lighting (if applied on parts of the network) will affect the ease of driving and the visual appearance of the roadway will deteriorate for both road users and local residents. Customer satisfaction surveys ((Ramdas, Thomas, Lehman, & Young, 2007) for the trunk road network show that road users regard roads in poor condition as one of the most significant detractors on their journeys, and Local Authorities will face similar concerns. Local Authority customer satisfaction surveys show the reduction in satisfaction with road maintenance and road condition to be the source of two of the biggest reductions in satisfaction with Local Authority services in recent years. The level of public satisfaction is expected to continue to fall under all 3 funding Scenarios considered.
	Planned maintenance	Reductions in the maintenance budget are aimed primarily at planned maintenance activities. Studies have shown that the costs of recovering from deterioration in infrastructure quality are much higher than the costs of retaining existing quality levels.
Wider economic benefits and *economic activity and location impacts* have not been considered further in this study. Surveys of business attraction to Scotland include the quality of transport availability such as airport connections, but do not address the more detailed issues of maintenance of road surfaces or the value of amenity and cultural provision. The effects are therefore considered marginal.		

Assessment of impacts on economy criterion		
Sub-criterion	**Item**	**Summary**
Infrastructure failures are likely to decrease economic activity and reduce local trade. The possible effects on local trade from potential breaks in network links have not been assessed in this study. Nevertheless, it is clear that failure of a major road through an area will decrease traffic flow into the area and reduce trade.		

Table 4 Assessment of impacts on integration criterion

Assessment of impacts on integration criterion		
Sub-criterion	**Item**	**Summary**
Policy integration	Physical fitness and health	The Scottish Government is seeking improved health outcomes which are in many cases strongly linked to the levels of physical fitness of a community. The potential for increased severance noted under the accessibility and social inclusion criterion will be a disincentive for affected communities to maintain physical fitness levels. There are strong connections between road condition and policies on health and obesity as poor carriageway and footway condition deter walking and cycling. Road condition also affects equalities since women will often view the public realm differently from men, primarily because of fear of crime and being alone in an unsafe environment. The success of Government policies (e.g. Cycling Action Plan for Scotland, Route Map to Healthy Weight) is directly related to the standard of provision of carriageways, footways and cycle-tracks. Scottish Government policies for Designing Streets (2007) and Designing Places (2001) set out the policies for streets and communities. They include Ministerial statements on the value placed on

Assessment of impacts on integration criterion		
Sub-criterion	**Item**	**Summary**
		delivering healthy lifestyles and growing local economies which are closely linked to well designed and well maintained environments. Designing Streets puts people and places before the movement of vehicles: “Attractive and well-connected street networks encourage more people to walk and cycle to local destinations, improving their health while reducing motor traffic, energy use and pollution”. The health benefits of increased walking (i.e. if 1 in 100 currently inactive people took adequate exercise) have been estimated to save the National Health Service in Scotland £85m per year (Scottish Government, 2003).
Transport integration and *transport and land-use integration* have not been considered further in this study. The effects of levels of maintenance funding on these aspects are considered marginal.		

Table 5 Assessment of impacts on accessibility and social inclusion criterion

Assessment of impacts on accessibility and social inclusion criterion		
Sub-criterion	**Item**	**Summary**
Community accessibility	Remote communities	New investment may be focused on improving links with rural communities which often do not show a quantifiable economic benefit. Lifeline roads, where there is usually only one route for access to a community, will be strongly affected if the condition of the route significantly deteriorates. Road maintenance management approaches inevitably focus funding where risks and traffic are most significant, therefore it is expected that remote communities will suffer a bigger disadvantage if

Assessment of impacts on accessibility and social inclusion criterion		
Sub-criterion	**Item**	**Summary**
		maintenance funding is reduced and less used routes are not prioritised.
	Structures, footpaths, cycle-tracks	Potential increases in risk of structural failure could have a significant effect on community accessibility (e.g. a bridge spanning a river with a community on both sides of the river) ((James, Harper, Reid, McColl-Grubb, & Tomlinson, 2004). However, due to safety concerns it is likely that such assets will be shielded the most from the effect of budget reductions. If facilities such as pedestrian underpasses or footpaths are poorly maintained and suffer reduced use due to fears of crime and accidents, as noted elsewhere, a similar effect of severance will be realised in the long term. Studies in the Netherlands have shown that well kept public areas had fewer incidents of dishonesty, suggesting they reduce the propensity to criminal activity, echoing the broken window theory noted in Table 1.
Comparative accessibility	Older people	Older people are more likely to be adversely affected if there are more and worse defects on footways and if street lighting and other amenity assets and activities are reduced. The elderly have a greater fear of crime and potential accidents and will therefore experience a comparatively bigger effect from these impacts than other road users.
	People with disabilities	Under the Disability Discrimination Act: Transport Scotland Good Practice Guide for Roads (2009) Local Authorities must ensure that road maintenance policies do not disadvantage disabled people. Uneven footways have a bigger impact on people with disabilities (e.g. visual impairment, or mobility) so that deterioration in the quality of such assets will have a comparatively bigger effect on disabled people. The Disability Discrimination Act: Good Practice for Roads (2009) lays out clearly the accessibility standards needed to enable disabled people to use road environments. If carriageways and footways fall below accepted standards of accessibility then this will have a direct impact on the use of the road network by disabled people by affecting access to local businesses and

Assessment of impacts on accessibility and social inclusion criterion		
Sub-criterion	**Item**	**Summary**
		facilities, and thus increasing the severance for those affected.
	Pedestrians	An increase in roadside noise or deterioration in local air quality, visual amenity and appearance (e.g. graffiti) and street lighting will have a comparatively bigger effect on pedestrians than other road users. Deterioration in road and footway condition can deter movement by pedestrians, particularly the elderly, adults with young children and the disabled. Reductions in planned maintenance will put more pressure on the need for unplanned maintenance and delays to unplanned maintenance will further deter pedestrians.
	Cyclists	Reduction in traffic calming measures will lead to less favourable conditions for cyclists (where the measures adequately address the needs of cyclists). Poorly maintained road surfacing with loose material, uneven edges and potholes increase the risk of accidents and are a major deterrent for cyclists. Such budget areas are often one of the first carriageway items to be reduced when funding is constrained. It is therefore likely that, for a given level of reduction in funding, cyclists will experience comparatively bigger impacts than other road users. Reductions in planned maintenance will put more pressure on the need for unplanned maintenance and delays to the unplanned maintenance will further deter cyclists.

5. QUANTITATIVE ANALYSIS RESULTS

5.1 Overview

The analysis over a 20 year period compared the savings to Government, through reduced maintenance works from smaller budgets, with the costs to society in terms of various economic, environmental and social impacts. In accordance with STAG, all figures are quoted at 2002 prices.

For the quantified analysis, the predicted conditions of the road network were derived using condition projection models currently in use by SCOTS (for the local road network) and Transport Scotland (for the trunk road network) and showed that the network would be expected to deteriorate over the analysis period for all three funding Scenarios.

As noted in Section 4, not all impacts can be quantified. Those impacts that were quantified were derived from the effect on road users of predicted network conditions for each Scenario. This paper does not include details of the analysis but the key summary points to emerge are given.

5.2 Components of the Quantified Economic Costs

Vehicle operating costs

As carriageways deteriorate in condition due to reduced funding, vehicles incur more costs through increased fuel consumption and vehicle wear and tear. The results of the analysis confirmed vehicle operating cost increases and showed they are the most significant quantifiable cost impact. For the 40% funding reduction Scenario, the total increase in vehicle operating costs, for local roads and trunk roads, discounted over 20 years was estimated to be more than £3.5 billion. Whilst a large figure, it represents an increase of only around 1% compared with Scenario 1 (Base Case). For this reason, the costs were the subject of significant sensitivity testing.

Travel time costs

As carriageways deteriorate in condition, vehicles travel more slowly and journey times increase. The analysis of this effect was based on earlier work in the UK and was considered only applicable for higher speed roads. The analysis was therefore only applied to trunk roads and A class local roads. For this reason, the effect had more significance on the trunk road results.

Skid related accident costs

Transport Scotland and some Local Authorities monitor skid resistance and apply skid resistance management policies. The justification of such strategies is that skidding accidents increase on lower quality road surfaces in wet conditions. Trends on the trunk road network allowed the effect to be quantified and suggested that, if the aim is to maintain road safety standards as far as possible, then only in the most extreme Scenario considered (i.e. a 40% funding reduction) will the effect appear. There was not enough evidence for local roads for the effect to be quantified in this study.

Delay costs at roadworks
Roadworks cause disruption to travel so fewer planned roadworks, due to funding constraints, will generate less disruption. The effect was proportionally more significant on the local road network as maintenance work zones on single carriageway roads cause comparatively more disruption than on multilane roads. Delays due to any increase in unplanned maintenance resulting from a reduction in planned maintenance were not assessed.

Lighting related accident costs
The economic justification for provision of street lights is primarily a reduction in night-time accidents on lit roads. The effect of budget cuts was therefore considered by reviewing current accident levels on roads with street lighting, and postulating more accidents (based on UK evidence) if the lights are switched off. The effect for both the trunk and local road networks was not significant in comparison with other impacts, but took no account of other aspects such as the public realm, amenity value and security which are also associated with levels of street lighting, particularly in urban areas. In 2010/11 there were around 2000 night-time accidents on the road network and with a 40% funding reduction this figure was estimated to increase by 50 by 2020.

Emissions costs (global air quality)
Reduced maintenance funding leads to less maintenance works activity and therefore lower emissions from maintenance works. There is also less vehicle travel through work sites. However, as roads deteriorate, vehicle speeds reduce and fuel consumption and the level of emissions change. Based on the projections from the model, the cost of CO_2 emissions was assessed in accordance with STAG appraisal parameters. Results for all roads showed that the biggest reduction in costs was due to the decrease in roadworks (but note that any potential increase in unplanned maintenance, which has not been assessed, will tend to increase the impact).

5.3 Overall Summary of Results

Table 6 shows the monetised costs and benefits and the Net Present Value[5] (NPV) for the maintenance funding reduction Scenarios 2 (20% funding reduction) and 3 (40% funding reduction) compared to Scenario 1 (the base case for which 2010/11 budgeted maintenance funding levels are retained). The NPV for each Scenario is negative and shows that the overall impact of the budget cuts would be an increase in economic cost for Scotland.

The NPV for the trunk and local roads network for Scenario 3 (40% funding reduction) is worse than Scenario 2 (20% funding reduction), showing that greater funding reductions would increase the economic cost to Scotland[6].

Results of the asset valuation analysis are also shown in Table 6. Whilst this is not an impact to society and is a figure used only for financial reporting, it does show that the asset value of the network would decrease with time (due to increases in the accumulated depreciation). This illustrates the predicted effect of deterioration in network condition, in current financial reporting terms, for all three funding Scenarios.

Table 6 Summary of quantified economic impacts for 20 year analysis period

Cumulative discounted[1] costs (£m 2002[2] Prices)	Trunk Roads[3]			Local Roads[3]			All Roads[3]	
	Scenario 1 (Base Case)	Scenario 2	Scenario 3	Scenario 1 (Base Case)	Scenario 2	Scenario 3	Scenario 2	Scenario 3
Financial Costs to Government								
Maintenance works	2,152	-266	-568	5,677	-688	-1,459	-954	-2,027
Impacts on Society								
Vehicle operating costs	73,223	+376	+625	274,246	+1,485	+2,966	+1,861	+3,591
Travel time (surface condition related)	362	+57	+94	1,572	+77	+158	+134	+252
Accidents (skid related)	345	0	+21	N/A	N/A	N/A	0	+21
Delays (through roadworks)	119	-25	-38	1,480	-354	-712	-379	-750
Lighting (accidents)	128	+1	+2	2,155	+18	+37	+19	+39
$C0_2$ Emissions	5,765	-36	-58	14,971	-14	-16	-50	-74
Overall impact on society	79,942	373	646	294,424	1,212	2,433	1,585	3,079
Economic analysis								
Works costs reduction	Base Case	266	568	Base Case	688	1,459	954	2,027
Increase in user costs	Base Case	373	647	Base Case	1,212	2,433	1,585	3,080
Net Present Value[4]	Base Case	-107	-79	Base Case	-524	-974	-631	-1,053
Effect on Asset Valuation[5]								
Reduction in asset value	-487	-489	-531	-727	-845	-961	-1,334	-1,492
Difference compared to Base Case	Base Case	-2	-44	Base Case	-118	-234	-120	-278

(1) Annual discount rate = 3.5%. *(2) 2002 prices are 2010 prices factored by 0.81.*
(3) Scenario 2 (20% reduction) and Scenario 3 (40% reduction) figures are shown as differences compared to figures for Scenario 1 (2010/11 funding retained).

(4) Negative NPV shows an overall increase in cost (i.e. user costs increase more than the reduction in maintenance expenditure).
(5) Valuation/depreciation information is shown at 2002 undiscounted prices. The information was provided as different parameters for local roads and trunk roads. The 2010 asset value for the trunk road network was estimated at £5,928m. The accumulated depreciation for the local road network in 2010 was estimated at £4,105m.

6. SENSITIVITY TESTING

Sensitivity tests were undertaken to assess the robustness of the conclusions around some of the key assumptions. The results of these analyses are shown in Table 7.

Table 7 Sensitivity analyses of quantified economic impacts

Net Present Value[1] for different assumptions	Trunk roads		Local roads	
	Scenario 2 (20% cut)	Scenario 3 (40% cut)	Scenario 2 (20% cut)	Scenario 3 (40% cut)
Base analysis (20 years, standard growth[2] and indexing assumptions)	-107	-79	-524	-974
Reduced time period analysis (10 year analysis period) (Section 7.1)	112	263	Not tested	Not tested
Higher inflation rates on works costs (Section 7.2)	-62	44	Not tested	Not tested
Varied assumptions on vehicle operating costs (traffic growth and projected fuel price increases removed)(Section 7.3)	307	983	332	743
Different scaling up methodology for local road sample to network effects (Section 7.4)	N/A	N/A	-447	-806

(1) For clarity, only the Net Present Value data for each Scenario is brought forward from Table 6. The purpose of the table is to show how NPV varies with different assumptions. All footnotes for Table 6 are applicable to this table where relevant.

(2) Base assumptions are for traffic growth rates as per national transport model.

6.1 Time Profile of Cost and Benefit Streams

The effect of road maintenance on road conditions (and hence user impacts) is long term. The effect of timing on costs and impacts was therefore analysed by reviewing the results of the trunk road analysis for a reduced analysis period of 10 years.

The analysis showed that the NPV becomes positive (i.e. maintenance expenditure savings outweigh user cost increases) for both Scenarios based on reduced maintenance funding when the shorter analysis period is adopted. This is due to the long term effects of budget reductions on network conditions and shows that the budget savings in years 1 to 10 would not be realised as increased costs to road users until years 10 to 20.

6.2 Inflation on Maintenance Works Costs

Inflation of road maintenance costs has been up to 8% per annum in recent years, which is higher than general rates of inflation (Audit Scotland, 2011). Even if current maintenance budget levels were maintained, if the same inflationary pressure continues in future, road authorities would be able to buy less maintenance work than they can today for the same level of budget.

The effect of differential inflation on maintenance works costs was explored in this study by projecting an annual increase in works costs for each of the Scenarios. A differential rate of 4% was used which was consistent with the rate that has been experienced in recent years.

The results showed that the NPV of each funding reduction Scenario would become less negative compared to the case with no differential rate for road maintenance costs. This result implies that it becomes more attractive to consider reductions to road maintenance budgets if there is high inflation for maintenance works, since the cost of delivering the benefits of road maintenance would increase during the analysis period.

However, with higher inflation for maintenance works costs, it would be more beneficial to invest now in maintenance than to defer spending to a time when road authority buying power is reduced (i.e. the case not to reduce the current levels of maintenance budgets would be strengthened).

6.3 Vehicle Operating Costs

The dominant influence on the quantified economic impacts of road maintenance funding reductions was shown in the study to be vehicle operating costs. A significant number of assumptions were made in that analysis. A ‘lower bound’ sensitivity was undertaken by changing some of the key assumptions.

From the analysis of vehicle operating costs (using the HDM-4 model) (HDMGlobal, 2011), fuel made up nearly half of the total vehicle operating cost. Fuel cost impacts are affected by assumptions on fuel price increases, traffic growth and predicted improvements in vehicle efficiency. The base analysis assumed fuel price increases, traffic growth and improving vehicle efficiency with time in accordance with STAG. If fuel prices were instead considered to remain static and there were no projected increases in traffic, then this could be considered a potential lower bound on the impact of fuel on the results.

The test showed that with the new assumptions, the conclusions in the original analysis were reversed and it became economically advantageous to reduce road maintenance budgets. The impact of the change was most significant for trunk roads, which had a more marginal NPV than the local roads for the base analysis.

In summary, with no increase in fuel costs and no traffic growth, there would be benefits in terms of reduced overall cost to society with reductions in the maintenance budget. Conversely, with fuel increases and traffic growth assumed in the original analyses, there would be an increased overall cost to society (i.e. a disbenefit) if the maintenance budgets were reduced. Therefore, it may be reasonable to assume that if the fuel increases and/or traffic growth are greater than assumed in the original analyses the effect of reducing the maintenance budget would be a bigger increase in the overall cost (i.e. disbenefit) to society.

6.4 Scaling Methodology for Local Roads

To calculate the costs for the whole local road network based on the analyses of the 8 sample Local Authorities, the results of the analyses for the sample Authorities were scaled to the whole local road network. Since the dominant cost in the overall analysis was the vehicle operating costs, the sensitivity of only that aspect of cost was considered in the sensitivity analysis.

For scaling up the results in the base analysis, the percentage of the network (for each road type) in need of repair within one year (i.e. categorised as red in the SRMCS report for 2009/10) (SCOTS, 2010) was used for each Authority not in the sample of 8 Authorities analysed. However, an alternative assumption that may better reflect the overall condition of the network would be to scale the results based on the percentage of the network (for each road type) showing signs of deterioration (i.e. as categorised red or amber in the SRMCS report for 2009/10).

The revised scaled values continued to show a worsening in the overall NPV if maintenance funding was reduced but the worsening was less severe.

7. KEY CONCLUSIONS

The key conclusions that were most significant to the original aims of the study are discussed in this Section. Major assumptions and sensitivities that might affect those conclusions are highlighted.

There would be an overall disbenefit to society of reducing road maintenance expenditure on the Scottish road network. The qualitative review of each criterion highlights the various impacts, almost all of which are negative. This supported the traditional view held by highway engineers that reductions in road maintenance are a long term disbenefit for developed road networks such as those in Scotland. The quantitative analyses, which only addressed certain aspects of the qualitative analysis, further supported the qualitative conclusions and show that for every £1 reduction in road maintenance, there would be a cost of £1.50 to the wider economy[7]. If figures were available to quantify aspects not currently included in the quantitative analyses, it is expected that these would only enhance the conclusion. For example:

- Impacts of the increase in road closures due to unforeseen events

- Costs of delaying major repair work on significant structures leading to possible closures, weight restrictions or more extensive maintenance work
- Wider economic disbenefits such as reduced tourism or local economic activity

It should also be noted that the two funding reduction Scenarios considered only reduced budgets below the base Scenario in the first 10 years and already allowed for an increase in funding and resulting improvement in the network beyond 2020. If the budget reductions were continued for longer or the increases in funding were at a lower rate, it is expected the conclusions would be strengthened further.

It is often thought that road maintenance only impacts on vehicle journeys. However, the review showed that there are wider impacts on society. Remote communities will be affected by poorer lifeline links. Pedestrians and particularly older people and those with disabilities will be affected if footways deteriorate. Cyclists will be affected if traffic calming measures are reduced and if the conditions of cycle-tracks and the edges of roads deteriorate. Communities in general will feel less secure and the quality of the public realm will deteriorate as road network conditions deteriorate, lighting is reduced and streets are cleaned less. Based on the literature review, the user group most affected by a reduction in road maintenance would be pedestrians, especially those with mobility and visual impairments. Pedestrians would be affected in every aspect including noise and vibration, global air quality, visual amenity, cultural and landscape, physical fitness, accidents, security, community and comparative accessibility.

For the same proportional budget reductions, the effect on road users of reduced local road maintenance budgets would be greater than the effect of reduced trunk road maintenance budgets. From the quantitative analyses, the Net Present Value for both networks was shown to be negative. But (for the 40% funding reduction Scenario) for every £1 saved there would be a disbenefit on local roads of £1.67 and on trunk roads of £1.12. The qualitative assessment showed that the types of the disbenefits are also different for each network. For the local road network, comparatively greater disbenefits would be realised in the form of social impacts on pedestrians, cyclists and local residents. For the trunk road network, the impact of the reductions would be more focused on vehicle users of the network and the associated economic impacts.

There is limited published evidence of many of the disbenefits arising from the reduction of road maintenance budgets and few have been quantified in economic terms. The literature review highlighted that there is a considerable amount of information available which recommends good road maintenance practice and discusses the implications of a lack of road maintenance. However, there is much less information available which provides evidence of the impacts of changing the levels of road maintenance. Of this information, only a small proportion attempts to quantify the impacts. The majority of quantifiable impacts described in the literature are associated with the effects

of carriageway maintenance on vehicle users. There is limited published evidence of any quantifiable impacts due to changes in conditions of non-carriageway assets.

The most significant quantified impact of reduced road maintenance budgets was the increase in vehicle operating costs. The predicted vehicle operating cost increases were small compared to the total annual vehicle operating costs on the network (for example, for the 20% maintenance funding reduction Scenario, the increase in vehicle operating cost is around 0.5%). However, for the Scenario with a 20% maintenance funding reduction, the predicted increase in vehicle operating costs was 40% more than the projected savings in road works expenditure on the trunk road network and more than double the savings for the local road network. By comparison, increases in each of the other quantified impacts are significantly less than the savings in the maintenance works expenditure.

Road conditions were predicted to deteriorate even with no reduction to maintenance budgets. For the Scenario based on retaining 2010/11 maintenance funding levels, the asset value of both networks was predicted to be lower at the end of the analysis period than in 2010/11, and the reduction in value increased as maintenance budgets reduced. This effect is a monetary representation of the predicted deterioration in carriageway condition and reflects, in some way, the cost to return the network to the current (2010/11) conditions at the end of the analysis period.

Public dissatisfaction with road conditions would be considered likely to increase. Results of public satisfaction surveys for both Transport Scotland and Local Authorities confirmed that road conditions are important. For trunk roads, surveys had suggested increased dissatisfaction with road conditions although it was not possible to assess this in any rigorous way[8]. Local Authority public satisfaction surveys had also shown similar concerns with many surveys showing increases in dissatisfaction over recent years. However, surveys had also shown improvements in satisfaction in some aspects (e.g. levels of street lighting). This may have been where an Authority has directed a higher proportion of funding to meet a particular local need and so is not necessarily a reliable indicator of improved overall satisfaction.

In final summary, the sensitivity tests showed that the most significant influence on the quantified impacts would be from the vehicle operating costs. If some base assumptions were changed to reduce the impact of vehicle operating costs then the effect of reducing road maintenance budgets, for those aspects that were quantified, was shown to be an overall economic benefit. A similar change to the conclusion was also reached if a shorter analysis period was used.

The results show that reductions in road maintenance budgets considered in this study would lead to an overall disbenefit to society. The effect would be long term and the conclusion could change if different assumptions were made to calculate vehicle operating costs. However, based on standard assumptions adopted for transport investment appraisals in Scotland, there

would be an economic disbenefit if maintenance budgets are reduced, compared with retaining the 2010/11 levels of maintenance funding.

Bibliography

Abbott, P. G., Morgan, P. A., & McKell, B. (2010). *A review of current research on road surface noise reduction techniques (PPR443).* Wokingham: TRL.

Asphalt Industry Alliance. (2011). *Annual Local Authority Road Maintenance (ALARM) Survey.* London, UK: Asphalt Industry Alliance.

Audit Scotland. (2011, February). Retrieved 2011, from http://www.audit-scotland.gov.uk/docs/central/2010/nr_110216_road_maintenance.pdf.

CABE. (2007). *Paved with gold - The real value of good street design.* London, UK: CABE.

DEFRA. (2006). *Code of Practice on Litter and Refuse.* London: Department for Environment, Food and Rural Affairs.

Emery, M. (2008). *Effect of street lighting on bats.* Urbis Lighting Ltd.

HDMGlobal. (2011). *HDM-4 Version 2*. Retrieved February 2011, from www.hdmglobal.com

Institution of Lighting Engineers. (2010). *Save money and keep the lights on.* London: Institution of Lighting Engineers.

James, E., Harper, H., Reid, S., McColl-Grubb, V., & Tomlinson, P. (2004). *Community severance research: Final review report (UPR/SE/075/04).* Wokingham: TRL.

National Transport Safety Board. (2007). *Collapse of I-35W highway bridge Minneapolis, Minnesota.* Washington DC, USA: National Transport Safety Board.

Parkman, C. C., & Bradbury, T. (2012). *RPN1570: Economic Assessment of the Impacts of Changes in Maintenance Spend on the Scottish Trunk Road Network.* Wokingham: TRL.

Parkman, C. C., Abell, R., Bradbury, T., & Peeling, D. (2011). *CPR1191: Economic, Environmental and Social Impact of Changes in Maintenance Spend on Roads in Scotland.* Wokingham: TRL.

Parkman, C., Bradbury, T., Peeling, D., & Booth, C. (2011). *CPR1210: Economic Impacts of Changes in Maintenance Spend on Local Roads in Scotland.* Wokingham: TRL.

Perth and Kinross Council. (2011). *Various internal reports (2010-11) supplied for study.* Perth: Perth and Kinross Council.

Ramdas, V., Thomas, C., Lehman, C., & Young, D. (2007). *Highway service levels (PPR251).* Wokingham: TRL.

SCOTS. (2010, August). *State of the Scottish Local road network.* Retrieved June 2011, from SCOTS Public Information: http://scots.sharepoint.apptix.net/Lists/Announcements/DispForm.aspx?ID=141

Scottish Government. (2001). *Designing places: A policy statement for Scotland.* Edinburgh: Scottish Government.

Scottish Government. (2003). *Let's make Scotland more active: A strategy for physical activity*. Retrieved August 2011, from Scottish Government: http://www.scotland.gov.uk/Publications/2003/02/16324/17924.

Scottish Government. (2010). *Designing streets: A policy statement for Scotland.* Edinburgh: Scottish Government.

Social Exclusion Unit. (2003). *Making the connections: Final report on transport and social exclusion.* London: Office of the Deputy Prime Minister.

Transport Scotland. (2009). *Disability Discrimination Act: Transport Scotland Good Practice Guide for Roads.* Glasgow: Transport Scotland.

Transport Scotland. (2011). Retrieved May 4th, 2011, from Transport Scotland Web site: http://www.transportscotland.gov.uk/strategy-and-research/scottish-transport-analysis-guide/STAG

Notes

[1] At the time of undertaking the study, 2010/11 budgets had not been finalised. The Base Case (Scenario 1) was considered the best estimate although later indications suggested some budgets had already been reduced below the Base Case.
[2] The increase in funding for Scenarios 2 and 3 in the second 10 year period reflects an assumption that funding will become available in future to improve the network back towards current conditions.
[3] A 2002 price base is used to enable comparison across studies completed at different times, as required by Government for all cost benefit analyses.
[4] Further details on the road network are available at http://www.scotland.gov.uk/Publications/2010/12/17120002/203
[5] Net Present Value is the difference between the present value of costs and benefits, discounted to 2002 prices. A negative NPV means that the reduction in benefits caused by reduced road maintenance expenditure is larger than the saving made in the road maintenance expenditure.
[6] It is noted that specifically for trunk roads, the NPV for Scenario 2 is slightly worse than Scenario 3 but the difference is small. The result was considered within the margins of error due to challenges of modelling long term road conditions.
[7] The ratio of reduction in benefits to reductions in expenditure from Table 6.
[8] It is likely that winter maintenance issues are a major driver of public perception of road performance. Whilst winter maintenance was not the subject of this study, it is important to note that there is a link between overall maintenance impacts and the effects of winter conditions and operations but this has not been investigated.