Mode Shift Benefit Values:

Technical Report

International Networks Analysis and Support (INAS) and
Freight and Logistics Division (FLD)

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Content

Section 1 Introduction

1. Sensitive Lorry Mile (or SLM) values have been used in allocating freight mode shift grants since 1991. The most recent SLM values have been in place since 2003 and will remain valid until the 31st March 2010.

Freight Mode Shift Grant Schemes

The Department as well as the Scottish Government and the Welsh Assembly Government (the 'Administering Bodies') administer three freight mode shift grant schemes whose objective is to facilitate the purchase of the environmental and social benefits that result from using rail or water transport instead of road. These are:

- Freight Facilities Grants (FFG) - which helps offset the capital cost of providing rail and water freight handling & infrastructure facilities;
- Rail Environmental benefit Procurement Scheme (REPS) - which assists companies with the operating costs associated with running rail freight transport instead of road (where rail is more expensive than road); and
- Waterborne Freight Grant (WFG) - which assists companies with the operating costs associated with running water freight transport instead of road (where water is more expensive than road).

2. The SLM values are used by the Administering Bodies' to value the environmental and other social benefits of removing one lorry mile of freight from road and transferring it to rail or water.

3. The Department for Transport in partnership with the Scottish Government and the Welsh Assembly Government has been conducting a review of the mode shift grant schemes in advance of submitting a request for state aids approval for continuation or replacement programs from April 2010. Associated with this wider review of grant schemes we have undertaken an in-house review of the SLM values. The values were previously reviewed by the Department and the Strategic Rail Authority in conjunction with the Scottish Executive in 2003[1].

4. For clarity the Administering Bodies have decided to rename the new values ‘Mode Shift Benefit values (or MSB values). The existing SLM values will be replaced with effect from the 1st April 2010. Mode shift grants that are awarded for spending from that date until the 31st March 2015 will be assessed using the new MSB values that are described in this paper.[2]

5. There are two main reasons why it has been necessary to update the SLM values that have been used since the previous review. First, circumstances have changed – for example, traffic levels and road capacities have increased, lorries have become more fuel efficient, the population

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[1] The results of the review are reported in SRA (2003).

[2] Whilst the values will only be used in the allocation of grants in the period 2010-2015 the FFG can be allocated on the basis of flows lasting 10 years from the date of grant allocation. This means that the values could be used to value the benefits of mode shift up to 2025.

density around roads has changed – so that, even using the same methods would yield different estimates of the benefits of mode shift. Second, recent research has yielded improved understanding of the impacts of mode shift and required us to use new methods in estimating their value.

6. For this review we have taken the approach that both changes in circumstances and improvements in methodology are best dealt with by making the calculation of the values consistent with the Department's published traffic forecasts and appraisal guidance (WebTAG). The Department's latest traffic forecasts produced using the Department's National Transport Model (NTM) can be found in DfT (2008d).[3]

7. We have reviewed the latest research evidence but only to check for issues relevant to the calculation of MSB values that have not yet been taken into account in the NTM or published WebTAG guidance. We have based this review on existing evidence and have undertaken no new research. We have also sought to ensure that the values do not make the process of applying for and administering the grants schemes disproportionately costly[4].

8. In June 2008 the Department circulated to stakeholders *Review of SLM values: Phase 1 report*. The initial phase of the review had focused on identifying the scope for updating the existing SLM values to be consistent with the Department's latest transport modelling and published appraisal guidance (WebTAG). The paper summarised the work that had been done as part of the initial phase of the review, proposing methods for updating the SLM values and inviting comments from stakeholders. We have received a number of comments and these have assisted us in finalising the approach to updating the values described in this report.

9. This paper describes the approach we have taken to creating the MSB values. We have endeavoured to make the approach we have followed as transparent as possible, and to create a template that can be used as the basis for future reviews of the values if they are required after 2015. This paper is structured as follows:

Section 1 Introduction

Section 2 Background - provides background to the estimation of MSB values and their use in the allocation of grants.

Section 3 Deriving Mode Shift Benefit values – General Principles - describes the approach we have taken to issues that relate to general principles, and are relevant to the way we have estimated values for all components of the benefits of mode shift.

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[3] For more details on the Department's National Transport Model see DfT (2005b).

[4] Approximately £25m will have been allocated under the grant schemes in 2008/09. The average grant reward is just £400,000 but individual grant rewards vary significantly around this value.

Section 4 Deriving Mode Shift Benefit values – **Detailed Methods** - looks at each of the components of the benefits of mode shift individually and describes the method employed to value them.

Section 5 Mode Shift Benefit Values – presents a table of 26 ‘input values’ and explains how we have used them to generate the new MSB values that will be used in the allocation of mode shift grants.

Section 6 Concluding Remarks

Section 2 Background

The values

10. Mode Shift Benefit (MSB) values have been estimated solely for use in the allocation of mode shift grants. They represent Administering Bodies' valuation of the environmental and other social benefits of removing one lorry[5] mile of freight from the road and transferring it to rail or water. In the next few paragraphs we explain why there is a net social benefit to transferring freight from road to rail or water and identify the components of that benefit.

11. In deciding whether to send freight by road an operator will compare the additional costs he expects to incur with the additional benefits he expects to obtain. The additional costs faced by the operator, or 'marginal private costs', will include wage costs, fuel costs, oil, tyres and any other mileage related repair costs, including any taxes (such as fuel duty) incurred.

12. However the operator will also impose costs on other groups in society, which it will not factor into its decision to transport freight by road. These are referred to as 'marginal external costs'. A number of studies have looked at the external costs of road freight[6]. In this review we have considered the same categories of external cost that were considered as part of the previous review of the values, reported in SRA (2003),:

- Congestion costs
- Accidents costs
- Noise costs
- Climate change costs
- Air pollution costs
- Infrastructure costs
- Other costs

13. These external costs are described in section 4. In this review we have focused on the external costs assuming road, rail and water infrastructure is fixed. This is equivalent to assuming that decisions relating to changes in the road and rail network are not significantly affected by mode shift grants. It is also consistent with the approach taken in other studies of the marginal external costs of transport[7] and received broad support from respondents to the phase 1 report of this review.

14. Previous studies have suggested that, in general, the external costs of road freight are only partially internalised, such that the additional tax incurred by freight operators is less than the value of the marginal external costs they impose. Annex A explains why, where this is the case, reducing the amount of freight traffic using road will yield a net social benefit. Annex A also shows

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[5] Throughout this document, unless otherwise stated, 'lorry' refers to articulated heavy goods vehicles for the reasons given in paragraphs 48 and 49.

[6] See Maibach et al. (2008), INFRAS (2000, 2004) and Piecyk & McKinnon (2007) for example.

[7] See INFRAS (2000, 2004) and Sansom et al. (2001) for example.

that if the taxes faced by operators only partially cover marginal external costs, for a given mode, any increase in freight traffic will impose a net social cost. Moreover it shows that for marginal changes in freight traffic the net social benefit (or cost) is approximately equal to the difference between the value of the marginal external costs and the marginal level of taxation at the existing level of freight traffic on that mode.

15. Mode-shift grants do not only reduce the amount of freight on roads. By reducing the costs to hauliers of transporting freight by water or rail, they also result in an increase in the amount of freight transported by water and rail. Thus in estimating the benefits of mode shift we must also consider any net social cost / benefit associated with increasing the amount of freight using other modes[8].

16. The preceding discussion of the costs of road freight also applies to rail and water freight. As for road, in deciding whether to send freight by rail or water operators compare the marginal private costs, in the form of wage costs, fuel costs, and other operating costs including fuel taxes, with the marginal benefits they expect to obtain. In addition they also impose external costs on other groups in society. Section 4 identifies the categories of external costs that are of most relevance to these modes.

17. In summary, the net social benefit of transferring freight from road to rail or water is made up of the net benefit of reducing the amount of freight traffic on road and the net cost of increasing the amount of freight traffic on other modes. For transfers of marginal amounts of freight from road to rail or water the value of this net social benefit is approximately equal to:

$$(MEC_r - MT_r) - (MEC_m - MT_m)$$

Where:

MEC_r = Marginal External Cost of road freight
MEC_m = Marginal External Cost of freight on mode 'm', where m = {rail, water}
MT_r = Marginal tax on road freight
MT_m = Marginal tax on freight on mode 'm', where m = {rail, water}

18. This is the calculation that we have sought to update as part of this review. In performing this calculation we have focused on estimating the net social benefit associated with shifting one lorry mile of freight from road to rail or water.

19. The value of the marginal external cost of road freight is obtained by estimating the value of each of the main external costs of road freight

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[8] It is assumed that for every tonne reduction in the quantity of freight transported by road there is an additional tonne transported by an alternative mode.

separately. From this an estimate of the value of the marginal change in taxation from road freight is netted off to reflect the assumption that indirect taxation partially internalises the external costs of road freight, providing a net social cost of marginally increasing road freight traffic. The value of the net social cost of marginally increasing freight traffic on rail / water freight is calculated by estimating the value of each of the main marginal external costs of rail and water freight separately before netting off an estimate of the marginal taxation paid on these modes. The net social cost of marginally increasing rail / water traffic is then netted off from the net social cost of marginally increasing road freight to provide an estimate of the net social benefit of transferring freight from road to rail.

20. The equation in paragraph 17 is a simplification. In practise the net social cost of increasing road freight, and perhaps to a lesser extent, the net social cost of increasing rail or water freight vary from one place to another, by the level of traffic and by time period. Consequently the net social benefit of transferring a unit of freight traffic from road to one of these modes will also vary. See section 3 for further discussion of how we have sought to reflect this variation in developing the new MSB values.

Use of MSB values in grant allocation

21. The new MSB values will be used by the Administering Bodies to estimate the net social benefit of transferring particular freight flows from road to rail or water. Currently the Department for Transport provides an online tool – the environmental benefit calculator – for use by potential applicants to estimate the net social benefit of transferring particular flows away from road. This will not be replaced. In future to calculate the benefit of mode shift potential applicants will be required to use route finding software to determine the most likely road route between the specified origin and destination[9]. This will enable them to estimate the distance travelled in each of the road types for which MSB values are provided. These distances will then be multiplied by the relevant MSB values and summed to provide an estimate of the net social benefit of transferring the freight flow from road to rail or water. [10] The Administering Bodies will make available a spreadsheet tool to assist applicants with these calculations and will advise which routing finding software they will be using in their assessments of applications.

22. Generally when freight is transported by rail or water it will be necessary to transport the freight to/from the rail terminal or port by road at one or both ends of the journey. The net social costs associated with these 'local road distribution' trips should be calculated in the same way as the net external benefits of removing the original lorry journey. The net social costs of the local road distribution are subtracted from the net social benefits of removing the original lorry trip to yield an estimate of the net benefits of

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[9] The Administrative Bodies will identify which software will be regarded as 'standard' for the purposes of estimating mode shift benefits in due course.

[10] For the MSRS (Intermodal) scheme the Department for Transport will use the same method, using recognised route finding software, to estimate the net social benefits of removing lorry trips for the routes covered by the scheme.

transferring the lorry load of freight from road to rail or water. Annex B illustrates this calculation using a simple example.

23. Since the SLM values take account of the net social costs of moving freight by rail or water, applicants are currently not required to estimate the net social cost of increasing the amount of freight sent by rail/water separately. This simplification is of great benefit to applicants and those administering the scheme. In effect this approach is consistent with the assumption that the distance the freight travels by rail or water is broadly similar to the difference between the length of the original road journey and the sum of any 'local road distribution' legs at the end of the rail or water journey. Clearly this assumption will be less accurate in some cases than in others. We have reviewed this approach by looking at a wide range of typical freight routes and comparing the road and rail journey distances for each. We found that on average the additional rail distance was roughly equal to the reduced road distance. Therefore we believe that the current approach provides estimates that are fit for purpose in the vast majority of cases.

24. However in recognition that there will be instances where the current approach produces misleading results we will provide guidance on how to obtain a more accurate estimate of the social benefit of transferring freight from road to rail/water by estimating the net social benefit of reducing road freight, and net social cost of increasing water/rail freight separately. The guidance will make clear that this will only be necessary when there is a significant difference between the distance of the road journeys removed and the replacement rail or water journey. The Administering Bodies will provide further details as part of revised scheme guidance to be published later in 2009.

25. The amount of grant offered will remain capped by the Administering Bodies’ estimate of the value of the mode shift benefits, estimated using the MSB values, and by 'financial need'. The 'financial need' is calculated for each flow included in each application. It is defined as the difference between the total costs of the rail or water based solution and the total costs that would be incurred if the traffic were moved by road. Capping the grants by financial need ensures that the grant paid is the minimum necessary to bring about the benefits of mode shift. State Aid rules prevent any grant exceeding the value of the benefits obtained from paying the grant. Within this constraint the Administering Bodies will continue to prioritise grant spending on the basis of each application’s benefit-cost ratio (BCR), where the BCR is calculated by dividing the estimated value of net social benefit by the amount of grant that is bid for.

Section 3 Deriving Mode Shift Benefit Values – General Principles

26. The next two sections describe the approach we have taken to producing the new MSB values. This section describes the approach we have taken to issues that relate to general principles, and are relevant to the way we have estimated values for all components of the benefits of mode shift. Section 4 describes the methods we have used to estimate the value of the individual components.

Variation in external costs

27. The marginal external costs generated by an additional lorry will vary both by where and by when the lorry is added to the road network. The implications of both these factors are discussed below. In principle these variations in external costs should be reflected in the MSB values used to allocate grants. This would help to ensure that freight grants were targeted at transferring freight from road to other modes where the benefits of doing so were the greatest.

28. In practise there are good reasons why it would be unrealistic and inappropriate to attempt to reflect all of this variation in the MSB values. Firstly, whilst grant applications provide a clear indication from where on the road network traffic will be removed and the year in which it will be removed, they do not provide sufficient information to allow, with any certainty, a determination of the time of day at which the traffic will be removed. Secondly, we have limited evidence on how the external costs of freight transport vary from one specific situation to another[11]. Finally, a large number of MSB categories, differentiated according to the location and time of day at which traffic is removed from the road, could make the process of applying for and administering the grant schemes disproportionately costly.

29. The structure of MSB values must therefore strike a balance between the desire to accurately target grants where the potential benefits of mode shift are the greatest and the desire to minimise the costs faced by the grant administrators and grant applicants in using those values.

Variation by location

30. The marginal external costs generated by an additional lorry will vary according to where the lorry is added to the road network. For example, the congestion element of the marginal external costs will vary significantly according to whether the lorry joins the A14 just north of Felixstowe (a relatively congested stretch of the road network) or it joins a relatively uncongested stretch of the road network. The marginal external costs of rail

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[11] For example, whilst there is evidence on how the noise costs imposed by a lorry vary according to the location in which the lorry is travelling, we do not have any evidence on how these costs vary by time of day.

and water freight will also vary spatially, although perhaps not to the same extent as for road freight.

31. The external costs generated by an additional lorry vary across the network in different ways. For example, whilst the local air pollution costs are likely to vary most according to the location the lorry is travelling, the infrastructure costs are likely to vary most according to the type of road it is travelling on. Our ability to assess how the components of the benefits of mode shift vary across the network also differs. Consequently the number of values we have produced to reflect variation across the network differs across the range of external costs covered. Section 4 provides more details.

32. We have combined the estimated values for each of the external costs on road and rail/water with estimated values for the marginal taxation on each of the modes to produce a set of 26 ‘input values' that vary according to the area type, road type and congestion band from which a lorry is removed. The 26 values represent different combinations of the 10 area types, 7 road types and 5 congestion bands used in the NTM (see Annex C for details). The values are presented in Table 5 (Section 5) and are called ‘input values’ because of the need to also account for variation by time of day, explained below.

Variation by time of day

33. The marginal external costs generated by an additional lorry will also vary by time of day. For example, the congestion element of marginal external costs will be higher for a lorry travelling in peak times than it will be for a lorry travelling at night. The marginal external costs of rail and water will also vary by time of day but again probably not to the same extent as for road freight.

34. It is not possible to use the 26 ‘input values’ directly in the allocation of mode shift grants. This is because the values vary by congestion band and, as the level of congestion on each road link varies by time of day, the appropriate value to apply to each link also varies by time of day. As mode shift grant applications cannot identify the time of day that lorries are removed from the network, we have had to use the input values to estimate average values for each link. In forecasting congestion the NTM uses 19 separate time periods (see Annex C for details). Calculating the average congestion level across all time periods and using that as the basis for assigning the values does not provide a solution. This is because the relationship between the marginal external cost of congestion and congestion level is non-linear such that the congestion costs imposed by an additional vehicle increase more quickly at high levels of congestion than at low levels of congestion. If we were to assign the 26 input values to links on the basis of the average congestion level we would assign lower values than if we were to assign the 26 values to each link by time period and were then to take an average.

35. We have used output from the NTM on the congestion level on all the motorways and A roads in Great Britain to determine the appropriate ‘input value’ to apply on each link in each time period. We have used the

appropriate input values for each time period to derive average values for each link. We have done this, for every link of A road and Motorway in Great Britain, by using data on the profile of articulated traffic by time period to traffic weight the input values for each time period. A more detailed explanation of the method used is contained in Section 5.

36. This approach yields individual estimates of the value of mode shift for each motorway and A-road link in Great Britain. In principle it would be possible to use these 'link-level' values as the basis for allocating mode shift grants. However the Administering Bodies have decided to choose an alternative approach, which uses just four road types to reflect the variation in the benefits of mode shift across the road network avoiding the practical disadvantages of using the 'link-level' values directly. Section 5 describes how the 'link level' values were used to derive the set of four MSB values that are to be used in the allocation of mode shift grants.

Variation in MSB values between 2010 and 2025

37. As explained in section 1, the values recommended as part of this review will be used in the allocation of grants in the period 2010-2015. For the FFG scheme, where grants can be allocated on the basis of flows lasting up to ten years from the date of application, they could be used to value the net benefits of mode shift in the period 2010 to 2025.

38. Aside from reflecting the variation in external costs by location and time of day there are two main reasons why the values used in allocating mode shift grants should, in principle, vary over this period:

i. To reflect changes in the real value of the benefits of mode shift over the period 2010 to 2025; and
ii. To ensure the external costs are valued in the correct price base

39. There are various reasons why the real value of the benefits of mode shift varies through time. For example, the climate change costs imposed by an additional lorry travelling on a given road link will change through time if:

i. the fuel consumption of lorries change;
ii. the carbon content of fuel changes; or
iii. the social cost of carbon emissions changes

40. We have investigated how each of the components of the benefits of modal shift are likely to vary over the period 2010 – 2025. Section 4 describes the approach we have used to derive estimates of each of these components for 2010, 2015 and 2025.

41. The question of which price base(s) to provide the MSB values can only be answered with reference to how the values are to be used. The Administering Bodies will use the values to:

i. set a ceiling for the amount that the Administering Body would be willing to pay to secure a given amount of modal shift; and
ii. compare the value for money of different applications, and to compare the value for money of mode shift schemes with other policies

42. In both cases the year in which the grant is due to be paid should, in principle, be used as the price base for the valuation of social benefits. For example, if the Department is trying to decide the maximum amount to pay in grant in 2011, the expected social benefits should be expressed in 2011 prices. As the values are to be used to determine grant payments in the period 2010 to 2015 this would mean having values expressed in price bases between 2010 and 2015.

43. In principle, we should take account of both changes in the real value of the benefits of mode shift through time and the need to express the benefits in the correct price base. This would mean having separate sets of MSB values for every year between 2010 and 2025 and providing advice on how the values could be expressed in any price base between 2010 and 2015 according to the year in which grant is to be paid.

44. As with the decision on how to reflect the variation by location, the Administering Bodies' decision on how to reflect variation in the value of mode shift benefits over time has had to strike a balance between accuracy and administrative simplicity. After considering a range of alternative options the Administering Bodies have decided that a single set of MSB values, based on impacts in 2015 expressed in 2010 prices, will be used in the allocation of mode shift grants. These values are to be used regardless of when an application is made or when the mode shift is due to take place.

45. In reaching this decision we have considered that, under the MSRS scheme, it is likely that the majority of the grant paid will be paid to operators for flows that will be removed for the entire period between 2010 and 2015. Our analysis suggests that, if this is the case, the decision to use 2015 values in 2010 prices for all years results in a similar amount of grant being paid to such operators over the five year period as would be the case if 2010 values and prices were used to value the benefits in 2010, 2011 values and prices were used to value the benefits in 2011 and so on to 2015. The decision also reflects the fact that we have only been able to estimate MSB values for 2010 and 2015; thus the use of a single set of values for all years between 2010 and 2015 avoids the need for us to interpolate between these two modelled years.

46. We have also had to consider the fact that for the FFG scheme the values could be used to value the benefits of modal shift up to 2025. Our analysis suggests that the use of a single set of values in valuing mode shift beyond 2015 could reduce the value placed on the benefits of FFG applications in 2015 by around 40%. The Administering Bodies' decision not to reflect this evidence reflects the additional uncertainty associated with the

estimates of MSB values in 2025, the desire to keep the application process simple and the intention to recalculate the MSB values again in five years time.

47. All the values presented in section 5 are 2015 values in 2010 prices.

Vehicle Types

48. As well as varying by location and time, the external costs of freight vehicles will vary according to the type of vehicle being used. On average the congestion component of external costs will be greater for a given road for a relatively larger articulated goods vehicle than for a smaller rigid goods vehicle. The existing SLM values are based on the external costs associated with an average heavy goods vehicle, including all articulated and rigid heavy goods vehicles weighing over 7.5t.

49. In recent years the vast majority of the flows for which grants are awarded would have been transported by articulated lorries on road. In light of this observation, and our belief that we would not be able to monitor the use of separate values for articulated and rigid vehicles, we have based the new MSB values on estimates of the external costs of removing an average articulated lorry from the road.[12] Our discussions with stakeholders and responses to the phase 1 report have indicated broad support for this approach.

Treatment of Uncertainty

50. There is significant uncertainty associated with the estimation of all of the components of the MSB values. This uncertainty could be reflected by providing values in a range rather than as a single value. The previous review, reported in SRA (2003), did not reflect this uncertainty into its recommended values. We have taken the same approach, focusing on producing best estimates based on what are considered to be the most likely values of each of the key parameters. The main reason for taking this approach is that the values are used by the Administering Bodies to determine the maximum amount they would be willing to provide in grant for each application. This forces us to place a specific value on the benefits of modal shift. The use of a range of values could lead to inconsistency in the way that benefits are valued across applications. Moreover it would also serve to make the process of preparing grant applications more time consuming. Given the size of the average grant reward (under £0.5 million) we are concerned that any increase in the complexity of the application process or greater uncertainty surrounding the basis of reward would be likely to deter would-be applicants.

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[12] It is likely that even in the small number of cases where the vehicles shifted by mode shift grants are rigid vehicles an MSB value based on the average characteristics of articulated lorries will provide a more accurate estimate of the mode shift benefits than would one based on the average characteristics of rigid lorries. This is because the types of rigid used by sectors targeted by mode shift grants are likely to be significantly heavier and larger than the average rigid. They are also likely to make similar use of different parts of the road network as an ‘average’ articulated vehicle.

Unit of Account

51. According to TAG Unit 3.5.4: *Cost Benefit Analysis* of the Department's appraisal guidance (WebTAG) any appraisal requires a consistent unit of account. It states that in an economy with indirect taxes the unit of account can be either at factor cost or at market prices. The *indirect tax correction factor* – 1.209 - is the conversion between the two units. The guidance makes it clear that if applied correctly the choice of unit of account should not affect the BCR of a scheme since the same factor is applied to all benefits and costs when changing from one unit of account to the other.

52. As explained in section 2, MSB values are also used to determine the maximum amount that the Administering Body would be willing to pay in grant to bring about specified amounts of modal shift. According to TAG Unit 3.5.4: *Cost Benefit Analysis* the amount that a Government pays in grant is expressed in the factor cost unit of account. This suggests that it would be appropriate to value the environmental and social benefits it hopes to procure in the factor cost unit of account.

53. To ensure consistency with the Department's published WebTAG guidance the new MSB values are expressed in the factor cost unit of account. In simple terms this means that the values placed on impacts borne by consumers are adjusted downwards using the *indirect tax correction factor* so that they are comparable with the values placed on impacts borne by business and government.

Mode shift grants and road freight forecasts

54. As explained in section 2, the marginal external costs of road and alternative modes, and therefore the benefits of mode shift, are dependent upon the levels of traffic on road, rail and water. The extent to which this is true will vary across the components of the benefits of mode shift. Road congestion is the largest component of the MSB values. As the value of the congestion component is dependent on the level of road traffic the MSB values will tend to be higher if road traffic levels are higher (all else being equal).

55. In producing new MSB values we have used traffic forecasts for 2010, 2015 and 2025 from the Department's National Transport Model (see Section 4 for further details). It is likely that these forecasts factor in, albeit implicitly, a continuation of the mode shift grants over this period, though it is impossible to determine the extent to which this is the case. In so far as the forecasts do factor in the continuation of the mode shift grant schemes they will understate the level of freight using the roads, and therefore the total level of road traffic, in the absence of the grants. Given the positive relationship between marginal external congestion costs and the level of traffic this would lead to us underestimating the congestion component of the MSB values.

56. However, estimating the marginal external costs from the level of traffic in the absence of mode shift grants instead would over-estimate the

congestion component of the MSB values. This is because if a significant (non-marginal) number of lorries are removed the congestion benefit declines on removing each successive lorry. Therefore, the average benefit of removing all the lorries will not be as large as the benefit of removing the first lorry. In theory the correct value would be greater than the MSB value estimated using the level of traffic assuming continued mode-shift grants, but lower than the level estimated using the level of traffic in the absence of mode-shift grants.

57. We have considered how significant an issue this might be by looking at the levels of freight removed from the network in the context of background road traffic levels. Given our expectation that this issue would only be significant for a small number of parts of the road network we focused on two parts of the network that are most affected by the mode shift grants. For the A14 from Felixstowe to Huntingdon, we have estimated that in the absence of mode-shift grants traffic would rise by about 4%[13], and for the A34 from Southampton to the junction with the M40 traffic is estimated to rise by about 3%. Therefore we can provide an upper bound to how important this issue is by considering the marginal external costs with these increases.

58. To estimate the impact of this increased traffic on MSB values we increased the congestion levels on the specific road links by the respective amounts and then recalculated the MSB value. This resulted in a 7% increase in MSB value for the A14 and a 5% increase for the A34; and for both roads together a 6% increase. To reflect the fact that these are likely to be the roads which will be most affected by this issue and that the correct value should not be as large as this upper bound for the reasons described above we therefore increased the congestion costs across the motorway and rural A road network by half of this estimate, i.e. 3%.

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[13] This is in terms of passenger car units (PCU) which treat an articulated lorry as equivalent to 2.9 passenger cars; see Annex C for more details.

Section 4 Deriving Mode-Shift Benefit Values – Detailed Methods

59. Having discussed some of the general principles that we have considered in producing new Mode Shift Benefit (MSB) values this section looks at the methods we have used to estimate the value of each of the components of the benefits of mode shift in more detail.

60. We examine each of the components in turn, describing the nature of the component before outlining the method that has been used to value them. We start with the Net Costs of Road Freight looking at the Marginal External Costs of Road Freight - Congestion; Climate Change; Noise; Accidents; Infrastructure Costs; Local Air Pollution, and; Other External Costs – and Marginal Taxation on Road Freight. We then look at the Net Costs of Rail and Water Freight.

<u>Net Costs of Road Freight</u>

Marginal External Costs of Road Freight

Congestion

61. When additional HGV traffic joins a road it will often reduce the average speed of other traffic travelling on it. This imposes costs on other vehicles in the form of longer journey times. In addition, the reduction in speeds will also affect other vehicles' operating costs. For example, a vehicle's fuel consumption will vary with speed, so a reduction in speed will change that vehicle's fuel consumption, and hence fuel costs.

62. There is evidence that, as well as reducing average journey speeds, increased traffic also increases the variability of journey speeds, often reducing the reliability of journey times[14]. The effect of reduced reliability is that businesses and other road users must leave more time for their journeys than the expected journey time to avoid lateness. Greater variation in speed will also affect operating costs. For example, acceleration and deceleration lead to increased use of fuel, as well as wear and tear on other parts of vehicles.

63. We use the term **'Marginal External Cost - Congestion' (MEC- C)** to refer to the costs imposed on other vehicles as a result of a marginal increase in traffic changing average speeds and/or the variability around average speeds.

Method used to value MEC-C

64. We have based the congestion element of the new MSB values on outputs from the DfT's National Transport Model (NTM). This approach ensures consistency with both the latest DfT traffic forecasts and the guidance

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[14] See Arup (2003) for example.

on valuing vehicle operating costs and changes in travel time given in WebTAG.

65. The NTM team have developed an approach to estimating the journey time and vehicle operating cost elements of the MEC-C using the NTM. The Department has previously used this method to estimate the MEC-C of cars as part of the development of TAG Unit 3.13.2: *Guidance on Rail Appraisal - External Costs of Car Use*. The method is described in TAG Unit 3.9.5: *MSA: Road Decongestion Benefits*.

66. The first step in estimating MEC-C using the NTM is to run the model to produce traffic forecasts for the year in which MEC-C estimates are required. For this work, we have performed runs for 2010, 2015 and 2025. These are very similar to the forecasts published in DfT (2008).[15]

67. The NTM calculates the MEC-C by adding an incremental amount of traffic, in this case HGV traffic, to each of the links in the model and using speed flow curves[16] to calculate the changes in average speeds experienced by other vehicles using the link. The model uses these changes in speed to calculate the impact on vehicle journey times. It then uses the guidance on valuing time savings in TAG Unit 3.5.6: *Values of Time and Operating Costs* to value the delays caused to other vehicles, and the guidance on estimating vehicle operating costs, also in TAG Unit 3.5.6: *Values of Time and Operating Costs*, to estimate the impact of the reduction in speed on other vehicles' fuel and non-fuel operating costs. The changes in operating costs and the value of delays are summed across all other vehicles to provide an estimate of the journey time and vehicle operating cost elements of the MEC-C.

68. The estimated MEC – C varies significantly according to where additional HGV traffic is added to the road network. We have used the output of the NTM to estimate 215 separate MEC-C values to reflect this. The values vary by type of road, area and level of congestion. The 215 values represent different combinations of the 10 area types, 7 road types and 5 congestion bands used in the NTM. Please see Annex C for details.

69. The NTM currently does not model changes in journey time reliability. Instead, we have uprated the journey time component of the external cost estimates by 50% on rural motorways and rural trunk roads and 20% on other roads to reflect the impact of additional HGV traffic on journey time reliability. These uprates were also used to derive the existing SLM values. They were derived from applications of the INcident based Cost-benefit Analysis (INCA) software[17]. They refer to the value of journey time reliability benefits as a

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[15] Some small changes to the input assumptions were made shortly before the publication of the forecasts. As the impact of these changes on the forecasts was minor, we decided not to delay the review by redoing our analysis using the revised forecasts.

[16] Speed flow curves are empirically based relationships between link traffic flows and average link speeds. See DfT (2005a) for further details.

[17] INCA is a software package developed on behalf of the DfT that is used for the appraisal of the benefits of schemes designed to reduce the occurrence of incidents and schemes or interventions designed to reduce the effect of incidents on the highways network. For more information see http://www.dft.gov.uk/pgr/economics/rdg/jtv/inca/

proportion of the value of journey time savings benefits across a sample of road schemes. The uprates cover changes in reliability arising from two sources: incident-related journey time variability; and day-to-day variability. It should be noted that these uprates are based on a limited number of applications of INCA. However, as well as being used to derive the existing SLM values they were used to value reliability benefits as part of the Eddington study.[18]

70. In estimating the impact of the reduction in speed on other vehicles' fuel costs the NTM values the changes gross of fuel duty. We have adjusted the NTM estimates to reflect the fact that the fuel duty element of the change in vehicle operating costs is not a true resource cost but a transfer from road users to the Government. The method we have used to estimate the proportion of the change in vehicle operating costs that is fuel duty is described in Annex D. It should be noted that this adjustment represents a very minor adjustment to the estimated MEC-Cs, but has been done to ensure consistency with the Department's published appraisal guidance.

Climate Change

71. Virtually all heavy goods vehicles (HGV) are powered by diesel fuel, the combustion of which generates greenhouse gases; the most significant of which is carbon dioxide. Therefore the addition of a lorry to the road network will directly lead to an increase in greenhouse gas emissions. The addition of HGV traffic to the network will also affect the speeds, and hence fuel consumption, of other vehicles on the road, further affecting greenhouse gas emissions. We use the term **Marginal External Cost - Climate Change (MEC-CC)** to refer to the combination of these two sources of changes in emissions.

Method used to value MEC-CC

72. The NTM estimates the level of carbon emissions associated with each set of traffic forecasts it produces using the parameters and relationships contained in WebTAG. We have used this output to estimate the MEC-CC of articulated HGVs.

73. As explained in the section on congestion the NTM estimates the impact of increased traffic on average speeds using speed flow relationships. The model then uses the forecast average speeds and the relationships between average speeds and fuel consumption given in TAG Unit 3.5.6: *Values of Time and Operating Costs* to calculate the fuel consumed by the marginal unit of traffic (in this case an additional articulated HGV), and the changes in fuel consumed by other vehicles. The changes in fuel consumption (in litres of fuel) are then multiplied by the carbon contents of diesel and petrol (in grams per litre), for the appropriate year, using the values provided in TAG Unit 3.3.5: *The Greenhouse Gases Sub-Objective*, to provide

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[18] See Annex E of DfT (2006b) for example.

an estimate of the change in carbon emitted (in grams) resulting from the additional HGV traffic.[19]

74. We have valued the change in carbon emissions resulting from the additional traffic using published Defra guidance on the shadow price of carbon - Defra (2007b) - to give an estimate of the MEC-CC.

75. Table 1 shows the shadow prices of carbon for 2010, 2015 and 2025 that we have used in our analysis:

Table 1: Shadow price of carbon (in tonnes CO2 equivalent, 2010 prices) [20]

Year	**Shadow Price of Carbon**
2010	£29.47
2015	£32.54
2025	£39.67

Source: Defra (2007b)

76. To reflect the variation in MEC–CC across the road network we have used the output of the NTM to estimate 43 separate MEC-CC values. The values vary by combinations of the 10 area types and 7 road types used in the NTM (see annex C for details of these area and road types).

Noise

77. Noise is emitted from vehicles' engines, from the interaction between their tyres and the road surface, and from intermittent sources, such as braking. Additional HGV traffic affects noise levels directly through the noise it emits itself and indirectly through its impact on the noise emitted by other vehicles as a result of changing their average speeds.

78. Noise affects amenity and may have adverse impacts on human health through a variety of direct and indirect effects. For example, previous studies have suggested that high levels of noise increase the risk of cardiovascular and circulatory disorders, affect children's learning ability and cause productivity losses. Therefore the costs of increased noise levels will tend to be higher in densely populated areas.

79. We use the term **Marginal External Cost - Noise (MEC - N)** to refer to these costs.

Method used to value MEC–N

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[19] For 2010, the NTM forecasts an average articulated lorry to emit 935g of carbon dioxide per km. This is equivalent to an average fuel economy, across all roads, of 7.7 miles per gallon.

[20] The mass of Carbon emitted can be translated into the mass of CO_2 by multiplying by 3.67 (equal to 44/12, the relative mass of Carbon to Carbon Dioxide).

80. The NTM does not specifically model the levels of transport related noise associated with its traffic forecasts. Instead the welfare module of the NTM[21] estimates the impact of changes in traffic levels on noise costs using marginal external cost values (in pence per vehicle km) based on data collected for Sansom et al. (2001). This is also the approach that was employed to derive the noise component of the existing SLM values and the noise values presented in TAG Unit 3.13.2: *Guidance on Rail Appraisal - External Costs of Car Use*[22].

81. Any attempt to produce a completely new estimate of the MEC - N, to reflect the latest DfT traffic forecasts and the webTAG guidance on valuing changes in transport related noise (see TAG Unit 3.3.2: *Noise*), would be a significant piece of work. Given this, and the fact that previous studies suggest that noise costs are a relatively minor component of the total marginal external costs of HGVs[23], we have taken a relatively simplistic approach and focussed on making simple adjustments to the noise values provided in Sansom et al. (2001). Responses to the phase 1 report expressed broad support for this approach.

82. Sansom et al. (2001) provided high and low estimates of the marginal external noise costs per kilometre for a range of vehicle types in 1998 prices and values. Values were provided for 28 area type and road type combinations across eleven area types and three road types (see Annex C for details). For this work we started by taking the mean of the low and high values provided for articulated HGVs to provide an estimate of the MEC - N in 1998 prices and values. We then considered what adjustments we should make to the values to produce estimates of the MEC - N in 2010, 2015 and 2025.

83. The MEC-N values used in the existing SLMs and in the welfare module of the NTM were both obtained by uprating the 1998 values found in Sansom et al. (2001) in line with GDP growth. In contrast the MEC-N values for cars presented in TAG Unit 3.13.2: *Guidance on Rail Appraisal - External Costs of Car Use* were obtained by uprating the Sansom et al. (2001) values in line with GDP per capita growth.

84. In choosing how to uprate the 1998 values in Sansom et al. (2001) to other years we have considered four potential sources of change:

i. changes in the noise characteristics of vehicles
ii. changes in background noise levels
iii. changes in the population affected by vehicle noise

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[21] See DfT (2005b) for details.

[22] Please note that whilst the existing SLM values are based on the arithmetic mean of the high and low values produced by Sansom et al. (2001) the marginal external cost values used in the welfare module and presented in TAG unit 3.12.2: *Guidance on Rail Appraisal - External Costs of Car Use* are based on the geometric mean. This serves to bias the numbers downwards relative to the existing SLM values.

[23] For example the existing SLM values suggest that noise costs represent around 4% of the total marginal external costs of HGVs.

iv. changes in the value people are willing to pay to avoid noise nuisance

85. The approaches used to uprate the Sansom et al. (2001) values elsewhere (i.e. uprating the values in line with GDP or GDP per capita growth) are rather broad brush. The advantage of using GDP growth rather than GDP per capita growth is that it implicitly allows for the size of the population affected by noise to grow in line with national population growth (iii above) as well as for people's willingness to pay to avoid changes in noise to increase in line with their income level (iv above). For this work we have assumed that GDP growth provides a reasonable approximation of the growth in MEC-N values caused by iii and iv. We have discussed the likely impact of i and ii with transport noise experts. They have advised us that the combined impact of these factors on MEC - N is likely to be negligible. Therefore we have derived estimates of MEC - N for the period 2010 to 2025 by uprating the Sansom et al. (2001) values for 1998 using GDP growth.

Accidents

86. When an operator decides to send a lorry load of freight by road it exposes the vehicle it uses to a given risk that it will be involved in an accident. In addition its decision may increase or decrease the accident risk faced by other road users. The impact an additional HGV has on accidents will vary by road type, speed, driver characteristics, time of day, traffic (volume and vehicle mix) and weather conditions.

87. Accidents impose a range of costs on society. The Department's guidance on assessing accident risks in DfT (2007a) highlights the following categories: medical and healthcare costs; lost economic output; pain, grief and suffering; material damage; police and fire service costs, insurance administration; and legal and court costs.[24]

88. A proportion of the social costs are factored into the operator's decision to send its freight by road. For example, the insurance system ensures that the victims of any accident involving a lorry are at least partially compensated for the costs they bear[25]. Here we are interested in the change in accident costs that is caused by the additional traffic but that is not factored into the operator's decision to send its freight by road. We refer to this change as the

Marginal External Cost - Accidents (MEC - A).

Method used to value MEC - A

89. We have been unable to estimate the MEC - A using the NTM because it does not specifically model the impact of changes in traffic on accidents. The welfare module of the NTM estimates changes in accident costs, like

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[24] Accidents are also one source of journey time variability. We have included the costs of this variability as part of our estimation of the MEC – Congestion.

[25] There is some debate as to the extent to which the social costs of accidents are perceived by road users in deciding to use the road. See Maddison et al. (1996) for a discussion.

noise costs using values (in pence per vehicle km) based on Sansom et al. (2001). This is also the approach that was used to estimate the accident component of the existing SLM values and the MEC - A values presented in TAG Unit 3.13.2: *Guidance on Rail Appraisal - External Costs of Car Use*.

90. Previous studies suggest that accident costs, like noise costs, are a relatively minor component of the total marginal external costs of HGVs[26]. Moreover whilst a number of studies have attempted to estimate the MEC – A of road traffic, there is no scientific consensus as to a best practise approach (see Maibach et al. (2008) for a discussion). Therefore for this work we have taken the same relatively simplistic approach that has been employed elsewhere, and have focussed on making simple adjustments to the accident values provided in Sansom et al. (2001).

91. Sansom et al. (2001) provided high and low estimates of the marginal external accident costs per km for a range of vehicle types in 1998 prices and values. Values were provided for 28 area type and road type permutations across eleven area types and three road types (see Annex C for details). As for noise, we started by calculating the mean of the low and high values provided for articulated HGVs. This provided us with estimates of the MEC - A of articulated HGVs in 1998 prices and values.

92. The MEC-A values used in the existing SLMs and in the welfare module of the NTM were both obtained by uprating the 1998 values found in Sansom et al. (2001) in line with GDP growth. In contrast the MEC-A values for cars presented in TAG Unit 3.13.2: *Guidance on Rail Appraisal - External Costs of Car Use* were obtained by uprating the Sansom et al. (2001) values in line with GDP per capita growth.

93. The approach we have taken to uprating the1998 values in Sansom et al. (2001) to obtain values for 2010, 2015 and 2025 is consistent with a bottom up approach to estimating MEC-A values. Under this approach the value of the MEC-A at a given time is defined as:

$$\text{MEC-A}_{i} = \text{Accident Rate}_{i} \text{ x External cost per accident}_{i}$$

Where:
MEC-A_{i} = MEC – A per vehicle kilometre on road link i
Accident rate_{i} = the number of accidents per vehicle kilometre on road link i
$\text{External cost per accident}_{i}$ = the value of external costs per accident on road link i

94. We have, therefore, considered the following potential sources of change:

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[26] For example, the existing SLM values suggest that accident costs represent 3% of the total marginal external costs of HGVs.

i. Changes in accident rates
ii. Changes in the value of external costs per accident

95. To inform the assumptions we have made in relation to these factors we have drawn as far as possible on published statistics. DfT (2007e) suggests that over the same period average accident rates have been falling across all road types at around 3 or 4% per annum on average. Looking at recent publications of the Highways Economics Note[27] suggests that the average value per accident (which is a function of the number of casualties per accident, the severity of the casualties and the value attached to each casualty) is increasing at about 3 or 4% per annum. In the absence of any evidence to the contrary we have assumed that there is no change in the proportion of the value per accident that can be treated as external.

96. Taking this information together suggests that the MEC - A of articulated HGVs are remaining broadly constant through time. This has led us to conclude that increasing the MEC-A values through time in line with nominal GDP or GDP per capita growth would overestimate the MEC-A values in future. Therefore, and on the basis that the analysis above allows us to draw nothing more than broad brush conclusions about how the MEC - A of articulated HGVs are changing through time, we have derived values for 2010, 2015 and 2025 assuming that the MEC - A increase through time in line with inflation.

97. In response to feedback from the phase 1 report we have reviewed the available literature to see what other studies can tell us about the MEC – A. Maibach et al. (2008) provides a good overview of previous studies that have attempted to estimate the MEC - A of road freight vehicles. It also provides recommended values for the UK drawing on the case studies carried out in UNITE (2002). Reassuringly these values are very close to those we have obtained using the approach described above.

Infrastructure

98. Heavy Goods Vehicles cause damage to the road infrastructure. The extent of the damage caused varies depending on the exact vehicle specification, road type and road conditions. Additional damage caused by HGV traffic will increase the frequency that road maintenance is required, increasing the cost to the local authorities and agencies responsible for maintaining the road network.

99. As discussed in section 2, in this review we have focused on the marginal external costs assuming the level of road capacity is fixed. The provision of new road infrastructure due to additional HGV traffic is therefore not included in our definition of **Marginal External Costs - Infrastructure (MEC - I).**

Method used to value MEC - I

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[27] See http://www.dft.gov.uk/pgr/roadsafety/ea/

100. The NTM does not specifically model how infrastructure costs vary with different traffic levels. The existing SLM values suggest that infrastructure costs represent a significant proportion (c15%) of the total marginal external costs of HGVs. Consequently we have taken a more sophisticated approach to estimating this component than we have for noise and accidents. The approach we have taken follows that used by Sansom et al (2001) which in turn follows the method developed in NERA (1999). This builds on a method for allocating road costs to different types of vehicle that was originally developed by the Department of Transport (DoT) in 1968 and which formed the basis of the annual publication *The Allocation of Road Track Costs* until it was discontinued in 1997[28].

101. We have updated the calculations performed in Sansom et al (2001) using the Department's latest data on road maintenance costs, published in DfT (2008a) and on the characteristics of different road vehicle types, published in DfT (2006c), DfT (2007d) and DfT (2008b)

102. A detailed description of the calculations is provided in Annex E. The key steps are as follows:

i. Disaggregate maintenance costs into 12 expenditure categories across 4 road types.
ii. Allocate the costs for each of the 12 cost categories across a number of cost 'drivers'.
iii. Exclude costs that are not related to traffic volume as they are irrelevant to the estimation of marginal costs.
iv. For each road type calculate the total traffic-related costs allocated to each cost 'driver'.
v. Calculate the total value of each cost 'driver' for each of the four road types.
vi. Estimate the costs per vehicle kilometre for each vehicle type across each of the 4 road types;
vii. Estimate the MEC - I for articulated HGVs for each of the four road types;
viii. Obtain estimates of the MEC - I for 2010, 2015 and 2025 by making assumptions about how the costs change through time.

103. This approach is based on the assumption that the road maintenance costs in a given year provide a reasonable indication of the damage caused by the traffic using the roads in that year. In practise this will only be the case under certain conditions. For example, the maintenance costs on a particular road in a given year will understate/overstate the damage caused by the traffic using the road in that year if the condition of the road is deteriorating/ improving.[29] We should also note that this approach yields estimates of the **average** infrastructure costs across all vehicles of each type using the road in

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[28] See DoT (1995) for example.

[29] DfT (2008a) suggests that in general the condition of the road network has been improving in recent years. However more reassuringly for this work it suggests that the condition of motorways has been broadly stable.

a given year. In the absence of any evidence to the contrary we have assumed that the average infrastructure costs estimated for articulated vehicles provide a reasonable approximation of the MEC – I of the vehicles removed by mode shift grants. Whilst acknowledging these limitations, we note that this is an established technique and one that we believe provides estimates of MEC – I that are fit for our purposes.

Local Air Pollution

104. Vehicle engines emit many types of air pollutants, including oxides of nitrogen (NO_x), particulate matter smaller than ten nanometres (PM_{10}), volatile organic compounds (VOCs) such as benzene and 1,3-butadiene, Carbon Monoxide (CO) and sulphur dioxides (SO_2). Brake and tyre wear can also cause pollution in the form of particulate matter. These pollutants can have health and environmental effects. The damage caused by these pollutants is location specific. In general, they tend to cause more damage in densely populated areas where more people are affected.

105. Additional HGV traffic creates additional air pollution in two ways. First, there are the pollutants that are emitted by the HGV itself - primarily through the consumption of fuel. Secondly the additional HGV traffic can affect the fuel consumption of, and therefore the amount of pollutants emitted by, other vehicles. We refer to the costs of this additional air pollution as the **Marginal External Costs – Pollution (MEC - P)**.

Method used to value MEC - P

106. We have based our estimate of MEC – P on outputs from the NTM. The NTM estimates the level of NO_x and PM_{10} emissions associated with each set of traffic forecasts it produces. For this work, we have used NTM runs for 2010, 2015 and 2025 (see section on congestion for details).

107. As explained earlier in this section, the NTM estimates the impact of additional traffic on average speeds using speed flow relationships. The model then uses the forecast average speeds and relationships between speed and NO_x and PM_{10} emissions similar to those recommended in TAG Unit 3.3.3: *The Local Air Quality Sub-Objective* to calculate the change in the emissions of these pollutants when the additional traffic is added to the road. The relationship between speed and NO_x and PM_{10} emissions varies through time to reflect changes in the makeup of the fleet.

108. We have valued the change in the emissions of each of these two pollutants caused by an additional articulated HGV kilometre using the values per tonne of NO_x and PM_{10} that were used in Defra (2007a) to yield an estimate of the MEC - P of HGVs. To reflect the fact that damage costs vary with local circumstances the costs per tonne of PM_{10} are differentiated by area type. The damage cost values provided by Defra increase by 2% per annum in real terms. Table 2 shows the damage cost values per tonne of NO_x and PM_{10} provided by Defra for 2010, 2015 and 2025, all expressed in 2010 prices.

Table 2: Damage cost values per tonne of NO_x and PM_{10} emissions (2010 prices)

Pollutant	**Area Type**	**2010**	**2015**	**2025**
NOx	**All**	£1651	£1823	£2222
PM_{10}	**Central London**	£482,367	£532,572	£649,202
	Inner London	£596,260	£658,319	£802,487
	Outer London	£342,865	£378,551	£461,451
	Metropolitan	£346,258	£382,297	£466,018
	Outer Conurbation	£115,803	£127,856	£155,856
	Urban Big	£198,883	£219,582	£267,670
	Urban Large	£139,513	£154,033	£187,766
	Urban Medium	£116,543	£128,673	£156,852
	Urban Small	£84,364	£93,145	£113,543
	Rural	£57,834	£63,853	£77,837

109. To reflect the variation in MEC – P across the road network (i.e. to reflect variation in the amount of pollution emitted by lorries as well as variation in damage costs) we have used the output of the NTM to estimate 43 separate MEC-C values. The values vary by combinations of the 10 area types and 7 road types used in the NTM. Please see annex C for details of the road and area types.

110. The NTM only estimates the impacts on NO_x and PM_{10} emissions and does not estimate the impacts on any of the other pollutants emitted by HGVs. Whilst DfT (2006) provides relationships between the other pollutants and journey speeds they are not currently incorporated within the NTM. We have examined the value of HGV emissions across a broader range of local air pollutants by taking emissions per tonne of fuel consumed from the National Atmospheric Emissions Inventory (NAEI) [30] and combining them with damage cost values per tonne of each pollutant provided by the Defra-led Interdepartmental Group on Costs and Benefits[31]. This work suggests that SO_2 causes damage costing the equivalent to around 0.2% that of NO_x emissions per litre of diesel burned. Further comparisons for Non-Methane VOCs and Ammonia suggest that the relative damage costs are around 4% and 0.1% compared with NO_x emissions. We have reflected this evidence by uplifting our estimates of the MEC – P by an amount equal to 4% of the external costs associated with NO_x.

Other External Costs

111. This category reflects a range of external costs that the Department's appraisal guidance requires scheme promoters to assess qualitatively in a full scheme appraisal. If a provision is not made to cater for these elements, the benefits of mode shift would be systematically undervalued.

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[30] See http://www.naei.org.uk/data_warehouse.php. We accessed the inventory in October 2008.

[31] This group provided the analysis to inform Defra's Air Quality Strategy paper. See http://www.defra.gov.uk/environment/airquality/panels/igcb/research/index.htm; values accessed in summer 2008.

112. Therefore, just as with the SLM values, we are including a provision for this. The external costs falling into this category are:

- Up and downstream processes[32]
- Soil and Water Pollution
- Nature and Landscape
- Driver frustration / stress
- Fear of accidents
- Community severance (i.e. restrictions on cycling and walking)
- Visual intrusion

113. Having been unable to draw on the NTM or WebTAG in valuing these impacts we have reviewed the existing literature to identify relevant material. Maibach et al. (2008) provides a useful overview of relevant European studies. It also provides exemplary values per vehicle kilometre for heavy goods vehicles in Germany in 2000 prices. The study provides estimates for all but one of the categories of external cost that we have already discussed.[33] In addition it provides values for three of the categories of external cost listed in paragraph 112 above. These include:

i. Up and downstream processes
ii. Soil and Water Pollution
iii. Nature and Landscape

114. The first of these – up and downstream processes – is described as referring to the indirect effects due to the production of energy, vehicles and transport infrastructure. The values provided cover the effects on air pollution and greenhouse gas emissions. The value placed on this category equate to about 5% of the total value placed on the categories of external costs we have valued. However the report points out that, of these costs, 60-70% actually relates to infrastructure use and so can be considered relevant to the calculation of ‘marginal’ external costs. This suggests that the value of the ‘marginal’ element of this category of costs is broadly equivalent to about 3% of the total value of the external costs we have already valued.[34]

115. The second category - Soil and Water Pollution – refers to the negative impacts of traffic on soil from the emission of heavy metals and polycyclic aromatic hydrocarbons (PAH). Pollutants lead to plant damage and decreased soil fertility alongside infrastructure. Maibach et al. (2008) suggest that the value of these costs is equivalent to about 2% of the total value placed on the categories of external costs we have already valued.

116. Finally the report explains that the third external cost category – Nature and Landscape – which is related to habitat loss and disturbance is primarily

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[32] The previous review, SRA (2003), refers to these impacts as upstream and downstream effects.

[33] The study does not cover infrastructure costs.

[34] The EU Greenhouse Gas Emissions Trading Scheme will serve to internalise some element of these costs. We have not adjusted the figures here because we have been unable to determine from Maibach et al. (2008) what proportion of these costs are associated with greenhouse gas emissions and therefore might be internalised.

related to infrastructure and not its use. Consequently this category of costs is not considered to be significant for marginal changes in road freight traffic.

117. In summary, the values provided in Maibach et al. (2008) suggest that at an aggregate level the value of these three categories of external cost might be equivalent to about 5% of the value of the impacts we have valued already. It is important to note, however, that Maibach et al. (2008) state that the values provided for Germany should not be applied elsewhere without first considering the need to adjust them for the specific situation in which they are to be used. Therefore we have only used the values to provide a broad indication of the scale of the impacts in relation to the other external costs we have already covered. Moreover it should be borne in mind that these values do not cover all of the external costs identified in paragraph 112.

118. To reflect the evidence identified in Maibach et al. (2008) and the fact that there are a range of other costs for which we have been unable to find quantified evidence, Ministers have decided that an uplift equivalent to 10% of the weighted average of the total value estimated for the other external costs already covered should be applied to the MSB values.

Marginal Taxation on Road Freight

119. As explained in section 2, freight operators pay taxes that internalise some of the marginal external costs of their road use. These taxes are in the form of vehicle excise duty (VED), which is paid annually and allows use of the public roads, and fuel duty which is paid on a per litre basis. Value added tax which is paid as a fixed percentage of the resource cost of fuel plus fuel duty is paid by freight operators but is not relevant here as it can later be reclaimed.

120. Here we are focusing on the additional tax paid by operators when they choose to increase the amount of freight they send by road by an amount equivalent to an additional lorry mile. This additional tax will include: 1) the additional fuel duty paid by the operator on its fuel consumption; and 2) the change in the amount of VED revenue paid by the operator as a result of any change in the number of vehicles it registers annually. We use the term **Marginal Taxation on Road Freight** to refer to the combination of these two sources of changes in taxation.

121. It is important to note the difference between the taxation paid by the operator of the marginal vehicle, which must be included in our valuation of the benefits of mode shift, and the change in taxation paid by the other vehicles, which should not be included. The key to understanding this is to note that whilst the operator of the marginal unit of freight will benefit from a reduction in the road taxation it pays when it transfers to an alternative mode there will be other costs that offset this benefit. The mode shift grant schemes ensure that, once the grant payment is factored in, the costs to the operator of using rail or water are the same as those it faces to use road. The fact that any operator who receives grant funding under the grant schemes is left indifferent between using road or the alternative mode means that the cost to the exchequer of a reduction in the taxation paid by the operator represents a net social cost. In contrast any change in the taxation revenue received by the exchequer from other road vehicles is exactly offset by changes in the tax paid by the road users themselves.

122. There is a second reason why we must take account of these taxation effects within the MSB values. As we use the values to compare the value for money of grant applications with other interventions, it is important that they are calculated in a way that is consistent with how value for money is assessed elsewhere. In assessing the value for money of other interventions we take account of changes in taxation revenue. Therefore we must also take account of these effects in assessing the value for money of mode shift grant applications. The simplest and most consistent way to do this is to include tax effects into the MSB values.

Method used to value Marginal Taxation on Road Freight

123. The NTM does not specifically model the impact of changes in traffic on taxation. Instead we have estimated the fuel duty element of the additional tax paid by the operators of the marginal HGV traffic indirectly by working backwards from the estimate of the carbon emitted by the marginal HGV traffic that is output by the model. We have calculated the change in VED revenue using NTM output alongside other data.

124. The first step in estimating the fuel duty paid by the marginal unit of HGV traffic was to estimate its fuel consumption. As explained in the section on climate change, the NTM implicitly estimates the fuel consumed by the marginal unit of HGV traffic when estimating its impact on carbon emissions. As the calculation is only implicit – the NTM does not output an estimate of the fuel consumed by the marginal HGV traffic - we have had to estimate the fuel consumed by working backwards from the estimate of the carbon emitted by the marginal HGV traffic that is output by the model. Specifically, we have translated the carbon emitted (in grams of carbon) into the quantity of diesel consumed (in litres) by dividing by the carbon content of diesel (in grams per litre) provided in TAG Unit 3.3.5: *The Greenhouse Gases Sub-Objective*. The assumed carbon intensities of diesel for 2010, 2015 and 2025 are shown in Table 3.

Table 3: Assumed carbon content of fuel and fuel duty rates

Year	Carbon content (grams per litre of diesel)
2010	696.23
2015	693.25
2025	690.26

125. Having estimated the quantity of diesel consumed by the marginal articulated HGV we have derived an estimate of the change in fuel duty paid by multiplying by the expected duty rate on diesel (in pence per litre). We have assumed that the rate of fuel duty remains fixed in real terms beyond the increases announced at the 2008 budget. This implies a rate of 55.7 pence per litre from 2010 onwards (in 2010 prices).

126. To calculate the change in VED paid by the operator of the marginal articulated HGV we have made the assumption that goods vehicles are used for a fixed number of hours per year. This is consistent with the assumption underlying the guidance on the calculation of non-fuel vehicle operating costs in TAG Unit 3.5.6: *Values of Time and Operating Costs*. The implication of this assumption is that marginal changes in goods vehicles' journey time will affect fleet size and therefore the amount of VED paid by operators.

127. Using 2007 total VED payments by articulated HGVs[35] and the NTM forecast of the total number of hours that those vehicles would be on the road, we were able to estimate the average VED payment per hour across all articulated HGVs. We have then used this to calculate the average VED paid per kilometre on different road types using the average speeds on each road type. In producing estimates for future years we have assumed that

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[35] The number of articulated HGVs licensed under different tax bands as of 31/12/07 were taken from the Driver and Vehicle Licensing Agency database; accessed by the Statistics Travel: Vehicle Licensing Statistics branch in the Department for Transport. The total amount of VED paid was then calculated using published VED rates by tax band as of October 2008 (http://www.direct.gov.uk/en/Motoring/OwningAVehicle/HowToTaxYourVehicle/DG_10012715)

articulated HGV Vehicle Excise Duty rates will remain constant in real terms at their current level. We have also assumed no change in the amount of time an average articulated HGV is in use or the proportion of articulated HGVs in each VED tax band.

128. Finally we have summed together the fuel duty, and change in the amount of VED paid to produce an estimate of the Marginal Taxation on Road Freight (expressed per lorry mile) . To reflect the variation in the taxation paid by lorries according to where they are added to the road network we have used the output of the NTM to estimate 43 separate marginal taxation values. The values vary by combinations of the 10 area types and 7 road types used in the NTM. Please see annex C for details.[36]

Net Costs of Rail and Water Freight

129. This component of the MSB values should represent the net social cost of adding a marginal amount of freight traffic to water or rail. As explained in section 2 this can be approximated as:

$$MEC_m - MT_m$$

Where

MEC_m = Marginal External Cost of freight on mode 'm', where m = {rail, water}
MT_m = Marginal tax on freight on mode 'm', where m = {rail, water}

130. In this review we have estimated the benefits of mode shift in terms of the benefits of shifting one lorry mile of freight from road to rail or water. Therefore in looking at the external costs of water and rail freight we have focused on deriving estimates of the marginal external costs of transporting additional freight equivalent to one lorry load, one mile.

Method used
131. The Department currently does not have the capacity to model the external costs of water and rail freight using an established transport model. However the Department is in the process of developing an evidence base that will be used to assess the external costs of these modes in the future. We have used this evidence to estimate the marginal external costs of rail and water and to estimate the extent to which these costs are internalised by taxation. In doing so we have tried as far as possible to ensure that the

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[36] As the amount of taxation is linked to average speeds it will also vary by congestion band. In principle we would have liked to reflect this. However the NTM output does not provide sufficient information to allow us to differentiate the marginal taxation by congestion band. WebTAG 3.5.6 suggests that lorries' fuel consumption is fairly stable across a wide range of speeds but is markedly higher at lower speeds. The implications of this is that basing the estimate of marginal taxation on the average speed of HGV traffic is likely to provide a reasonable indication of the taxation except where traffic is travelling at very low speeds.

method we have used is consistent with that used to estimate the marginal external costs of road freight.

132. In estimating the marginal external costs of increasing the amount of freight transported by rail and water by one lorry load we have had to consider what impact the additional freight would have on the number of trains / ships that travel. It is the case for both rail and water freight that the addition of a lorry load of freight to an existing service will have a less than proportionate impact on the total external costs of the freight train / vessel. However if we were to continue to shift freight onto rail or water there would come a point at which a new train / vessel would be required. At this point the additional lorry load of freight would have a more than proportionate impact on external costs. For this work we have assumed that the increase in freight induced by the mode shift grants is just as likely to result in an additional freight train / vessel being used as any other freight being sent by rail / water. This assumption allows us to focus on estimating the marginal external costs per train / vessel before dividing by the average amount of freight carried by such trains / vessels to derive an estimate of the marginal external costs per lorry load.

Water Freight

133. The available evidence on the external costs of water freight is limited. In 2004 one of the Department's maritime economists produced an internal paper summarising his attempts to estimate the marginal external costs of transporting freight by water. The paper presented estimates of the marginal external costs of water transport per vessel kilometre in 2000 prices and values for a range of different vessel types. The estimates cover the external costs identified to be the most significant in previous studies – local air pollution and climate change.

134. The paper went on to derive estimates of external costs per lorry mile equivalent by making assumptions about the average load of the vessel types they considered. It ultimately concluded that, whilst the marginal external costs of transporting freight by water are likely to vary significantly according to the vessel being used, they are likely to be broadly similar to the marginal external costs of rail freight movements (per lorry mile equivalent) on average. However the paper included caveats highlighting the fact that the assumed average vessel loads used to translate the estimates per vessel-kilometre to per lorry mile equivalent were based on assumptions made in the absence of comprehensive evidence.

135. The Department's current maritime economists are in the process of reviewing the calculations underpinning the 2004 paper in light of the latest evidence. However their work is not yet sufficiently advanced to allow them to confirm whether the conclusions reached by the previous work still stand.

136. We have therefore reviewed the literature to see what other studies can tell us about the marginal external costs of transporting freight by water. Maibach et al. (2008) provide an overview of the small number of relevant studies – focusing in particular on estimates of the marginal external costs of sending freight by inland waterways. They present the estimates of the

marginal external costs per vessel kilometre as a range and as a weighted average for European countries in 2000 prices. The values cover three categories of external cost – local air pollution, climate change and up and downstream processes (see section on Other External Costs for a definition) – but do not consider the extent to which these costs are internalised by taxation. The values per ship are broadly comparable with those presented in the 2004 DfT internal paper, and so give us more confidence in the conclusions it reached.

137. INFRAS (2004) presents estimates of the marginal external costs of waterborne freight per tonne kilometre. Like Maibach et al. (2008) the values reflect the external costs on inland waterways and the results are presented as European averages in 2000 values and prices. They cover the same range of external cost categories as are covered in the values presented in Maibach et al. (2008) and also do not consider taxation[37].

138. The values of marginal external cost presented in the report are based on very different values for the costs of greenhouse gas emissions and local air pollution than we have used in estimating the marginal external costs of road and rail freight. Therefore we believe it would be inappropriate to use the values in this work. However the report is useful in that it presents estimates of the marginal external costs of rail freight per tonne kilometre allowing comparison with the estimates presented for waterborne freight. The paper estimates the marginal external costs of waterborne freight as being equal to approximately 15 euros per 1000 tonne kilometres (in 2000 prices and values) whilst the estimates of the marginal external costs of rail freight range between 8 euros and 16 euros per 1000 tonne kilometres depending on the type of the freight train (with diesel trains to the top of this range).

139. It is clear that the evidence on the marginal external costs of water freight remains limited. On the basis of the evidence we have been able to obtain we believe there to be a strong case for continuing to assume, for the purposes of allocating freight grants, that the marginal external costs of water and rail freight movements per lorry mile equivalent are broadly similar. This approach will result in one set of MSB values being used for all mode shift grants.

Rail Freight

140. Maibach et al. (2008) provides a comprehensive overview of previous European studies that have attempted to estimate the marginal external costs of rail freight. The report suggests that many of the categories of marginal external cost that are relevant to road freight are also relevant for rail freight. It highlights air pollution, noise and climate change costs as being the most significant. We have focused on estimating values for these three categories of external cost and on estimating the extent to which taxation serves to

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[37] The marginal external costs values presented also include 'Nature and Landscape' costs. However the paper explains elsewhere that these costs are associated with new infrastructure and are therefore not relevant to the definition of marginal external costs used in this review.

internalise these costs. Our estimation of external costs is based on an assumption that the trains used for modal shift are diesel hauled.[38]

141. The approach we have taken to estimating the Marginal External Costs - Noise (MEC-N) of rail freight is the same as that we have used for road freight. Sansom et al. (2001) provided high and low estimates of the MEC-N per freight train kilometre in 1998 prices and values. We have taken the mean of these values and used it to derive values for 2010, 2015 and 2025 by assuming the MEC-N increase through time in line with GDP growth. Unlike for road the MEC-N values for rail freight provided by Sansom et al (2001) do not vary by area type or road type.

142. We have based our estimate of the Marginal External Costs – Climate Change (MEC-CC) per rail freight train kilometre on the assumption that the fuel consumption remains constant at 5.74 litres per kilometre for fully-loaded bulk trains, 3.73 litres per kilometre for an empty bulk train and 4.8 litres per kilometre for intermodal trains. These assumptions are based on evidence provided to Freight and Logistics Division's by freight operating companies.[39] We have translated the estimated fuel consumption of each type of freight train (in litres per kilometre) into an estimate of the carbon emitted per freight train kilometre by using the carbon intensities of fuel (in grams of carbon per litre) provided in TAG Unit 3.3.5: *The Greenhouse Gases Sub-Objective.* Finally, we have valued the carbon emitted per freight train kilometre by using the published Defra guidance on the shadow price of carbon – Defra (2007b).[40]

143. To be consistent with the approach we have taken for road freight, in estimating the Marginal External Costs – Pollution (MEC – P) we have focused on NO_x and PM_{10}. We have based our estimates on the assumption that the emissions of these gases per train kilometre remain constant at their 2006 levels reported in the National Atmospheric Emissions Inventory[41]. We have valued our estimates of NO_x and PM_{10} emitted per freight train kilometre using the values per tonne that were used in Defra (2007a). This is consistent with the approach we have taken for road freight. However in contrast to the road freight calculations, because of a lack of evidence, we have not used values that vary by area type.

144. Rail freight operators pay taxes on fuel which, to some extent, cover the external costs which they impose on others. We have used the latest gas oil duty rates announced at the time of the budget.[42] In deriving estimates

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[38] We recognise that a small proportion of freight funded traffic will be transported by electric traction. However this proportion is likely to be sufficiently small as to not significantly affect the value of rail external costs we have estimated.

[39] We have tested the sensitivity of our estimates to the use of alternative assumptions about the fuel consumption of bulk and intermodal trains.

[40] We have combined our estimates of the carbon emitted per train kilometre with assumptions about the typical number of lorries removed by a typical freight train (see paragraph 145) to derive estimates of the carbon emitted per lorry kilometre equivalent. This suggests that carbon emissions of rail freight are equal to between 25 and 30% of the average of road freight.

[41] See http://www.naei.org.uk/data_warehouse.php. (accessed October 2008)

[42] For details, please see http://www.hmrc.gov.uk/budget2008/bn71.pdf

beyond 2010 we have assumed that the duty on gas oil increases at the same rate as duty on road diesel. We have estimated the amount of duty paid per kilometre by multiplying the fuel consumptions of a bulk and intermodal freight train (in litres per kilometre) calculated as described in paragraph 142, by the duty rate per litre of fuel.

145. We obtained separate estimates of the marginal external costs per bulk and intermodal freight train kilometre by summing together the noise, climate change and local air pollution costs and subtracting the amount paid in fuel duty. In order to transform these into estimates of the marginal external costs of transporting additional freight equivalent to one lorry mile we have estimated the typical number of lorries removed by additional bulk and intermodal freight trains. Based on discussions with industry stakeholders we have assumed that a typical intermodal freight train used for modal shift removes thirty lorries from the road while a typical bulk train removes sixty lorries.

146. We have combined the estimates of the marginal external costs per lorry mile for bulk and intermodal by weighting by the proportions of total rail freight tonne kilometres that are bulk and intermodal. In doing so we have drawn on data from National Rail Trends[43] which suggests that in 2007, 76% of the freight transported by rail was bulk and 24% was intermodal. We recognise that the proportions of rail freight that are currently bulk and intermodal may not provide an accurate indication of the proportions of freight supported by grants in the future that is bulk and intermodal.[44] However we decided that a more detailed assessment of the type of traffic likely to be funded in the future would not be possible. We have rejected the option to include separate values for bulk and intermodal traffic on the basis that any increase in the accuracy of the MSB values would be outweighed by the added complexity for the Administering Bodies and grant applicants.

147. Maibach et al. (2008) provides exemplary values for the marginal external costs of rail freight for Germany in 2000 prices. As well as providing estimates for the three categories of external cost we have calculated it provides values for the following external cost categories:

i. Accident Costs
ii. Up and downstream processes
iii. Soil and water pollution
iv. Scarcity Costs

148. The first three of these categories of external cost are defined in the road freight section. Scarcity costs refer to the opportunity costs to service providers for the non-availability of paths. As freight operators must enter into

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[43] http://www.rail-reg.gov.uk/server/show/nav.1863 (data from version available as of 11th December 2008)

[44] Since 2001 intermodal traffic has received approximately 80% of grant funds and bulk traffic has received around 20%. We have not used these proportions because there are a number of reasons why the amount of bulk traffic receiving grant over the past few years is likely to significantly understate the amount in the future.

track access agreements with Network Rail these costs should, in principle, be internalised.[45] Therefore we don't intend to take account of any scarcity costs externality for freight trains. The values provided in Maibach et al. (2008) suggest that the value of the marginal element of the other three categories of cost might be equivalent to about 10% of the value of the marginal external impacts we have valued above.

149. For the reasons set out in paragraph 117 the values in Maibach et al. (2008) should not be seen as providing anything more than a broad indication of the scale of the impacts in relation to the other external costs of rail freight we have valued. To reflect the evidence identified in Maibach et al. (2008), the fact that some of the other costs identified in paragraph 112 are also relevant for rail, and to be consistent with the approach taken to reflecting the 'Other' external costs of road freight (see paragraph 118) the Administering Bodies have decided that an uplift equivalent to 20% of the weighted average of the total value estimated for the other external costs of rail should be applied to the MSB values.

150. It should be noted that these calculations are relatively broad brush and are subject to significant uncertainty. In particular in producing these estimates we have had to use evidence from a range of sources and have had to make a number of assumptions in the absence of suitable evidence. Nevertheless we have tested the sensitivity of the estimates to changes in the key assumptions and believe the values we have produced are fit for purpose.

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[45] We acknowledge that this may not be the case in practise. However as freight trains tend to run in the off peak periods any scarcity costs should be negligible.

Section 5 – Mode Shift Benefit Values

151. This chapter presents the values that are obtained from applying the approach described in the preceding two sections and explains how these have been used to derive the new MSB values that are to be used in the allocation of mode shift grants. For the reasons given in section 3 all values are for 2015 expressed in 2010 prices.

Input values

152. Sections 3 and 4 describe the approach we have taken to estimating the values of each of the components of the benefits of mode shift. They explain how we have attempted to reflect the way each of the components varies according to where on the network a lorry is removed. Table 4 shows how the estimated values for each component vary across combinations of the area types, road types and congestion bands used in the NTM. .

Table 4: Variation in components of mode shift benefits by area type, road type and congestion band (pence per lorry mile)[46]

	Congestion band	London and Conurbations			Other Urban		Rural		
		M'way	A-roads	Other roads	A-roads	Other roads	M'way	A-roads	Other roads
Congestion	1 (Low)	0	4	18	2	14	0	2	1
	2	1	19	64	10	51	1	6	11
	3	27	141	138	69	105	44	19	51
	4	171	571	553	230	434	201	265	230
	5 (High)	427	1374	1585	458	1396	695	734	924
Accidents	All	1	5	5	5	5	1	6	6
Noise	All	18	19	19	16	16	3	3	4
Pollution	All	3	8	8	5	5	2	2	2
Climate Change	All	4	6	5	5	5	4	4	4
Infrastructure	All	5	11	69	11	69	5	11	69
Other Road Costs	All	6	6	6	6	6	6	6	6
Taxation	All	-34	-38	-42	-33	-38	-35	-33	-32
Rail or Water costs[47]	All	-6	-6	-6	-6	-6	-6	-6	-6

Notes:
All values are 2015 values in 2010 prices
All values are in the factor cost unit of account

153. We have combined the estimated values for each of these components to produce a set of 26 'input values', reported in Table 5. The 26 input values vary across different combinations of the 10 area types, 7 road types and 5 congestion bands used in the NTM. Annex C provides details of the area

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[46] This is a summary of the values estimated for each of the components of mode shift benefits. The number of values we have produced to reflect the variation across the network varies across the components. For the components calculated using the NTM (congestion, climate change, pollution and marginal taxation on road freight) we have calculated values to a finer level of disaggregation than is shown in Table 4. Section 4 provides further details.

[47] This includes 'Other' rail and water costs

types, road types and congestion bands used in the NTM and shows how these have been combined to create the area type / road type combinations used in Table 5.

154. We decided to use a single input value for other (B, C and unclassified) roads in all areas. Not only did this make the values easier to use but was justified because the traffic data for these roads is subject to significantly greater uncertainty than other roads and because these roads account for such a small proportion of the distance travelled by lorries removed by modal shift (and so the added simplicity should not come at the expense of any significant loss in accuracy). We derived the single value by taking a weighted average of the values for these roads across all the congestion band and area type combinations, weighted by the lorry flow in each.

Table 5: Input values (pence per lorry mile)

Congestion band	London and Conurbations		Other Urban	Rural		All areas
	Motorway	A-roads	A-roads	Motorway	A-roads	Other roads
1 (Low)	-4	17	12	-20	-5	143
2	-3	31	20	-19	-1	
3	23	153	78	24	13	
4	167	583	239	180	258	
5 (High)	423	1386	467	674	727	
Weighted average[48]	*31*	*389*	*149*	*12*	*9*	*143*

Notes:
All values are 2015 values in 2010 prices
All values shown in the factor cost unit of account
Negative values indicate that the amount the road freight operators pay in tax exceeds the external costs imposed on the rest of society. The level of freight traffic on roads falling into these categories will be below its efficient level so that there would be a social cost associated with modal shift to other modes.

155. As explained in section 3, it is not possible to use these ‘input values’ directly in the allocation of mode shift grants. This is because the congestion band that a particular road link falls into varies by time of day and consequently the appropriate value for each link also varies by time of day (because the values vary by congestion band). As mode shift grant applications cannot identify the time of day that lorries are removed from the network we have had to use the input values to estimate average values for each link. We refer to the values in Table 5 as ‘input values’ to distinguish them from the final values which are to be used by the Administering Bodies in allocating freight grants, referred to simply as ‘MSB values’.

MSB values

156. In order to use the ‘input values’ to estimate the average benefit of removing a lorry from individual links we have used NTM congestion forecasts. More specifically we have used congestion forecasts[49] by time of

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[48] Weighted by the proportions of annual articulated traffic kilometres in each congestion band

[49] These are expressed as the ratio between the forecast traffic flow and the maximum flow the link is theoretically designed to handle (or volume to capacity ratios).

day and by direction[50] for all the individual motorway and A-road links in Great Britain[51]. We have then assigned each road link in each direction at each time of day the appropriate input value from Table 5. This provides us with separate values for each of the 19 time periods used in the NTM, for each road link. We have calculated the average value of removing a lorry from each road link by taking the weighted average across these 19 time periods, weighting by the articulated lorry flow in each time period on each link. Annex F describes the calculation in more detail. This provided us with individual values for all 17,500 links of the A road and motorway network in Great Britain. We refer to these as ‘link level’ values.

157. These link-level values form the basis of the MSB values that are to be used in applications for mode shift grant. In principle it would be possible to use the link-level values to calculate the total benefit of removing lorries from particular routes directly. Indeed this would best reflect the evidence from the NTM and allow us to estimate the likely benefits of mode shift at a very high level of detail. However, there would be a significant risk of spurious accuracy as the data underlying the NTM is designed to be accurate at the area type and road type level of detail. The level of uncertainty in the forecasts at an individual link level is high. For example, for many links road traffic counts are taken on only one day of the year with expansion factors applied (calculated from automatic continuous counts on a small number of links) to give yearly data. This may result in distortions which undermine the accuracy of this method.

158. There are other reasons why we have decided not to use the link-level values directly in allocating mode shift grants. As every road link attracts a different value there would be no way to summarise the values applied to different parts of the network without reference to a detailed map. This would reduce transparency to potential applicants. In addition the calculation of benefits would require specialist software that would be costly for the Administering Bodies to develop and maintain.

159. We considered a range of alternative options for segmenting the road network that avoid the disadvantages associated with directly using the link-level values. Each of the alternative options considered represents a different approach to aggregating the link level values, such that whilst the value placed on the mode shift benefits for a given application vary across the options, the weighted average MSB value, weighted across all road links, remains the same.

160. In choosing between the options it has been necessary to strike a balance between accurately reflecting the evidence, ensuring administrative simplicity and a range of other factors. The Administering Bodies have chosen a relatively simple option, which segments the road network into four

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[50] The NTM uses a ‘busy’ and ‘non-busy’ direction, which may change during the day.

[51] There are 1,031 modelled motorway links and 16,625 A-road links in the NTM. This link-level information has been used by the Department for Transport in the past, for example, to underlie information presented in the Eddington Transport Study (see Figure 6 : Congestion on the road network, Great Britain, 2003).

road types. The new MSB values using these four road types are presented in Table 6.

Table 6: MSB values to be used between 2010 and 2015 by road type (£ per lorry mile)

Motorways	**Low benefit**	£0.07
	High benefit	£0.86
All A-roads		£0.74
All other roads		£1.43
Weighted average[52]		£0.44

Notes:
All values are 2015 values in 2010 prices
All values shown in the factor cost unit of account

161. There are two values for motorways: a standard value for most motorways and a high value for those sections of motorway with the highest link-level values. The links identified as having the highest values have been grouped to create a manageable number of continuous ‘high benefit’ parts of the motorway network (for example, the whole of the M25). We then calculated a MSB value for these high benefit motorway links along with a MSB value for all other (low benefit) motorway links. A list of the parts of the motorway network that fall into the high benefit category can be found in Annex G. There is then a single value for all A-roads and a further value for all other roads (including all B, C and unclassified roads).

162. Whilst this option does not reflect the evidence from the NTM as well as some of the other options considered, it avoids many of their disadvantages. It avoids the risk of spurious accuracy and the need for the Administering Bodies to develop and maintain specialist software to assist applicants in calculating the value of mode shift benefits. It also provides publishable rates and should help to minimise the costs to applicants and Administering Bodies in using the values.

163. Tables 7a and 7b disaggregate the new MSB values into each of the components discussed in section 4.

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[52] Weighted by the proportions of articulated traffic kilometres in each category

Table 7a: MSB values by road type and component (pence per lorry mile)

	Motorway		A roads	Other roads	Weighted average[53]
	High	**Low**			
Congestion	100.2	24.1	75.9	85.2	52.4
Accidents	0.5	0.5	5.7	5.6	2.8
Noise	8.6	6.0	7.2	9.1	7.0
Pollution	1.9	1.8	3.3	3.8	2.5
Climate Change	3.6	3.6	4.2	4.2	3.8
Infrastructure	4.7	4.7	10.8	68.7	9.0
Other (road)	6.4	6.4	6.4	6.4	6.4
Taxation	-34.4	-34.5	-33.6	-34.8	-34.1
Rail or Water costs	-5.7	-5.7	-5.7	-5.7	-5.7
Total	**86**	**7**	**74**	**143**	**44**

Notes:
All values are 2015 values in 2010 prices
All values shown in the factor cost unit of account
The values in the 'Total' row are rounded to the nearest penny

Table 7b: Net costs of Rail Freight by component (pence per lorry mile)

Noise	2.6
Pollution	2.2
Climate Change	1.3
Other	1.2
Taxation	-1.7
Total	**5.7**

Notes:
All values are 2015 values in 2010 prices
All values shown in the factor cost unit of account
For the purposes of allocating grants we have concluded that the net costs of water and rail freight (per lorry mile equivalent) are broadly similar. However we would not expect the way the net costs of water freight to be distributed across the components in Table 7b to be the same as for rail freight. See paragraphs 129 to 150 for further details.

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[53] Weighted by articulated goods vehicle kilometres and their use of the road network

Section 6 Concluding Remarks

164. This paper has summarised our review of the Sensitive Lorry Mile (SLM) values. It describes the methods we have used in producing new ‘Mode Shift Benefit’ (MSB) values to replace the SLM values, and presents the new values themselves.

165. Our work has focused on producing new values that are consistent with the Department's latest traffic forecasts and published appraisal guidance. We have also reviewed a wider range of literature in considering how to handle factors that are not yet taken into account in WebTAG or the NTM. We have taken the Department's guidance as given and have not attempted to identify weaknesses in the forecasts or WebTAG guidance. In practise there is significant uncertainty surrounding both the forecasts and the parameters provided in WebTAG. The Department's transport modelling and WebTAG guidance are continuously evolving to reflect advances in transport modelling techniques and emerging research evidence.

166. The main objective of this paper is to be transparent in explaining the methods that we have used to derive the new MSB values. Having subjected earlier drafts of this paper to the scrutiny of stakeholders and peer reviewers we are confident that the methods we have used, and values they provide, are fit for purpose.

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TAG Unit 3.3.2: *Noise*
TAG Unit 3.3.3: *The Local Air Quality Sub-Objective*
TAG Unit 3.3.5: *The Greenhouse Gases Sub-Objective*
TAG Unit 3.4.1: *The Accidents Sub-Objective*
TAG Unit 3.5.4: *Cost Benefit Analysis*
TAG Unit 3.5.6: *Values of Time and Operating Costs*
TAG Unit 3.5.9: *The Estimation and Treatment of Scheme Costs*
TAG Unit 3.9.5: *MSA: Road Decongestion Benefits*

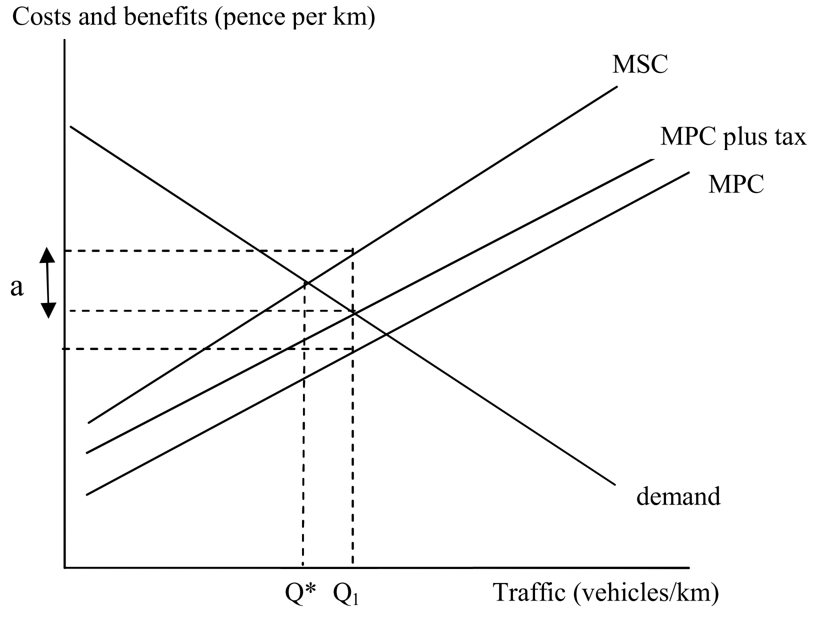
Annexes

Annex A The benefits of mode shift with partially internalised marginal external costs.

1. The efficient allocation of a resource, road space for example, requires that the costs faced by users, including any taxes, are equal to the costs their use of the resource imposes on society. In economics the additional costs incurred by users, excluding taxes, are generally referred to as 'marginal private costs' whilst the total additional costs imposed on society are referred to as 'marginal social costs'. These 'marginal social costs' include the 'marginal private costs' but also include any 'marginal external costs' - the additional costs the use of a resource imposes on others in society.

2. In order for the costs faced by freight operators, including tax, to be equal to the costs they impose on society, the additional tax they face must be equal to the value of the marginal external costs, or equivalently, the tax must fully internalise the marginal external costs. Where taxes only partially internalise external costs the market will deliver an inefficiently high level of freight traffic. There will be social benefits to reducing the level of freight traffic and social costs to increasing it. This is illustrated in figure 1.

Figure 1: Partially internalised externalities and efficiency[54]



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[54] Please note that this diagram is purely illustrative and the shape of the lines should not be taken to accurately represent their true shape.

3. In figure 1 the marginal private costs, marginal private costs plus marginal taxation and marginal social costs at each level of traffic are shown by the lines labelled ‘MPC’, ‘MPC plus tax’ and ‘MSC’ respectively. The demand curve represents the social benefits generated by additional freight traffic.[55] The vertical distance between the MSC and MPC lines is equal to the value of marginal external costs.

4. The market equilibrium occurs at the point where the costs of transporting additional freight faced by operators, including tax, equal the additional benefits they receive. In figure 1 this occurs at traffic level Q_1 - the point at which the lines labelled ‘MPC plus tax’ and ‘demand’ intercept. This is above the efficient level of freight traffic, labelled Q*. At Q_1 marginal social costs exceed marginal social benefits (labelled demand).

5. This means that a marginal reduction in the level of freight traffic will reduce total social costs (given by the area under the MSC line) more than it will reduce total social benefits (given by the area under the demand line). Conversely a marginal increase in the level of freight traffic will increase total social costs more than it will increase social benefits.

6. In general the net social benefit / cost of a change in the level of freight traffic is equal to the difference between the change in social costs and social benefits.[56] For marginal changes in traffic this benefit / cost is equal to the difference between the value of the marginal external costs and the marginal tax at the existing level of traffic. In terms of figure 1 this is equal to the difference between marginal social cost and ‘marginal private costs including taxes’ at traffic level Q_1 – the distance labelled a.

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[55] In figure 1 it is assumed that all the benefits associated with road freight accrue to the road users themselves. In other words it is assumed that there are no significant external benefits to road freight such that marginal private benefits are equal to marginal social benefits.

[56] In fact by significantly reducing congestion levels for other road users non marginal changes in road freight will lead to increases in other types of road traffic (i.e. induced traffic). Any consideration of non-marginal changes in road freight traffic should, therefore, also consider the net social costs of increases in other forms of road traffic.

Annex B Use of MSB values: Example

1. This annex provides an overview of the how the new values will be used. The Administering Bodies will provide further detailed guidance later in 2009.

2. If a grant applicant proposes to remove a lorry journey, the applicant must identify a route and then calculate the external benefits of a lorry journey removed from that route. It is appropriate that routing software is used to do this. The following is an example, based on the current routing software that is available on the Department for Transport web site[57].

3. Consider a firm moving material by road from a notional location in Tonbridge to Andover. The alternative routing (by rail in this case) has a short road leg at one end between Winchester and Andover.

4. By inputting the origin and destination into the software a route broken down by road type is created. A summary of this output between Tonbridge and Andover is shown below.

Tonbridge Andover
Distance: 92.7 miles

Cumulative Distance		**MSB Road Type**	**Road**	**Section Distance**	**Direction**
0	Depart On	O	B2260	0.5	Northeast
0.5	Continue straight on	A	A227	0.1	North
0.6	Bear left onto	O	B245	4.2	Northwest
4.7	Bear left onto	A	A225	0.2	South
4.9	Turn left onto	A	A21	4.3	Northwest
9.2	Continue straight on	M(H)	M25	35.9	Northwest
45.2	Continue straight on	M(L)	Unknown Road	0.7	Northwest
45.8	Continue straight on	M(L)	M3	31.2	Southwest
77	Continue straight on	A	A303	14.5	Southwest
91.6	Turn Right Onto	A	A3057	1	North
92.6	Turn left onto	O	B3402	0.1	West
92.6	Bear Right Onto	O	Junction Road	0.1	North
92.7	Turn left onto	O	Osborne Road	0	West
92.7	Arrive at destination	O	Osborne Road		No Direction

5. Based on the distance travelled on each type of road, a value is calculated for each lorry journey removed from the network. In this case the value is £ 54.99.

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[57] This can be found at www.dft.gov.uk/eb-calculator/

Road Type	Miles	MSB value (per mile)	Total Value
Motorway [58] (High Benefit)	35.9	£0.79	£28.36
Motorway (Low Benefit)	67.8	£0.07	£4.75
A Roads	20.1	£0.74	£14.87
other	4.9	£1.43	£7.01
			£54.99

6. As there is a new road journey from a terminal (in Winchester) to Andover, there is an cost associated with this that needs to be taken into account. The route for this is identified and valued in the same way as above. In this case the value given is £ 14.33. This is made up of 12.8 miles travelled on A roads and a further 3.4 miles travelled on other roads.

Cumulative Distance		MSB Road Type	Road	Section Distance	Direction
0	Depart On	O	St George's Street	0	Northwest
0.1	Continue straight on	O	B3404	0.4	Northwest
0.5	Turn Right Onto	O	B3044	0.1	North
0.6	Continue straight on	O	B3420	2.4	North
3	Continue straight on	O	Three Maids Hill Roundabout	0.1	Northwest
3.1	Bear left onto	O	Unknown Road	0.2	Northeast
3.3	Continue straight on	A	A34	4.9	Northwest
8.2	Bear left onto	A	Unknown Road	0.3	Northwest
8.5	Bear left onto	A	A303	6.6	West
15	Turn Right Onto	A	A3057	1	North
16.1	Turn left onto	O	B3402	0.1	West
16.1	Bear Right Onto	O	Junction Road	0.1	North
16.2	Turn left onto	O	Osborne Road	0	West
16.2	Arrive at destination		Osborne Road		No Direction

7. Therefore the estimated net external benefit of moving from the road journey to a road and rail journey is £ 54.99 minus £14.33, equal to £40.66 per lorry journey removed. An implicit assumption within this calculation is that the rail distance is equal to the difference between the all road journey and the road leg of the road-rail journey. That will not always be the case.

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[58] See Annex G for a list of the motorway links that are included in the high category

Annex C Definitions

NTM Road and area types

1. This Annex contains information and tables explaining the definitions of terms used in the NTM. The relevant sub-model of the NTM is the road capacity and cost model, called FORGE (Fitting On of Regional Growth and Elasticities). This annex uses the information published in the annex to TAG Unit 3.13.2: *Guidance on Rail Appraisal: External Costs of Car Use* of the Department's Appraisal Guidance.

2. Table 8 shows the area type codes that FORGE uses and table 9 gives a detailed breakdown of the components of these area types. Table 10 contains the road types.

Table 8: FORGE area type codes

FORGE area type	Description	Population
1	Central London	
2	Inner London	
3	Outer London	
4	Inner conurbation	
5	Outer conurbation	
6	Urban big	> 250,000
7	Urban large	> 100,000
8	Urban medium	> 25,000
9	Urban small	> 10,000
10	Rural	

Table 9: FORGE area types

1. Central London	City of London, Westminster south of Westway, and a few adjacent wards of neighbouring boroughs.
2. Inner London	Remainder of: Westminster, Camden, Islington, Kensington & Chelsea, Lambeth, Southwark. All of: Hackney, Hammersmith & Fulham, Haringey, Lewisham, Newham, Tower Hamlets, Wandsworth.
3. Outer London	Barking & Dagenham, Barnet, Bexley, Brent, Bromley, Croydon, Ealing, Greenwich, Harrow, Havering, Hillingdon, Hounslow, Kingston-upon-Thames, Merton, Redbridge, Richmond upon Thames, Sutton, WalthamForest.
4. Inner conurbation	Cities of Birmingham, Manchester, Liverpool, Sheffield, Leeds, Newcastle Upon Tyne and Glasgow.
5. Outer conurbation	Remainder of former Metropolitan counties: i.e. rest of West Midlands, rest of Greater Manchester, rest of Merseyside,

	rest of South Yorkshire, rest of West Yorkshire, rest of Tyne & Wear and the Greater Glasgow area (including Kirkintilloch, Airdrie, Wishaw, East Kilbride, Paisley, Erskine and Milngavie).
6. Urban big	Blackpool, Bournemouth, Brighton, Bristol, Cardiff, Edinburgh, Hull, Leicester, Middlesbrough, Nottingham, Plymouth, Portsmouth, Southampton, Stoke.
7. Urban large	Aberdeen, Basildon, Blackburn, Cheltenham, Colchester, Derby, Dundee, Gloucester, Ipswich, Luton, Milton Keynes, Newport(Gwent) Northampton, Norwich, Oxford, Peterborough, Preston, Reading, Slough, Southend, Swansea, Swindon, Telford, Torbay, Warrington.
8. Urban medium	Abbots Langley, Abingdon, Accrington, Aldershot & Farnborough, Alfreton & Heanor, Amersham & Chesham, Ashford, Ashtead, Aylesbury, Ayr, Banbury, Banstead, Bargoed & Newbridge, Barnstaple, Barrow, Barry, Basingstoke, Bath, Bedford, Bedworth, Belper & Duffield, Bexhill, Billericay, Bishop Auckland, Bishop's Stortford, Blyth & Cramlington, Bognor Regis, Boston, Bracknell, Bradford & Trowbridge, Braintree, Brentwood, Bridgend, Bridgwater, Bridlington, Bromsgrove, Buckhaven & Leven ,Burnley & Padiham, Burton upon Trent, Bury St Edmunds, Bushey Heath, Camberley & Frimley, Camborne & Redruth, Cambridge, Cannock, Canterbury, Canvey Island, Carlisle, Caterham & Warlingham, Chatham, Chelmsford, Chertsey, Chester, Chesterfield, Chippenham, Chipping Sodbury, Chorley, Clacton/Frinton/Walton, Cleethorpes, Clevedon & Backwell, Codsall & Wombourne, Congleton, Consett & Stanley, Conwy & Llandudno, Corby, Crawley, Crewe & Nantwich, Cumbernauld, Cwmbran, Darlington, Dartford, Deal, Dover, Dumbarton & Alexandria, Dunfermline, Durham, East Grinstead, Eastbourne, Eastleigh, Egham, Ellesmere Port, Epping/Loughton/Chigwell, Epsom & Ewell, Exeter, Exmouth, Falkirk & Grangemouth, Falmouth, Farnham, Fleet, Gillingham, Glenrothes, Glossop, Grantham, Gravesend, Grays & Ockenden, Great Malvern, Great Yarmouth, Greenock & Port Glasgow, Grimsby, Guildford,, Hailsham & Polegate, Harlow, Harpenden, Harrogate, Haslingden & Rawtenstall, Hassocks & Burgess Hill, Hastings, Hatfield & Welwyn, Hartlepool, Haywards Heath, Hemel Hempstead, Hereford, Herne Bay & Whitstable, High Wycombe, Hinckley, Hitchin/Letchworth/Baldock, Hoddesdon/Cheshunt, Horsham, Hucknall, Hythe/Folkestone, Ilkeston, Inverness, Kettering, Kidderminster, Kilmarnock, King's Lynn, Kirkcaldy, Lancaster, Lancing, Leatherhead, Leighton Buzzard, Leyland, Lichfield, Lincoln, Littlehampton,, Livingston, Llanelli, Loughborough, Lowestoft, Lymington/New Milton, Macclesfield, Maidenhead, Maidstone, Mansfield, Margate, Marske/Saltburn/Brotton, Merthyr Tydfil, Mold/Buckley, Neath, Nelson/Colne, Newark, Newbiggin/Bedlington, Newbury, Newhaven & Seaford, Newton Abbot, Northwich, Nuneaton, Ormskirk/Skelmersdale, Penarth, Perth, Peterhead, Peterlee, Pontypridd, Port Talbot, Radlett/Elstree/Borehamwood, Rainham/Wigmore, Ramsgate/Broadstairs, Rayleigh/Rochford, Redditch, Reigate, Rhyl/Prestatyn, Rickmansworth, Rochester, Rugby, Runcorn, Salisbury, Sandown & Ventnor, Scarborough, Scunthorpe, Seaham, Sheerness, Shildon/Newton Aycliffe, Shrewsbury, Sittingbourne, South Oxhey, Spennymoor/Coxhoe, St Albans, St Neots, Stafford, Staines/Sunbury, Stanford-le-Hope, Stevenage, Stirling, Stroud/Nailsworth, Sutton/Kirkby, Swadlincote, Tamworth, Taunton, Tonbridge, Tunbridge Wells, Waltham Abbey, Walton/Weybridge/Esher, Warwick & Leamington Spa, Watford, Wellingborough, Weston-super-mare, Weymouth & Portland, Whitehaven, Widnes, Wilmslow, Winchester, Windsor, Winsford, Witham, Woking, Wokingham, Worcester, Worksop, Worthing, Wrexham, Yateley, Yeovil, York.

Table 10: FORGE road codes

Road type	**London & conurbations**	**Other urban**	**Rural**
1	Motorway	n/a	Motorway
2	n/a	n/a	Trunk Dual A
3	n/a	n/a	Principal Dual A
4	Trunk A	Trunk A	Trunk Single A
5	Principal A	Principal A	Principal Single A
6	B & C Roads	B & C Roads	B Roads
7	Unclassified	Unclassified	C & Unclassified

3. Table 11 shows how the area types and road types in FORGE have been combined to create the combinations used in Table 5 in section 5. All motorways outside conurbations are assumed to be in rural areas for the purposes of the model. For example, A-roads in rural areas includes the 4 A-road categories used in FORGE: trunk and principle, dual and single A-roads.

Table 11: Specification of Conurbations, Other Urban, Rural, Motorways, A roads and B&C roads in terms of FORGE area and road type codes

FORGE Area Type	**Conurbations 1 to 5**			**Other urban 6 to 9**			**Rural 10**		
FORGE Road Type	M’ways 1	A roads 4 and 5	Other roads 6 & 7	M’ways n/a	A roads 4 and 5	Other roads 6 & 7	M’ways 1	A roads 2 to 5	Other roads 6 & 7

NTM Congestion bands

4. The congestion bands used in FORGE are defined in terms of the volume to capacity (or v/c) ratio of a traffic link. The volume (v) is the actual traffic flow and the capacity (c) is the theoretic maximum traffic flow. These can be expressed in terms of vehicle (or PCU (passenger car unit)) per time period per road (or lane) length. Table 12 shows how the congestion bands relate to the ratios.

Table 12: FORGE congestion bands

Congestion band	**Volume / capacity**
1	$v/c < 0.25$
2	$0.25 < v/c < 0.5$

3	0.5 < v/c < 0.75
4	0.75 < v/c < 1
5	v/c > 1

5. When assigning traffic to the v/c bands the process assumes ’average network’ lane capacities. However, depending on local conditions, the actual capacity of a link may be somewhat more or less than the capacity assumed at the site. In some cases actual flows may exceed the theoretical capacity of a link and lead to v/c ratios in excess of 1.
6. The unit used to describe traffic volume and road capacities is a PCU, passenger car unit. A passenger car unit (PCU) is a parameter used to measure the relative amount of road space used by and the congestion caused by different vehicles types relative to a passenger car (cars are given a PCU value of 1). Table 13 shows the PCU factors used for different vehicle types in FORGE. A passenger car unit (PCU) is a parameter used to measure the relative amount of road space used by and the congestion caused by different vehicles types relative to a passenger car. Cars are given the value 1.

Table 13: FORGE PCU factors by vehicle type

Vehicle Type	PCU Factor
Car	1.0
Light goods vehicle	1.0
Rigid goods vehicle	1.9
Articulated goods vehicle	2.9
Public service vehicle	2.5

NTM Time Periods

7. FORGE uses 19 time periods, which are summarised in table 14.

Table 14: FORGE time periods

FORGE Period Number	Day and time	FORGE Period Number	Day and time
1	Mon-Fri 00:00-06:00	11	Mon-Fri 22:00-24:00
2	Mon-Fri 06:00-07:00	12	Saturday 00:00-09:00
3	Mon-Fri 07:00-08:00	13	Saturday 09:00-14:00
4	Mon-Fri 08:00-09:00	14	Saturday 14:00-20:00
5	Mon-Fri 09:00-10:00	15	Saturday 20:00-24:00
6	Mon-Fri 10:00-16:00	16	Sunday 00:00-10:00

7	Mon-Fri 16:00-17:00	17	Sunday 10:00-15:00
8	Mon-Fri 17:00-18:00	18	Sunday 15:00-20:00
9	Mon-Fri 18:00-19:00	19	Sunday 20:00-24:00
10	Mon-Fri 19:00-22:00		

Road and area types used in Sansom et al. (2001)

8. In calculating some of the components of the new MSB values we have drawn on the evidence produced as part of the work to produce Sansom et al. (2001). The area types and road types used by Sansom et al. (2001) are very similar to those used in the NTM. They use three road types; ‘motorways’;’ trunk and principal’; and ‘other’. The area types used are identical to those shown in Table 8, except for urban small which in Sansom et al. (2001) was split into two sections. In this work we have included both categories used in Sansom et al. (2001) under the urban small category by taking simple averages.

Annex D Method used to calculate change in fuel duty paid by other vehicles

1. The NTM outputs the effect on carbon emitted by all other vehicles by the addition of the marginal HGV. The NTM does not output the impact on the fuel consumption of other vehicles and does not breakdown the total change in carbon emissions by vehicle type or fuel type. In order to calculate the change in duty paid by other vehicles it is necessary to work backwards from the change in carbon produced by other vehicles to estimate the change in fuel consumption, split by fuel type. This annex describes the approach we have employed to do this.

2. For each model run the NTM outputs the total carbon emitted broken down across five vehicle types (cars, vans, Rigids, Artics and buses). This can be used to find the proportion of all carbon emitted by each vehicle type. In the absence of any more appropriate data we have assumed that these proportions also apply to the change in carbon emitted by other vehicles associated with a marginal increase in HGV traffic. By making this assumption we can subdivide the change in carbon into the change in carbon emitted by cars, vans, rigid HGVs, articulated HGVs and buses.

3. For simplicity we have assumed that all HGVs and buses are powered by diesel fuel. Things are more complicated for cars and vans as it is necessary to subdivide the change in carbon emitted according to whether it is emitted by a petrol or diesel vehicle (to reflect the fact that carbon content varies for petrol and diesel).

4. We have split the change in carbon emissions from cars and vans into those emitted from petrol and diesel vehicles by using the average fuel consumption for petrol and diesel cars (in litres per km), provided in TAG Unit 3.5.6: *Values of Time and Operating Costs*, and the carbon intensities of petrol or diesel (in grams per litre) provided in TAG Unit 3.3.5: *The Greenhouse Gases Sub-Objective* to derive estimates of the average carbon emitted, in grams per km travelled, for cars and vans of each fuel type. We then combined these estimates with the proportions of total car and van distance travelled that are done by petrol and diesel vehicles, provided in TAG Unit 3.5.6: *Values of Time and Operating Costs*, to estimate the proportion of total carbon emitted from cars and vans that is from petrol and diesel fuelled vehicles. As before, in the absence of any more appropriate date we propose to assume that these proportions can be applied to the change in carbon emitted by cars and vans associated with a marginal increase in HGV traffic.

5. We have translated the change in carbon emitted by vehicles of each fuel type into the change in the amount of each fuel consumed by dividing by the carbon content of each fuel (in grams per litre) from TAG Unit 3.3.5 *The Greenhouse Gas Sub-Objective.* We have then multiplied the changes in the amount of each fuel consumed by the

appropriate duty rate for each fuel (in pence per litre) given in TAG Unit 3.5.6 *Values of Time and Operating Costs*.

6. This process was applied to the data from each of the 43 area type and road type combinations in the NTM, giving for each combination an implied change in duty paid by other vehicles per lorry kilometre. It is not possible to do this process by congestion band because the NTM does not output marginal changes in carbon emissions by congestion band. Therefore we have used the implied changes by the 43 area type and road type combinations to calculate a percentage adjustment to apply to the congestion figures for each congestion band.

Annex E Method used to estimate Marginal External Costs – Infrastructure (MEC – I)

Step1 Disaggregate published maintenance costs into 12 expenditure categories across 4 road types

1. We have used data on maintenance expenditure presented in DfT (2008a). In order to smooth out the annual variation in maintenance costs data we have used the average of the maintenance costs data provided for 2004-05, 2005-06 and 2006-07. The maintenance cost data is for England and is provided for three road types (trunk, principal and other) disaggregated into two cost categories - Structural Maintenance and Routine Maintenance[59].

2. In order to follow the approach used by Sansom et al (2001) it was necessary to further disaggregate the data by splitting up the maintenance costs on trunk roads into two categories - motorway and other trunk - and by disaggregating the structural and maintenance costs on each road type into 12 cost categories. In the absence of sufficiently disaggregated data for the period 2004 to 2007 we have disaggregated the costs using the 1998 data that was used in Sansom et al. (2001). Table 15 provides details of the proportions of the total structural and routine expenditure, on each road type, that have been assumed to fall into each of the 12 cost categories. For example, this shows that 21% of the total structural maintenance costs on motorways are assumed to be spent on long-life pavements.

Table 15: Allocation of Structural and Routine Maintenance Costs: classified by cost category

Structural Maintenance Costs

	Road Type				
Cost Category	Description	Motorway	Trunk	Principal	Other
1	Long-Life Pavements	21%	5%	0%	0%
2	Resurfacing	34%	8%	0%	64%
3	Overlay	30%	54%	60%	0%
4	Surface dressing	0%	8%	14%	0%
5	Patching and minor repairs	3%	5%	6%	24%
6	Bridges and remedial earthworks	12%	19%	20%	12%
Total %		100%	100%	100%	100%

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[59] Please note that we have based this analysis on data for England only, as cost data is not available for Scotland or Wales in a form consistent with the data for England. Sensitivity tests suggest that including Scottish and Welsh data on traffic and maintenance costs would not significantly affect the estimated MEICs we have derived.

Routine Maintenance Costs

		Road Type			
Cost Category	Description	Motorway	Trunk	Principal	Other
7	Drainage	7%	7%	7%	11%
8	Footways, cycle tracks & kerbs	20%	20%	20%	41%
9	Fences and barriers	3%	3%	3%	2%
10	Verges, traffic signs and crossings	43%	43%	44%	23%
11	Sweeping and cleaning	21%	21%	21%	20%
12	Road markings	6%	5%	6%	3%
Total %		100%	100%	100%	100%

Step 2 Allocate the costs for each of the 12 cost categories across 'cost drivers'

3. This step involves allocating the maintenance costs in each category across a number of 'cost drivers'. These 'cost drivers' represent the different characteristics of traffic that contribute to damage to the road network. We have followed the allocation method originally developed by the Department and more recently used in Sansom et al. (2001). Table 16 shows the proportion of each of the 12 cost categories that is allocated to each of the following three cost drivers:

- Average gross vehicle weight kilometres (AvGWt-km). This is obtained by multiplying the distance travelled (in vehicle kilometres) by each vehicle type by its average weight and summing across all vehicle types. It is used to allocate costs which are dependent on the total weight of vehicles, such as bridge maintenance;
- Standard axle kilometres (SA-km). This is obtained by multiplying the PCU kilometres (see below) for each vehicle type by its average standard axle equivalence factor[60]. This is used to allocate costs for categories of expenditure related to repairing the road surface.
- Passenger car unit kilometres (PCU-km). This is obtained by multiplying the distance travelled (in vehicle kilometres) by each vehicle type by its PCU factor[61] and summing across all vehicle types. This driver is used to allocate costs that are not related to vehicle weight.

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[60] A standard axle is a measure of the relative road wear caused by different vehicles. See DoT(1995) for an explanation. The Standard Axle Equivalence Factor refers to the road wear caused by a vehicle compared with the road wear caused by a 'Standard' Axle of a particular weight.

[61] A passenger car unit (PCU) is a parameter used to measure the relative amount of road space used by and the congestion caused by different vehicles types relative to a passenger car. See annex C for details.

Table 16: Allocation of costs to cost drivers and inclusion in MEC calculation

Category	Description	PCU -km	Av.GWt -km	SA - km	Included in MEC - I?
1	Long-Life Pavements			100%	Yes
2	Resurfacing			100%	Yes
3	Overlay			100%	Yes
4	Surface dressing	20%	80%		Yes
5	Patching and minor repairs		20%	80%	Yes
6	Bridges and remedial earthworks		100%		Yes
7	Drainage	100%			Yes
8	Footways, cycle tracks & kerbs		100%		No
9	Fences and barriers	33%	67%		No
10	Verges, traffic signs and crossings	100%			No
11	Sweeping and cleaning	100%			No
12	Road markings	10%	90%		Yes

Note: A proportion of costs in categories 9 and 11 are attributed to pedestrians. They are not shown in this table as we have removed them before allocation to motorised vehicles.

Step 3 Exclude costs that are not related to traffic volume

4. The final column of Table 16 highlights which categories we consider to vary with changes in traffic volume and have therefore included in our calculation of MEC - I. This choice is based on that in Sansom et al (2001). However in contrast to Sansom et al. (2001) we have also included category 6 – Bridges and remedial earthworks – following advice from DfT colleagues working in road maintenance division. We then summed costs which were related to the same cost driver to find the total marginal infrastructure costs for each road type disaggregated by cost driver.

Step 4 Calculate the total traffic-related costs allocated to each cost driver across each of the four road types

5. This step involves adding up, for each road type, the costs allocated to each cost driver in step 2 across the eight cost categories considered to vary with changes in traffic volume. This provides an estimate of the total traffic-related costs allocated to each cost driver for each road type. For example, for motorways we have added up the costs allocated to the cost driver 'average gross vehicle weight kilometres' across the eight cost categories that are considered to vary with changes in traffic volume. This provided us with an estimate of the total traffic related motorway costs that are allocated to average gross vehicle weight kilometres

Step 5 Calculate the total value of each cost driver for each of the four road types

6. In this step we estimate the total value of each of the three cost drivers described in step 3 for each of the four road types. To be consistent with the maintenance costs data we have smoothed out the annual variation in traffic data by using the average of the traffic and vehicle characteristics data provided for 05, 2006 and 2007. We obtained data on the total distance travelled on each road type by vehicle type for 2005, 2006 and 2007, consistent with that shown in DfT (2008c), from DfT statisticians. We then used data on the average gross weight and the standard axle equivalence

factors of each vehicle type for 2005, 2006 and 2007 published in DfT (2006c), DfT (2007d) and DfT (2008b). Finally, we used the PCU factors for each vehicle type presented in annex C [62].

7. The traffic data and vehicle characteristics data published by the DfT is disaggregated by the following nine vehicle type categories:

i. Cars
ii. Vans
iii. Buses and Coaches
iv. Rigid HGVs 2 axles
v. Rigid HGVs 3 axles
vi. Rigid HGVs 4+ axles
vii. Articulated HGVs 3 and 4 axles
viii. Articulated HGVs 5 ax les
ix. Articulated HGVs 6+ axles

8. We calculated the total value of each cost driver on each road type by multiplying the distance travelled by each vehicle type on each road type by the vehicle type's cost driver value (e.g. average vehicle weight). For example in estimating the total average weight kilometres on motorways, we multiplied distance travelled (in vehicle kilometres) by each vehicle type **on motorways** by its average weight and summing across all vehicle types.

Step 6 Estimate the costs per kilometre travelled for each vehicle type across each of the four road types

9. For each of the four road types we have divided the proportion of costs allocated to each cost driver (calculated in step 4) by the total value of that cost driver (calculated in step 5) to determine the cost per unit of each cost driver. We then multiplied this by the appropriate 'cost driver' values for each vehicle type to obtain estimates of the costs allocated to each cost driver per kilometre travelled by each vehicle type on each road type. Finally we summed across the three cost drivers to yield estimates of the infrastructure cost per kilometre travelled on each road type for each of the nine vehicle types identified in paragraph 7. These values are averages for the period 2005 to 2007 in 2006 prices.

10. For example, in step 4 we estimated the total costs on motorways allocated to the cost driver 'average gross vehicle weight kilometres'. In step 5 we calculated the total average gross vehicle weight kilometres on motorways. In step 6 we divide the total costs on motorways allocated to average gross vehicle weight kilometres by the total average gross vehicle weight kilometres on motorways to obtain an estimate of the cost per unit of average gross vehicle weight kilometres on motorways. We can then multiply the cost per unit of average gross vehicle weight kilometres by the average gross weight of each vehicle type to estimate the cost per kilometre travelled by each vehicle type on motorways associated with average gross vehicle weight. It is necessary to perform this calculation for each of the three cost

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[62] In the absence of evidence to the contrary we have assumed that the characteristics of each vehicle type are constant across road types.

drivers (i.e. it must be repeated for PCU kms and SA kms). Finally, it is necessary to sum across the costs per kilometre travelled by each vehicle type associated with each of the cost drivers to yield estimates of the total cost per kilometre travelled on motorways for each vehicle type. The same method is applied across each of the road types.

Step 7: Estimate the MEC – I for articulated HGVs for each of the four road types.

11. As explained in section 3 this work is focusing on deriving estimates of the marginal external costs of articulated HGVs. We derived estimates of the infrastructure cost per kilometre travelled by an average articulated HGV for each of the road types by traffic weighting the values estimated for the 3 vehicle types covering articulated HGVs.

Step 8: Obtain estimates of the marginal external infrastructure costs for 2010, 2015 and 2025

12. The steps above have allowed us to derive estimates of the average marginal external infrastructure costs over the period 2005 to 2007 in 2006 prices. We have used these estimates to estimate the marginal external infrastructure costs of articulated HGVs in 2010, 2015 and 2025. In order to do so it was necessary to make some assumptions about how marginal infrastructure costs change through time.

13. We have based our assumptions about how marginal infrastructure costs change through time on a comparison of the values we have derived for 2005-2007 with those derived by Sansom et al (2001) for 1998 using a similar methodology. The values we have derived for 2005-7 are broadly similar in nominal terms to the values estimated for 1998. This suggests that the physical damage done to the road network by articulated vehicles is decreasing through time at such a rate that it is approximately offsetting increases in the costs of maintenance due to inflation. Therefore we have estimated values for 2010, 2015 and 2025 by assuming that marginal external infrastructure costs are constant in nominal terms.

Annex F Estimating 'link-level' values from input values

1. Section 5 describes how we have identified the appropriate 'input value' from Table 5 to apply to each of the 19 time periods used in the NTM for each motorway and A-road link. This annex shows how we have combined the input values for each time period to obtain an estimate of the average net benefit of removing a lorry from each link. We refer to the averages that we have calculated for each road link as link-level values. The following equation shows how we have calculated the link-level value for link 'j' by taking a weighted average of the input values for each time period 'i' using traffic forecasts for link 'j' in each time period 'i'.

$$link - level \ value_j = \frac{\sum_{i=1}^{19} ((input \ value_{ij})(Annual \ Artic \ flow_{ij}))}{Annual \ Artic \ flow_j}$$

2. We have obtained forecasts of the articulated HGV traffic flow in 2010, 2015 and 2025 by applying forecasts of the growth in articulated HGV traffic by region and area type, provided by version 5 of the Great Britain Freight Model (GBFM) to 2003 observed traffic flow data.

Annex G List of motorway sections included in ‘High Benefit’ category

1. The “High Benefit” MSB values will apply between the junctions stated on the following motorways. A map highlighting these sections and a full table with associated mileages between all junctions will be available for download in due course. In addition, a spreadsheet to aid applicants with the calculation of MSB values will be made available.

	Junction	Road	Junction	Road
Scotland				
M8	**8**	A8/M73	**19**	
North West				
M60	**All**			
M6	**15**	A500	**21a**	M62
M62	**18**	M60	**21**	Rochdale
Midlands				
M6	**4**	M42	**10a**	M54
M42	**3a**	M40	**7**	M6
M1	**15**	A508	**17**	M45
Yorkshire				
M1	**28**	A38	**35a**	A616
M62	**26**	A642	**30**	M606
South East				
M25	**All**			
M4	**7**	A4	**4b**	M25
M3	**14**	M27	**9**	A34
Wales				
M4	**30**	A4232	**33**	A4232