Speed Limits Summary

ECCI commissioned work from the Transport Research Laboratory to provide an independent, authoritative overview of issues relating to speed limits: specifically to help understand how and where changing speed limits might help reduce greenhouse gas emissions without causing adverse social/economic impacts.

The key insights (appended) demonstrate the clear trade-offs that occur. For example, reducing urban speed limits has concomitant health, community and safety benefits but is likely to raise greenhouse gas emissions; while reducing motorway or trunk road speeds will have greenhouse gas and safety benefits but may have economic impacts (if roads are not already congested).

Key insights from this report include:

• **Carbon dioxide emissions**: Reducing speeds to 40mph is likely to have a positive impact on vehicle emissions; reducing speeds beyond ~40mph is likely to have a disbenefit;

• **Observed vehicle speeds**: Reducing a speed limit alone typically results in a change in average speed of as little as quarter of the change in speed limit; use of speed zones with additional physical measures are effective at reducing vehicle speeds.

• **Road safety**: Small changes in mean speeds can be expected to result in much larger changes in crash outcomes. In other words, lowering vehicle speeds reduces severe crashes (resulting in severe injuries/deaths) disproportionately. But context matters. Reduction of speed in urban environments reduces severe crashes more than in rural areas. Keeping traffic flowing at similar speeds is also safer: roads with a small speed differential between the fastest/slowest vehicles are safer than roads with high-speed differential.

• **Air pollutants**: Like carbon dioxide emissions, pollutant concentration is minimized at ~40mph; decreasing traffic speed beyond 40mph is likely to increase pollutants

• **Noise**: Noise increases with speed and traffic volume. Noise arises from both engine and tyre noise. The ratio of tyre to engine noise is greater for cars than HGVs and tyre noise is more dependent on vehicle speed than engine noise. The greatest benefits of speed reduction on noise are seen on lower speed roads with low proportion of HGVs.

• **Communities and health**: Reducing vehicle speeds can reduce social exclusion – by removing barriers to local mobility - and increase “healthy” modes of transport such as walking and cycling. Communities with the greatest levels of deprivation are likely to experience the greatest community and health benefits.

• **Journey times**: Changes to journey times are normally the biggest contributor to economic impacts of speed limit changes, but are frequently over-estimated because they assume free-flowing traffic. The relationship between traffic flow and road capacity is crucial. The economic cost of reducing a speed limit typically peaks when flow is approximately two thirds of capacity. Drivers are poor at estimating time gains or losses when travelling at different speeds: savings in travel time by small increases in speed when driving at a high speed are overestimated; savings in travel time by a small increase in speed when driving at a low speed are underestimated. In other words, on congested roads, reducing speed limits has limited negative economic impact.
A summary of the evidence on the costs and benefits of speed limit reduction

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1 Introduction

Transport Scotland is responsible for managing Scotland’s trunk roads and has strategic responsibility for safety on all Scotland’s roads. The Scotland Act recently received Royal Assent (UK Parliament, 2012). This act devolves more powers to the Scottish Parliament, including the setting of national speed limits.

The topic of speed limit reduction is multifaceted and overlaps with other areas of policy. For example, Scotland’s Climate Change Delivery Plan (The Scottish Government, 2009a) includes consideration of a speed limit reduction to 60mph on motorways. Meanwhile, Scotland’s Road Safety Framework to 2020 commits to encouraging local authorities to consider 20mph speed limits in all residential areas (The Scottish Government, 2009b).

However, speed limits generate emotive debate on issues such as the values placed on changes to journey times and thus on the economy, the effects on the environment, on safety, and on health more generally. It is important, therefore, that such debate is properly informed by scientific evidence.

The objective of this review is to present a high level overview of the evidence of the effect of reducing speed limits. A number of areas are considered:

- Vehicle speeds (Section 2)
- Road safety (Section 3)
- Vehicle emissions (Section 4)
- Air quality (Section 5)
- Noise (Section 6)
- Communities and health (Section 7)
- Journey times and the economy (Section 8)
- Behavioural factors (Section 9)

Relevant views of political parties or transport agencies are presented in boxes in many sections.

(As this report was being finalised, Box & Bayliss (2012) independently released a report on a similar subject, many of the findings of which corroborate much of what is reported here.)

In 2011, the British Coalition Government announced, at the Conservative Party’s Annual Conference, that it would consult on increasing the national motorway speed limit. The reaction was mixed. Almost a year on, the consultation has still to be launched and details of the proposed increase remain unclear. It now seems likely that the consultation will not be launched until after the new Secretary of State for Transport has got to grips with his brief following the Government’s current reshuffle.

The British Coalition Government has encouraged local authorities to implement more 20mph speed limits. At their forthcoming annual conference, the Liberal Democrats are to debate a motion to make 20mph the default speed limit for all residential streets.

The difference in emphasis of the two Coalition parties may be partly due to the different responsibilities that different ministers have in their respective roles: a Conservative minister is responsible for the management of England’s strategic road network, i.e. most English motorways, whereas a Liberal Democrat minister is responsible for the management of local roads.

It has been suggested that there was a political exchange in respect of the two speed-related policies of the Coalition: the motorway speed limit increase being a policy desired by the Conservative party and the encouragement of more 20mph speed limits being a policy desired by the Liberal Democrats.
2 Observed vehicle speeds

Reducing a speed limit alone typically results in a change in average speed of as little as a quarter of the change in speed limit.

In contrast with many people’s expectation, reducing a speed limit does not lead to an equivalent drop in actual vehicle speeds. In 2011, for example, the British Government announced that it was to consult on the possibility of raising the national motorway speed limit for cars from 70mph to 80mph. Many road safety campaigners assumed that this would mean that average car speeds would increase by 10mph or, even less accurately, that the average vehicle speed (i.e. for all vehicles) would increase by the same amount (see, for example, Brake 2012). Such claims are also made when speed limit reductions are proposed; it is often assumed that a 10mph speed limit reduction will result in an average speed reduction of a similar amount. Subsequently, journey time increases, casualty number reductions and other impacts are over-estimated.

A considerable amount of research has been undertaken to assess the effect of changes in speed limits on actual speeds. Although reducing the speed limit can have a considerable safety benefit due to reduction in average speed, in places where speed limits have been changed and no other action taken, the change in average speed may be as little as about one quarter of the change of the speed limit (DETR, 2000; Finch et al., 1994; Sexton & Johnson, 2009). Meta-analyses show that lowering the limit by 10km/h (6.2mph) achieves a decrease in average speed of 3-4km/h (approximately 2mph).

This has been confirmed by research carried out on changes in speed limits in the United States (Cohen et al., 1998) and also in Switzerland, Hungary and Norway (Le Breton, 2005; Hollo, 1999; 2004). When, for example, a speed limit was lowered from 80km/h to 70km/h (49mph to 43mph) (without changing the road infrastructure) it led to a decrease in average speed of 5% (Ragnøy, 2004). In New South Wales in Australia, the speed limit on a 40km stretch of the Great Western Highway was lowered to 100km/h (62mph) from 110km/h (68mph), leading to a reduction in speeds of 5km/h (3mph) and a 26.7% reduction in casualty crashes (Bhatnagar et al., 2010). To maximize the impact, any changes in speed limits should ideally be accompanied by appropriate enforcement, engineering and educational measures.

A recent GB Department for Transport consultation on the revision of its speed limit guidance (DfT, 2012) supports this in explaining that “Research into signed-only 20mph speed limits [in place of 30mph speed limits] shows that they generally lead to only small reductions in traffic speeds” (paragraph 83). This contrasts with 20mph zones, where additional physical measures are effectively used to reduce vehicle speeds through self-enforcement (Full Fact, 2012). In residential areas and near schools a recent British Medical Association (BMA) report strongly recommends traffic calming and especially area-wide 20mph speed limits (BMA, 2012). In the Netherlands, SWOV (2010) concluded that when a 50km/h (31mph) residential area is redesigned into a ‘Zone 30’ (i.e. a 30km/h (19mph) speed limit is introduced), the average decrease of the number of injuries is approximately 25%.

There are a variety of reasons why only a fraction of the change in speed limit is reflected in the change in average speed. The speed limit is far from the only cue that drivers use to choose their speed. Vehicle type, task demand, attitudes toward speeding, compliance, perceived risk of apprehension and severity of penalties, perception of risk and road characteristics all have an impact on speed choice (for more detail on behavioural issues see Section 9). Road characteristics such as visibility, road curvature, lane width, adjacent land use, junction density, traffic flow and road function influence speed choice whether consciously or otherwise. This has led some to suggest the concept of credible or self-enforcing speed limits that are either intuitively obeyed or cannot comfortably be exceeded, the design of the road being such that the
signed speed limit is not required to inform drivers of a safe driving speed for the road concerned (Wegman & Aarts, 2006).

A further reason that a change in a speed limit does not result in a similar change in the average speed is that, even in free-flowing conditions, most people spend much of their time travelling below the speed limit on most roads: drivers often have to accelerate and decelerate (particularly in more built-up areas) as junctions, crossings and hazards are encountered along a road. When most journey time is spent below a speed limit, a change in the speed limit alone is therefore unlikely to have a proportionate effect on average speed.

There is some evidence that changes in a speed limit have an effect on speeds on adjacent roads, but there is little research in this area (ETSC, 2008a).

<table>
<thead>
<tr>
<th>A recent survey by the RAC (2012) has identified that a large percentage of motorists admit to speeding regularly. However, recent research has shown that compliance with 30mph speed limit has improved, and that the number of speed limit offences has declined.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The RAC identified that, while 92% of motorists believe they are law abiding, 83% admitted to speeding regularly. Although most drivers are happy with current speed limits, motorways aside, 36% of drivers admit to driving above the speed limit in a 20mph zone, 46% of drivers to speeding in a 30mph limit, and 37% to speeding in a 50mph or 60mph speed limit. The RAC expresses concern about attitudes to speeding across the population, and a perceived lack of police presence. More information on driver attitudes towards speed is considered in Section 9.</td>
</tr>
<tr>
<td>However, Mitchell (2012) identifies that compliance with the 30mph speed limit has been improving since 1998. Since 2006, the proportion of car drivers exceeding this speed limit at survey sites in free flow conditions has been below a half, and the proportion exceeding 35mph in free flow conditions where the speed limit is 30mph has been less than a fifth. The average speed reduced from 32mph in 2001 to 29.8mph in 2010.</td>
</tr>
<tr>
<td>There have also been reductions in the number of speed limit offences since 2005. Mitchell (2012) suggests that more than half of this reduction is a result of real reductions in car speeds in free flowing traffic, and suggests that the remainder may have come about from increased awareness of speed enforcement locations and because some drivers have opted to take speed awareness courses instead of receiving penalty points. This reduction may also partially reflect changes in the priority given to enforcement, but Mitchell (2012) does not appear to have considered this.</td>
</tr>
<tr>
<td>The RAC has welcomed the DfT’s consultation into the revision of its speed limit guidance which may reduce speed limits on some country roads to 40mph and the introduction of more 20mph zones on urban roads, though is concerned about enforcement.</td>
</tr>
</tbody>
</table>
3 Road safety

Small changes in mean speeds can be expected to result in much larger changes in crash outcomes. Severe crashes (resulting in serious injuries and deaths) are much more sensitive to speed changes than crashes in general. (ETSC, 2008a; 2008b).

There is a clear relationship between speed and both the likelihood and severity of collisions. Lower vehicle speeds can potentially reduce the likelihood of a crash occurring through decreases in the distance travelled during perception, reaction time and stopping.

Speed also affects the severity of crashes. Lower speed crashes involve less kinetic energy (kinetic energy is proportional to the square of the speed) and the less energy that is dispersed in a crash, the less severe it tends to be. It is the scale of this energy exchange that determines the severity of injury. With an impact speed of 50mph, the likelihood of death for car occupants is about 20 times that for an impact speed of 20mph (IIHS, 1987).

The likelihood of being involved in a serious or fatal crash increases significantly with even small increases in vehicle speed (OECD, 2008). An increase in mean speeds of 5% leads to an increase in injury crashes of 10%, and a 20% increase in fatal crashes (Nilsson, 2004).

A commonly cited rule of thumb suggests that a 1% change in mean speed is associated with a 2% change in the injury collision rate, a 3% change in the severe collision rate and a 4% change in the fatal collision rate (Nilsson, 1990; Aarts & van Schagen, 2006), the changes in collision rates being in the same direction as the change in mean speed, whether upward or downward.

However, this rule of thumb does not necessarily apply in all contexts and is dependent on factors such as the original mean speed, the variability of the speed between different vehicles, and environment complexity (Elvik et al., 2004). For example, a decrease in mean speed on urban roads will result in a lower crash rate than an equivalent decrease on rural roads (Nilsson, 2004). Kloeden et al. (1997) and Kloeden, McLean & Glonek (2002) demonstrated that on 60km/h (37mph) urban roads, risk of involvement in a casualty crash doubles with every 5km/h (3mph) increase in travelling speed above 60km/h. Kloeden et al. (2001) found the same was true for rural roads, but not to the same extent.

In urban areas, a 1mph increase in average speed can lead to a 10-15% increase in crash frequencies (Taylor, Lynam & Baruya, 2000). Research on urban roads indicates that crash rates increase as the proportion of drivers who exceed the speed limit increases (Maycock, Brocklebank & Hall, 1998; Quimby, Maycock & Palmer, 1999).

One must be cautious when inferring a relationship between relative speed and individual risk from an observed relationship between average speed and aggregated risk (Davis, 2002): the risk associated with an individual vehicle's speed is not the same as the risk associated with the average traffic speed. A higher crash involvement rate has been observed for vehicles that are driven faster than other vehicles in the traffic concerned; a similar effect has been observed for vehicles that are driven slower than other vehicles in the traffic concerned but the evidence for this is less robust (Kloeden, McLean & Glonek, 2002). Aarts & van Schagen (2006) show that roads with a small speed variance are safer than those with larger variance.

The use of 20mph zones has been shown to reduce the number of road injuries and deaths by approximately 40%, with a greater reduction associated with children and with the most severe injuries (Grundy et al., 2009). On the other hand, the use of 20mph speed limits alone is far less effective: the number of collisions did not reduce by demonstrably more than the background trend when introduced in Portsmouth, for example (Atkins, 2010). This difference correlates with the effects the two different approaches have on vehicle speeds, discussed in Section 2.

There were increases to speed limits in many states in the USA after 1995, when the national maximum speed limit was repealed: limits on interstate highways and freeways increased,
typically from 65mph to 70-75mph or from 55mph to 60-65mph. This was associated with a 17% increase in the number of deaths (Farmer, Retting & Lund, 1999).

A 130km/h (81mph) speed limit was introduced on a previously unlimited 62km section of Autobahn in Germany in 2002. A three year before and three year after study found that the number of injury / material damage collisions decreased by 48% and the number of casualties decreased by 57%. All other empirical evidence relating to the introduction of speed limits on German Autobahns also indicates that they significantly reduce casualties (ETSC, 2008a).

Managed Motorways (MM) use MIDAS queue protection (which is also deployed outside MM environments using advisory speed limits). This works by triggering 40mph limits behind areas of dense, slow-moving traffic, the aim being for people to arrive at the back of the queue at 40mph, rather than 70mph, reducing both the probability and consequence of a crash occurring.

Other interventions in MM are Congestion Settings and Hard Shoulder Running. Neither of these is specifically designed to improve safety, but may improve safety as a secondary effect as they decrease the occurrence of queuing (reducing the probability of queue-tail accidents). Congestion Settings (the use of 50mph and 60mph limits to delay the onset of flow breakdown) also reduce speed differentials between vehicles and, in principle, reduce lane changing, as well as reducing the speed of the fastest vehicles. All these aspects theoretically improve safety.

Tucker et al. (2006) indicated that MIDAS automatic queue protection improved safety by 13%, and produced significant congestion relief benefits. In addition, Crinson, Notley & Lawton (2007) examined the effect on safety of the Congestion Settings on the M25; the central estimate was that these reduced the number of injury collisions by 15%.

More recently, Mott McDonald (2011) conducted a three year safety review of the M42 Managed Motorway. This indicated that there was a reduction in the number of injury collisions and the severity of the collisions during the first three years of four lane variable mandatory speed limit operation compared to three lane variable mandatory speed limit and no variable speed limit operation. However, the figures used to calculate this are not robust and this relationship was not shown to be causal.

The Green party has a clear stance on speed limit reduction, and reducing speeds is considered an important component in improving road safety. Conversely, the Freight Transport Association argues that slower speeds do not necessarily mean safer roads.

The Conservative Party approaches road safety in a more general way, with concerns over the use of speed cameras. However, drivers show concerns over people breaking traffic laws, which could translate into a perceived lack of law enforcement.

The Green Party has said that it would introduce a maximum speed limit of 55mph on motorways and trunk roads, and 40mph on rural roads, to make them safer for all road users.

The Scottish Green Party has said that “We will cut the national speed limit to 50mph on single carriageways to make roads safer and to help cut the costs of driving.”

The Freight Transport Association (FTA) has argued that slowing freight vehicles would not necessarily mean safer roads, particularly if it increased the speed differential between different vehicle types. Reducing the speed limit of other vehicles to that of freight vehicles would, of course, reduce the differential issue.

The Conservative Party has said “We will stop central government funding for new fixed speed camera and switch to more effective ways to make our roads safer.”

Bizley (2012), reporting on an RAC driver survey, identified that the number of road collisions is a ‘top five’ concern for 22% of drivers. ‘Other people breaking traffic laws’ was a ‘top five’ concern for 41% of drivers.
4 Vehicle emissions

Reducing speeds to 40mph is likely to have a positive impact on vehicle emissions; however 40mph is optimum for vehicle emissions and so reducing vehicle speeds beyond 40mph is likely to have a dis-benefit.

A typical trip will consist of a variety of different driving speeds and driving modes – acceleration, deceleration, cruise and idling. These all contribute to the overall emissions, though accelerations usually demand the greatest energy and result in the highest emissions. For emission modelling purposes, vehicle operation along a specific link (a road section) is usually considered.

To allow emissions to be evaluated, a set of emission factors have been developed to characterise the emissions of different vehicles over various speeds. Vehicles produce a variety of emissions. Of greatest importance to local air quality are the emissions of oxides of nitrogen ($NO_x$ – nitric oxide (NO) and nitrogen dioxide (NO$_2$)) and particulate matter (PM).

In general, the impact of CO$_2$ from vehicles on the climate is a global impact, so determining the climate impacts of an individual localised scheme is difficult. Nonetheless, the predicted consequences of climate change will have many community impacts, hence the relationship of speed and CO$_2$ should not be overlooked in this context. As only the total amount of CO$_2$ emitted counts, not its location, the impacts of a speed limit change will be in proportion to the amount of traffic affected by it, so a change affecting the motorway network and rural A roads, which carry nearly 50% of total traffic (DfT, 2011a), will, for example, have more effect than individual schemes affecting trips on minor roads that are used for much shorter journeys. The share of carbon dioxide emissions made up by road transport has been increasing (ETSC, 2008b).

Emission factors are available from a number of sources including:

- The 2009 DfT emission factors developed by TRL (DfT, 2009)
- Defra’s Emission Factors Toolkit (EFT), which incorporate the above emission factors (Defra, 2012)
- COPERT – a European emissions model (EMISISA S.A. 2009)

To show how the emissions vary with different average link speed, the fleet emissions have been calculated using the Emission Factors Toolkit (EFT) using the following input parameters:

- Flow: 1 vehicle
- Percentage heavy-duty vehicles: 10%
- Year: 2012

Using these values produces the typical emissions per vehicle for a normal fleet containing 10% heavy-duty vehicles (trucks, buses and coaches). The resulting emissions of CO$_2$ in grams per kilometre (g/km) are plotted against average speed in Figure 1.
Speed limit reduction: A summary of the evidence

**Figure 1: Relationship between CO₂ emissions and average trip speed** (Source: Defra, 2012)

Those for NOₓ and PM are of a similar shape and are shown in Appendix A. These speed related emission curves are U-shaped. Minimum emissions (in g/km) occur at around 40mph for NOₓ, PM and CO₂; decreases below this have more impact on emissions than increases above it. Anable, Mitchell & Layberry (2006) have questioned the validity of these curves at steady speeds e.g. on motorways.

Although reductions in speed can increase emissions, schemes that promote steady speeds can also improve emissions. Accelerations require a large input of energy, so any traffic schemes that involve stop/start driving and/or lots of braking and accelerating tend to produce high emissions. Road safety benefits of such schemes therefore need balancing against this. Traffic schemes that can smooth the flow will normally reduce emissions, save fuel and may also have other benefits. It should be noted that standard emissions curves take no account of changes in levels of traffic.
5 Air quality

*Like vehicle emissions, pollutant concentration is minimised at around 40mph. Decreasing traffic speed beyond 40mph is likely to increase pollutant concentrations.*

The effect of speed on air quality is similar to the effect of speed on vehicle emissions. The air quality at a particular receptor (e.g. at the front door of a house in close proximity to the road) is affected by a number of factors, including:

- The emissions generated by the traffic on the road
- The distance of the receptor from the centre of the road
- The wind strength and direction
- The background pollutant concentrations (occurring from other activities – e.g. local factory emissions, domestic heating/cooking, construction etc.)
- The local topology

Road vehicles produce a variety of exhaust emissions. Of greatest importance to local air quality are the concentrations of nitrogen dioxide (NO$_2$) and particulate matter (PM). PM is referred to as PM$_{10}$: particles less than 10 micron (µm) in diameter. UK national air quality objectives, based on EU Directive 2008/50/EC, set limits for these two pollutants, as shown in Appendix B. All of the petrol and diesel vehicle particulate emissions are smaller than 10 micron; in fact, the vast majority are smaller than 2.5 micron.

PM$_{10}$ is estimated to cause up to 50,000 premature deaths per year, while ground level ozone may cause another 1,500 premature deaths per year (BMA, 2012). The health implications of any change in emissions arising from changes in speed would be very much dependent upon location, as PM$_{10}$ concentrations are highest, and have greatest impact on health, when there is a large population near the affected roads. This means that emission changes from much of the motorway network are less important in health terms than those affecting roads in large centres of population. However, ground level ozone, O$_3$, can be highest in rural areas, and the emissions from motorways are a significant contributor to the pollutant NO$_x$, from which it derives.

To be able to accurately model the air quality, a complex dispersion model needs to be used, such as ADMS (Atmospheric Dispersion Modelling System). This requires emissions data for each link (with hourly, daily and monthly variation factors if necessary), meteorological data for each hour of a given year and numerous other parameters. An additional complication is the NO$_2$/NO$_x$ relationship. Vehicle emissions are generally given as total NO$_x$, which is the sum of NO and NO$_2$. The proportion will vary according to the vehicle technology and operation. Once released into the atmosphere, chemical reactions occur which convert NO into NO$_2$. This is dependent on the background concentrations of NO$_2$ and the availability of ozone.

To allow quick approximate assessments to be carried out, simpler models are available, such as the DMRB (Design Manual for Roads and Bridges) screening model (HA, 2007). This simply requires the traffic flow and speeds, the distance to the link and the background concentrations to be entered. The results give an indication on the likely pollutant concentrations – where concentrations are approaching or exceeding the required limits, a more in-depth investigation needs to be carried out.

To illustrate the effect of speed on air quality, the DMRB screening model has been used to evaluate a scenario with various average speeds. The model was run with the input parameters listed in Appendix C, at average speeds of 10mph, 20mph, 30mph, 40mph and 50mph. The resulting pollutant concentrations are listed in Table 1 and are also shown plotted in Appendix D.
example, decreasing traffic speed from 30mph to 20mph will cause a 4.1% increase in NO\textsubscript{x}, a 2% increase in NO\textsubscript{2} and a 1.6% increase in PM\textsubscript{10}. It should be noted that the majority of the pollutant concentrations in these examples are from the background pollution, as shown by the dashed line in the graphs in Appendix D.

**Table 1: DMRB screening model results**

<table>
<thead>
<tr>
<th>Average speed (mph)</th>
<th>Annual mean ((\mu g/m^3))</th>
<th>NO\textsubscript{x}</th>
<th>NO\textsubscript{2}</th>
<th>PM\textsubscript{10}</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>38.01</td>
<td>19.39</td>
<td>16.49</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>34.21</td>
<td>18.41</td>
<td>15.99</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>32.86</td>
<td>18.06</td>
<td>15.73</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>32.56</td>
<td>17.98</td>
<td>15.63</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>33.06</td>
<td>18.11</td>
<td>15.70</td>
<td></td>
</tr>
</tbody>
</table>

The above examples assume the same traffic flows. In practice, reducing speeds may result in changes to traffic flows, which should be accounted for when considering the effect on air quality.

In their manifestos at the last general election in 2010, all three major British political parties recognised that road transport has a role to play in taking care of the environment. However, all appear to focus on improving vehicle technology rather than reducing vehicle speeds:

The Conservative Party said that “Britain has the chance to lead the world in making our transport system greener. So we will introduce incentives for electricity network operators to establish a new national car recharging network.”

The Labour Party said that “Labour has put Britain at the forefront of electric and low carbon vehicle manufacturing. To promote the rapid take-up of electric and low-carbon cars, we will ensure there are 100,000 electric vehicle charging points by the end of the next Parliament.”

The Liberal Democrats said, in relation to cutting carbon emissions, that “in many places there will always be a need for car travel, so we need to ensure that it is as environmentally friendly as possible” and that they will “work through the European Union for a zero emissions target for all new cars by 2040 and extend targets to other vehicles.”

Transport groups such as the FTA and ETA generally support the notion of reducing emissions through lower speeds, though raise logistic concerns.

The Freight Transport Association (FTA) has said that the benefits of lower speeds could include reduced emissions, though is concerned about increased journey times, and that there may be some modal shift to aviation to ensure on-time delivery.

The Environmental Transport Association (ETA) emphasises the benefits of driving at 50mph-60mph to minimise emissions, and points out that driving below 15mph creates most pollution. However, the ETA supports the introduction of 20mph speed limits on road safety grounds.

Bizley (2012), reporting on an RAC driver survey, identified that the environmental impact of motoring is a ‘top five’ concern for just 12% of drivers.
6 Noise

**Noise increases with traffic speed. The greatest benefits of speed reduction are seen on lower speed roads with a small proportion of HGVs** (where a 2db reduction might typically be achieved with a 10mph reduction in vehicle speeds). At higher speeds, a 1dB reduction in noise typically results from decreasing vehicle speeds by 10mph.

Noise increases with speed and traffic volume and impacts the most people on roads near centres of population. However, it can have a disproportionate effect in rural areas, which is not necessarily identified by the official procedures for assessing noise disturbance (Taylor et al., 2008). Noise causes annoyance, reduces people’s quality of life and has been linked with health problems associated with sleep deprivation and stress. In relation to the effect of noise on health, the BMA (2012, p26) concludes that “The cheapest intervention, and the one with large co-benefits, is speed reduction” suggesting that this is an argument for 20mph zones. Details of the way in which noise is measured are described in Appendix E.

Vehicle noise is primarily generated through two sources: noise from the interaction of the tyres with the road surface and noise from the vehicle’s propulsion components such as the engine. The ratio of tyre noise to propulsion noise is greater for cars than it is for HGVs and tyre noise has a greater dependence on speed than propulsion noise. As such, reductions in traffic speed will be most beneficial with respect to noise for traffic with a low percentage of HGVs. Additionally, noise reductions depend on the absolute speed of the traffic; however, this relationship is more complex and closely related to the traffic composition. (It should also be noted that a change in speed limit can impact on traffic volumes.)

Table 2 shows some nominal traffic noise predictions, made using the Calculation of Road Traffic Noise (CRTN) methodology (DfT, 1988), for various speeds and percentage of HGVs. The numbers represent noise levels 7.5m away from a road with a flow of 1,000 vehicles per hour, expressed as $L_{A10,1hr}$ – the A-weighted noise exceeded for 10% of the time.

<table>
<thead>
<tr>
<th>$L_{A10}$ (dB)</th>
<th>Mean Traffic Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% HGVs</td>
<td>70</td>
</tr>
<tr>
<td>0</td>
<td>75.8</td>
</tr>
<tr>
<td>10</td>
<td>77.4</td>
</tr>
<tr>
<td>20</td>
<td>78.5</td>
</tr>
<tr>
<td>30</td>
<td>79.5</td>
</tr>
</tbody>
</table>

A reduction in mean traffic speed of 10mph will typically benefit noise reduction by 0.2db to 2db depending on traffic parameters; however, in the majority of cases, benefits of around 1db are typically achieved. For example, the noise benefit expected from a speed reduction from 70mph to 60mph on a high speed road with 20% HGVs is 1.1db, in comparison to 1.7db for a speed reduction from 30mph to 20mph on a low speed road with no HGVs.

The expected noise reduction from a 10mph reduction in mean traffic speed could be close to 2db on lower speed roads with few HGVs but minimal on low speed roads with a large proportion of HGVs. On higher speed roads, benefits appear to be slightly more consistent at around 1db.

Such reductions are unlikely to be noticeable but factor considerably into noise assessments (for example DMRB (HA, 2007)) and corresponding costing (for example, ScotTAG). A reduction of 1db is broadly equivalent to taking 20% of the vehicles off the road and much work goes into altering vehicle noise regulations for similar magnitudes of benefit (e.g. Muirhead, Morris & Stait, 2010). On the other hand, this reduction is not as significant as might be achieved through pavement re-surfacing (Steven, 2012).
7 Communities and health

Reducing vehicle speeds can reduce social exclusion and increase ‘healthy’ modes of transport such as walking and cycling. Communities with the greatest levels of deprivation are likely to experience the greatest community and health benefits.

7.1 Introduction

In discussing the effect of traffic speed on communities it is necessary to consider that many of the reported impacts resulting from speed are also associated with traffic flow more generally. The consequences of changing speed are hard to assess in isolation; as discussed in Section 2, there is not a simple relationship between changes in speed limit and changes in speed.

Traffic speed has a number of different impacts on communities from direct impacts such as road casualties to indirect impacts arising from changes in travel behaviour. The British Medical Association (BMA) has produced a graphical representation of the health implications of these different impacts, the ‘Road Transport Morbidity and Mortality Iceberg’, which can be seen in Appendix F. The main impacts of traffic speed and consideration of speed limit reduction on the community can be summarised as follows:

7.2 Community severance

Along with high traffic volumes, faster traffic acts as a barrier to movement within and between communities, especially for those travelling on foot or by bicycle, those with mobility impairments, older people and young children. The barrier effect is a consequence of greater danger, both real and perceived, fewer opportunities to cross the road safely and an environment that is unattractive for walking or cycling because of noise, emissions etc. “Streets with low traffic speeds and volumes have been found to have more indicators of a better quality of life – more street activity, more signs of street care (e.g. flower boxes) and more open windows” (Tranter, 2010). This improves access to services, shops, increases independent mobility, and also makes local shops and services more commercially viable, all of which combine to reduce social exclusion. A local authority review reports that “The greater the traffic volume and speed the less the street functions as a place as opposed to space for the movement of vehicles.” (Bristol City Council, 2012, p82). Similarly, SWOV (2010) noted that the ‘Zones 30’ (30km/h zones) scheme has had “a positive effect on the quality of life: there is less noise, crossing the road is easier, and emissions are less” (p1).

While reducing perceived traffic danger is a necessary step in encouraging walking and cycling, it will not usually be a sufficient condition, because of issues such as travel distances to school and work etc., as well as because 20 mph zones are rarely large enough to contain complete journeys, so traffic conditions outside can remain a barrier. However, some interventions reducing vehicle speeds appear to be associated with increases in walking and cycling, often when combined with cycle way creation (World Health Organisation, 2006), and there is a strong association between increasing speeds and volumes of traffic and decreasing levels of walking and cycling (Jacobsen, Racioppi and Rutter, 2009).

1 The British Medical Association (BMA) has recently produced a very comprehensive report on the health impacts of transport – Healthy Transport, Health Lives (BMA, 2012), which reviews a wide body of literature. This has been used as the main reference for much of the discussion.
7.3 Changes in travel behaviour and physical activity

Where traffic volume and speed act as barriers to walking and cycling, shorter distance trips are undertaken by car, which further increases the negative impacts of vehicle traffic. A further consequence is a reduction in the amount of physical activity people undertake. This is increasingly being regarded as a serious health problem, as inactivity is linked to a number of conditions including obesity, cardiovascular diseases, mental illness, diabetes and stroke (BMA, 2012). There is an extensive body of literature linking travel behaviour and health, reviewed by the BMA (2012; page 27). It is suggested that accumulating just 30 minutes of moderate physical activity on most days is enough to provide substantial health benefits (BMA, 2012). Walking and cycling for everyday journeys can make a valuable contribution to this, hence safety concerns and the barrier presented by traffic speed and volume may need to be reduced to benefit the community. The National Institute for Clinical Excellence (NICE, 2008, p7) recommends that “…. pedestrians, cyclists and users of other modes of transport that involve physical activity are given the highest priority when developing or maintaining streets and roads. (This includes people whose mobility is impaired.)”

7.4 Equality impacts

Cutting across both the direct and indirect impacts mentioned above are inequalities; that is the extent to which these impacts affect different social groups. Because of the nature of the locations where significant populations live in close proximity to high traffic flows and speeds, there is strong evidence that many of the adverse impacts disproportionately affect vulnerable and minority groups. For example, deprived communities are far more likely to suffer poor air quality (BMA 2012) and are overrepresented in road traffic collisions, particularly when they involve vulnerable road users (e.g. children, pedestrians and cyclists) (BMA, 2012; DfT, 2011b).

Thus a general conclusion is that any impact on collisions, emissions or noise, health or community severance (positive or negative) that comes from changes in speed limit will have greatest impact on the most socially excluded groups in the community, because they, in most instances, live closest to the traffic.

The Scottish Green Party has argued for more 20mph zones to make streets safer and to help increase walking and cycling. Similarly, organisations such as Sustrans and ‘20’s Plenty’ argue for more widespread adoption of 20mph speed limits on the basis of factors such as safety, social inclusion, and the health benefits of walking and cycling.

SafeSpeed, a vocal group that argues that there should be less emphasis on speed limits, recently alerted the media to an increase in accidents on roads with 20mph speed limits, implying that they are unsafe. However, scientists and road safety charities promptly debunked this suggestion, pointing out that the increase was associated with an increase in the number of such roads, and that the reduction in casualties on 30mph speed limited roads, as speed limits have been reduced, has been far greater.
8 Journey times and the economy

Changes to journey time are normally the biggest contributor to economic impacts, but are frequently overestimated. The relationship between traffic flow and road capacity is critical to calculate the effect on journey time and the economy. The cost of reducing a speed limit typically peaks when flow is approximately two-thirds of capacity.

8.1 Calculating the economic impact

When considering the effect of a change in traffic conditions on the economy, the effect on many of the factors considered in this report are normally brought together in financial terms. For example, once the casualty effects have been estimated, these are converted into an economic benefit or disbenefit using 'values of prevention' that differ depending on the severities of the casualties, the type of road, and whether the collisions occur on links or at junctions. Similarly, the carbon impact is normally converted into financial terms.

Vehicle operating costs are also included in calculations of the economic effects. Finally, changes in journey time are converted into financial values using standard ‘values of time’, which normally differ by journey purpose, for example. Values of time are normally the largest input in the calculation of economic effects.

Programs such as COBA and traffic assignment models (e.g. CUBE, SATURN) are often used to assess the aggregate effect of all of these factors, specific to a particular scheme, in detail.

The effect of reducing the speed limit on collisions and the carbon impact are discussed in Section 3 and Section 0 respectively. This Section provides a brief overview of possible impacts of reducing speed limits on changes in vehicle operating costs and valuation of time savings only, and uses a general example involving a change to a speed limit on a single road section.

8.1 Perceived effect on journey times

Elvik (2009) reports on two studies by Svensson analysing the relationship between the perceived and actual relationships between speed and travel time when travelling at given average speeds. These found that “the saving in travel time by small increases of a high speed is overestimated, while the saving in travel time by a small increase in a low speed is underestimated. The relationship between speed and travel time is thus perceived to be more linear than it actually is.” This means that, having been delayed by travelling at a lower speed than was desired, “drivers believe they must increase speed more than they actually have to in order to save a certain amount of time. Conversely, gains in travel time by increasing a comparatively high speed are overestimated” (pages 38-39). Fuller, Gormley, Stradling, Broughton et al. (2008) also found that British drivers were poor at estimating time gains or losses when travelling at different speeds.

8.2 Actual effect on journey times and associated costs

As has been discussed, changes in average speed as a result of a change of speed limit are frequently overestimated. Even empirical traffic speed data can be misleading since the results of on road speed surveys normally consider data under free-flow conditions only. Estimating the effect of reducing traffic speeds on journey times is therefore dependent on knowledge of the driver speed profile on the particular road in question.

If a speed limit on a single section of road is changed, the impact on the economy in terms of time and operating costs depends on the level of flow on the road and what the actual behavioural response from drivers is to the change in speed limit (e.g. whether the new limit is
being complied with or not – see Section 2). The relationship between the traffic flow on and the capacity of the road, i.e. the particular ‘speed-flow curve’ in question, are critical to outcomes.

When there is no traffic, there is no change in drivers’ costs. As traffic flow on the road increases, the number of drivers affected increases and multiplies the effect between the before and after states. However, when the road is at capacity the flow and speed will not be affected because of traffic volume and traffic speed at capacity is likely to be below the speed limit. The impact of these assumptions is that when a road is working at capacity a change in speed limit will have little or no effect because the speed at capacity will not change.

This is demonstrated in Figure 2 for the simplest case where a single road, one kilometre long, has its speed limit reduced from 40 to 30mph. The costs vary by traffic flow, as shown. Over most of the flow range, the largest economic impact is on travel time.

![Figure 2: Total costs to the driver of reducing the speed limit from 40mph to 30mph on a 1km section of road. (Based on WEBTag 3.5.6 and SPT’s SITM4 SATURN assignment model.)](image)

The above relationship will vary slightly between road types and with the level of actual speed change but should be very similar. It also depends on the ‘speed-flow curves’ that are used: those used in this example are continuous but those used in the COBA model for motorways have a flat speed-flow curve at the low/medium flow end. Using this alternative could shift the peak of the curve further to the right, i.e. the peak is at a higher flow, as the speed-flow impacts will not appear until the flow is closer to the road’s capacity.

This example assumes that drivers do not re-route, change transport mode or their destination because of the change in speed limit. With widespread adoption of changed speed limits driver behaviour could change but the effects will be network specific. Changing all the speed limits on certain types of road can easily be undertaken in traffic assignment models and the impact on routing behaviour examined. Extraction of travel costs from such runs should give some idea of the possible changes in other travel demand responses such as changing destination or mode of travel. These changes can be expected to both lessen the total costs of a change, and widen the spatial impact in terms of number of roads/travellers affected.

Journey time is only one of many aspects of traffic conditions that has an economic impact, and as such political groups may not have specific policies to address this topic. This said, reducing journey times is a concern for many drivers, including those in the freight industry.

The Freight Transport Association (FTA) has argued for increasing the speed limit for commercial vehicles on single carriageway roads (where it is lower than for other vehicle types), claiming this would improve safety, reduce journey times, improve fuel efficiency and reduce emissions.

However, the FTA also believes that repair and maintenance costs might be reduced if vehicle speeds were limited.

Bizley (2012), reporting on an RAC driver survey, identified that traffic congestion / slower journeys is a ‘top five’ concern for 30% of drivers, this falling by 6% from the previous year.
9  Behavioural factors

9.1  Attitudes to speed and speeding

In a study of UK drivers’ speed choice and attitudes to speed, Stradling et al. (2008) identified three types of driver: low, moderate and excessive speeding drivers. Over half of the drivers in this study fell into the first, low speeder, category and were generally speed limit compliant. Thirty-three per cent of drivers were moderate speeders with between a third and a half of this group regularly driving at 5-10mph over the speed limit; however, they are unlikely to drive much faster than this. The final group (14% of respondents) were categorised as excessive speeders and were more likely to have driven at 90mph on the motorway, for example. This group includes a small sub-group of socially deviant speeders. This distinction of driver types based on speed choice is important in the current context as it gives an indication of how we might expect drivers to respond to a reduction in speed limits.

Studies often reveal that drivers do not have to try hard to justify driving above the speed limit (Gabany et al., 1997; Silcock et al., 2000). This is important to the current review as it allows us to appreciate that a proportion of drivers are likely to choose to drive at a speed that they feel is appropriate for the conditions, rather than at a speed that the authorities indicate is appropriate. Qualitative analysis of focus groups by Fuller et al. (2008a) found that all groups in their study agreed that they may not comply with the speed limit if it is perceived to be too low for the road characteristics.

Musselwhite et al. (2010) surveyed drivers about their attitudes towards speed and their normal driving behaviour. This found that drivers generally see speeding as dangerous, but that the link between speed and accidents was not so evident when drivers discussed their own behaviour. Many drivers tended to consider themselves to be law-abiding even if they were driving a few miles per hour faster than the speed limit. Musselwhite et al. references previous research indicating that approximately one in five drivers thought it was safe to drive at 35mph or more when the speed limit was 30mph, and approximately one in three thought it was safe to drive at 80mph on a clear motorway.

Musselwhite et al. (2010) found that five out of six drivers thought that the 70mph speed limit on dual carriageways was about right, and that three out of five drivers thought that the same speed limit on motorways was about right. The majority of respondents wanted slower speeds near schools and in residential areas, with 89% supporting 20mph zones outside schools and 77% supporting 20mph speed limits in general on all residential roads according to work referenced by Musselwhite et al. (2010). Musselwhite et al. (2010) noted that support for 20mph zones amongst Scottish drivers rose from 22% in 1991 to 86% in 2002.

Approximately a third of drivers interviewed indicated that they normally drove above the speed limit when on a motorway or some other roads, with one in ten suggesting they did so on a country road. Drivers in their twenties indicated that they were most likely to exceed the speed limit. Musselwhite et al. (2010) also references previous research suggesting that approximately one in five drivers said they would prefer speeds below 70mph on a motorway, and more than half of drivers indicated that they would prefer speeds below 60mph on a rural road. A third of drivers also indicated that they thought a 30mph speed limit on a narrow residential road was too high.

Reasons for speeding included doing so because other drivers do so, and because their perception was that the speed limit was inappropriately low. Indeed, the primary reason given by drivers for speeding was that their chosen speed ‘feels about right’. Musselwhite et al. suggested that speeding beliefs are informed by views that speed limits are arbitrary, that apparently
similar roads often have different limits, and that vehicle advances mean that speed limits are outdated.

9.2 Task demand and regulation

It is postulated that drivers aim to drive within an accepted range of difficulty that feels comfortable, leaving a margin for error which the driver is prepared to accept (Fuller, 2005; 2008). The physical and mental demand of driving runs along a spectrum and is dependent on many factors in the driver’s environment, the most important of which is speed. Control of speed allows a driver to increase or decrease this demand dependent on the road conditions. If demand is high and approaches a driver’s capability to control the vehicle then feelings of anxiety or fear, for both safety and prosecution if breaking the speed limit, are likely to cause a driver to reduce their speed (for a minority of drivers this feeling may be construed as a positive sensation and may encourage rather than discourage the behaviour). Conversely, if a driver is unable to drive at a speed that feels comfortable because of road conditions (e.g. congestion) or compliance with the speed limit (e.g. the speed limit feels too slow), this is likely to result in dissatisfaction and frustration.

There is substantial detailed support for this process of speed management (see Fuller et al. 2008b; Fuller et al. 2008a) including experimental evidence that drivers are informed of task demand not through conscious risk appraisal but through their feelings of risk (Kinnear et al., 2008; Fuller et al., 2008c). In addition to controlling the vehicle’s speed, drivers may also take on tasks, such as using in-car entertainment or sat-nav, when the driving context is unchallenging (low task demand); conversely, drivers might dump tasks when driving requires extra attention (high task demand).

9.3 Compliance

Compliance is an issue when there is clear separation between a driver’s desired speed and the speed limit. In this situation a driver’s disposition to comply with the speed limit will influence their decision making process but will be evaluated against more proximal motivations and influences (e.g. running late for an appointment). The driver must move from speed choice determined by what ‘feels right’ to speed choice by compliance. An important influence on this decision will be the perceived legitimacy of the speed limit. Tyler (2003) has argued that perceived fairness is a key determinant of whether people accept legal decisions and conform. It is clear from literature that moderate speeding is viewed as socially acceptable and perceived to be more prevalent than it actually is. Despite hard hitting media campaigns justifying the 30mph limit for many years, the speed limit in 30mph areas is regularly exceeded by a large proportion of drivers (although not as much as drivers perceive it to be). In one roadside survey of free-flowing traffic, it was reported that 69% of drivers broke the 30mph limit (DETR, 2000), and in another almost 90% of 17-24 year olds admitted to speeding in 30mph areas (Stradling et al., 2008). It is worth noting that drivers consider speeding on the motorway as less dangerous than speeding in built up areas suggesting an appreciation of risk at some level (Fuller et al., 2008a).

9.4 Enforcement and collisions

Compliance is obviously related to enforcement; Oei (1996) presents a theoretical relationship between enforcement and collision rates, as can be seen in Figure 3. Oei proposes that the relationship between enforcement and collision rates is S-shaped. With no enforcement, offence rates are likely to be high, resulting in large numbers of collisions. An initial increase in enforcement will have very little effect on collision rates, however at a ‘threshold’ level of enforcement a tipping point is reached, where the objective risk of drivers being caught for offending is sufficiently high that driver behaviour is affected on a wider scale and collision rates
reduce noticeably. This reduction continues until a saturation point when increasing the enforcement any further does not affect collision rates; this is due to a small population of drivers who continue to commit traffic offences despite high levels of police enforcement being present.

**Figure 3: Theoretical relationship between enforcement and collision rates**

Support for this theoretical model is limited given the difficulties in measuring enforcement and its direct effect on collision rates. Nevertheless, there is some support in the literature. De Waard & Rooijers (1994) evaluated the effect of stopping offenders with different rates: every 100th offender, every 25th offender and every sixth offender. Mean speeds observed before, during and after the enforcement period were compared with speeds on control sites. When every 100th offender was stopped, mean speeds did not change; there was a small change in observed speed with every 25th offender stopped, and a large effect when every sixth offender was stopped. The effect on mean speed of stopping every sixth offender was also found further along the road from the stop site and for a time after the enforcement was reduced. These results suggest that the initial tipping point for this type of situation is between stopping every 100th offender and every 25th offender.

More recently, Walter (2008) has studied the effect of a four week period of police enforcement. This found that the number of speeding offences fell over the period concerned, suggesting that drivers became increasingly cautious of being stopped for speeding during the operation. Larger reductions were observed at the sites where average speeds were most in excess of the speed limit.

Speed reductions were also observed at other sites close to, but not on, the sections of road on which enforcement took place, though these were smaller, whereas no speed reductions were observed at control sites.

The findings also suggested that behaviour is affected by the severity and probability of likely punishment.
References


British Medical Association (BMA), (1997), Road Transport Morbidity and Mortality Iceberg. London: BMA.


Crimson, L., Notley, S. & Lawton, B. (2007). Safety Benefits of the M25 Controlled Motorway: 1990 to 2006 Data. Unpublished project report. Crowthorne: TRL. [Although this report has not been published, the findings reported herein have been reported in various publications by TRL’s customer for this report.]


Dewaard, D. & Rooijers, A.J. (1994). An experimental study to evaluate the effectiveness of different methods and intensities of law enforcement on driving speed motorway. Accident Analysis & Prevention, 26, 751-765.


Speed limit reduction: A summary of the evidence


SWOV Fact sheet, Zones 30: urban residential areas
http://www.swov.nl/rapport/Factsheets/UK/FS_Residential_areas.pdf


Appendix A  Example of effect on emissions

An illustration of the effect of a reduction in average speed from 30mph to 20mph is shown in Table 3. This sort of speed reduction causes an 18% increase in NO\textsubscript{x} emissions, a similar increase in CO\textsubscript{2} emissions and a 6.6% increase in PM emissions.

Table 3: Effect of a change in average speed (Source: Defra, 2012)

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>NO\textsubscript{x} (g/km)</th>
<th>PM (g/km)</th>
<th>CO\textsubscript{2} (g/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.537</td>
<td>0.043</td>
<td>210.6</td>
</tr>
<tr>
<td>20</td>
<td>0.637</td>
<td>0.046</td>
<td>246.9</td>
</tr>
<tr>
<td>Change</td>
<td>18.5%</td>
<td>6.6%</td>
<td>17.3%</td>
</tr>
</tbody>
</table>

However, changing the speed limit alone is unlikely to achieve a 10mph speed reduction: other factors, which may involve a complete change in driving operation, are likely to change. The slower speed cycle will include a lot more stops and accelerations and the entire speed range will have changed. When considering a speed reduction strategy, this may not be the desired plan; the aim may be simply to cap the maximum speed while leaving the other speed unchanged.

Figure 4: Relationship between NO\textsubscript{x} emissions and average trip speed (Source: Defra, 2012)

Figure 5: Relationship between PM emissions and average trip speed (Source: Defra, 2012)
To illustrate the effect of reducing the speed limit to 20mph from 30mph we have compared potential outcomes that represent a complete change in speed and a capping of the maximum speed:

1. A medium speed cycle (a typical 30mph speed limited road)
2. A slow speed cycle (a typical 20mph speed limited road)
3. The medium speed cycle with the maximum speed capped (a typical 30mph speed limited road but with a strictly enforced 20mph speed limit)

The specifications of these three cycles are listed in Table 4 and their speed traces are shown below. Cycle 2 has about half the maximum speed of Cycle 1 and almost half the average speed. Cycle 3 has a lower maximum speed than Cycle 1 (almost a third lower), but the average speed is only slightly lower.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Duration (s)</th>
<th>Distance (km)</th>
<th>Average speed (mph)</th>
<th>Minimum speed (mph)</th>
<th>Maximum speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle 1</td>
<td>81</td>
<td>0.508</td>
<td>14.0</td>
<td>0</td>
<td>28.0</td>
</tr>
<tr>
<td>Cycle 2</td>
<td>147</td>
<td>0.504</td>
<td>7.7</td>
<td>0</td>
<td>14.3</td>
</tr>
<tr>
<td>Cycle 3</td>
<td>86</td>
<td>0.506</td>
<td>13.2</td>
<td>0</td>
<td>19.9</td>
</tr>
</tbody>
</table>

These speed traces have been run through PHEM, the Passenger car and Heavy duty vehicle Emission Model. This model is a vehicle dynamics based model that takes the second by second speed trace as input, works out the load on the engine each second and calculates the resulting emissions. The model was developed by the Technical University of Graz as part of the European ARTEMIS project. The emissions have been calculated for two vehicle categories – a Euro 4 petrol car and a Euro 4 diesel car.

The resulting emissions are shown in Table 5, for NO\(_x\), PM and CO\(_2\). PM is only given for diesel vehicles (PHEM currently does not include PM emissions for petrol vehicles). Cycle 2, where all the speeds have been changed, results in a large increase in all the emissions. For Cycle 3, where only the maximum speed has changed, the increase is much smaller. In fact the emissions of NO\(_x\) from petrol cars has decreased by over 20%.
Table 5: Resulting emissions for the three cycles (Source: Defra, 2012 / Rexeis et al., 2005)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Cycle</th>
<th>NO\textsubscript{x} (g/km)</th>
<th>PM (g/km)</th>
<th>CO\textsubscript{2} (g/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol car</td>
<td>Cycle 1</td>
<td>0.066</td>
<td>243.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cycle 2</td>
<td>0.096</td>
<td>364.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cycle 3</td>
<td>0.051</td>
<td>245.6</td>
<td></td>
</tr>
<tr>
<td>Diesel car</td>
<td>Cycle 1</td>
<td>0.527</td>
<td>0.020</td>
<td>187.6</td>
</tr>
<tr>
<td></td>
<td>Cycle 2</td>
<td>0.602</td>
<td>0.033</td>
<td>263.8</td>
</tr>
<tr>
<td></td>
<td>Cycle 3</td>
<td>0.577</td>
<td>0.029</td>
<td>201.6</td>
</tr>
</tbody>
</table>

Relative changes compared to cycle 1

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Cycle</th>
<th>Relative change in NO\textsubscript{x} (%)</th>
<th>Relative change in CO\textsubscript{2} (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol car</td>
<td>Cycle 1</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Cycle 2</td>
<td>44.5%</td>
<td>49.9%</td>
</tr>
<tr>
<td></td>
<td>Cycle 3</td>
<td>-22.6%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Diesel car</td>
<td>Cycle 1</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Cycle 2</td>
<td>14.4%</td>
<td>59.3%</td>
</tr>
<tr>
<td></td>
<td>Cycle 3</td>
<td>9.6%</td>
<td>43.0%</td>
</tr>
</tbody>
</table>

Figure 7: Medium speed cycle (Source: Defra, 2012)
Figure 8: Slow speed cycle (Source: Defra, 2012)

Figure 9: Medium speed cycle with the maximum speed capped (Source: Defra, 2012)
### Appendix B  UK Air quality limits

#### Table 6: UK national air quality limits for PM<sub>10</sub> and NO<sub>2</sub> pollutants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Measured as</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM&lt;sub&gt;10&lt;/sub&gt;</td>
<td>24 hour mean</td>
<td>50 µm&lt;sup&gt;3&lt;/sup&gt;, not to be exceeded more than 35 times a year</td>
</tr>
<tr>
<td></td>
<td>Annual mean</td>
<td>40 µg/m&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>NO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>24 hour mean</td>
<td>200 µg/m&lt;sup&gt;3&lt;/sup&gt;, not to be exceeded more than 18 times a year</td>
</tr>
<tr>
<td></td>
<td>Annual mean</td>
<td>40 µg/m&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

### Appendix C  DMRB screening model input parameters

#### Table 7: DMRB Screening model input parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2012</td>
<td></td>
</tr>
<tr>
<td>Distance for road centre</td>
<td>10</td>
<td>M</td>
</tr>
<tr>
<td>Traffic flow (AADT)</td>
<td>10000</td>
<td>Veh/day</td>
</tr>
<tr>
<td>Percentage heavy-duty</td>
<td>10</td>
<td>%</td>
</tr>
<tr>
<td>Road type</td>
<td>Urban</td>
<td></td>
</tr>
<tr>
<td>Background NO&lt;sub&gt;x&lt;/sub&gt;</td>
<td>21.63</td>
<td>µg/m&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Background NO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>14.79</td>
<td>µg/m&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Background PM&lt;sub&gt;10&lt;/sub&gt;</td>
<td>14.76</td>
<td>µg/m&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Appendix D  Resulting pollutant concentrations at varying traffic speeds

**Figure 10:** Resulting pollutant concentrations for NO\textsubscript{x}

**Figure 11:** Resulting pollutant concentrations for NO\textsubscript{2}

**Figure 12:** Resulting pollutant concentrations for PM\textsubscript{10}
Appendix E  Measuring noise

Noise from traffic can be measured using a number of different metrics depending on the application and requirement. These can be $L_{A10}$ (the noise exceeded 10% of the time) used in the standard method for predicting traffic noise in England and Wales, $L_{Aeq}$ (an equivalent average noise level) used in other traffic noise prediction models, $L_{den}$ (a 24 hour $L_{Aeq}$ with weightings for different times of the day) used in EU noise mapping and $L_{Amax}$ (the maximum noise level) used with respect to the noise from individual vehicles.

In some cases the metric used to measure the noise will have an impact on the noise reduction predicted (or measured) as a result of a change in traffic speed. For example, if the volume of traffic and background noise is low, as may be the case in rural areas, quieter vehicles will still yield a quieter $L_{Aeq}$ as their noise provides the primary contribution to the average noise, but $L_{A10}$ levels will remain unaffected if traffic noise is present less than 10% of the time.

Appendix F  Health impacts from road transport

![The Road Transport Morbidity and Mortality Iceberg](image)

Figure 13: The ‘Road Transport Morbidity and Mortality Iceberg’ Source: (BMA, 1997).

Disclaimer

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