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Measure No.6: Environmental Zones

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Defining areas of a city as having particular conditions attached to traffic in that area. These might relate to types of vehicle, or to vehicle speed, noise or emissions.

Cities can attempt to address a range of issues using these zones, such as the frequency or severity of road collisions and casualties, levels of active travel (walking and cycling) and the quality of the street environment. They can also reduce levels of emissions from traffic helping to reduce negative effects on human health.

6.1 Context and background

There are a number of zone types that can applied to promote sustainable mobility: Specifically, this Measure Review will cover two distinct forms of low speed restriction, reflecting experience of developments in the UK, and LEZs. An additional study considered in the review relates to a 'Traffic restriction zone' in Milan, (Invernizzi et al., 2011), however as this zone essentially operates as a low emission zone it will be treated together with the studies on LEZ. Insufficient material was found to discuss Noise reduction zones in this review, and restrictions on lorry traffic are discussed in Measure No.3: Urban Freight.

6.1.1 Speed reduction Zones

Low speed restrictions in a street or across an area of a city are intended to reduce speeds of motor traffic within the areas treated. The aims of such initiatives are to reduce the frequency or severity of road collisions and casualties (Webster & Layfield, 2003, Grundy et al., 2009), to encourage walking and cycling, to promote a more communal street environment (Bristol City Council, 2012, Atkins, 2010) and,

Key messages:

- There is evidence that speed restriction 'zones' using road engineering and other physical measures can reduce vehicle speeds, injuries and fatalities. The studies did not find evidence of traffic collisions 'migrating' to surrounding streets.
- Compared with speed restriction zones, schemes which rely on sign-only low speed limits are much less expensive to implement on an area-wide basis, although they lead to far smaller reductions in average speed.
- Lower speed zones were found to be cost- effective in areas with high numbers of casualties, but not so in areas which already had low levels of casualties. (Although the study authors did note some issues with the quality of data behind this finding. The UK also has relatively low casualty levels compared to some other nations).
- Low Emission Zones can be beneficial in reducing emissions of harmful pollutants, from transport although there are uncertainties due to other sources of pollution that can affect measurements of air quality.
- Low Emission Zones can help local authorities comply with European limit values and thus avoid fines.

Potential interventions

- Speed restriction zones, which can include engineered or signed-only limits (or a combination). Covering part of a street to a whole area of a city.
- Environmental zones such as low emission zones (LEZ) and noise reduction zones.
- Traffic restriction zones. These include bans on heavy goods vehicles and car-free areas or cities (e.g. residential areas, inner-city and historic areas, retail locations)

arguably, to provide economic benefits from the reduction of casualties (Peters & Anderson, 2012). From a wider perspective, the importance of reducing road injuries reflects the fact that they are seen to be a leading cause of loss of life and disability worldwide (Grundy et al., 2009). An important feature of speed reduction initiatives as originally deployed in the UK was that the term 'low speed zone' specifically implied the use of calming measures such as speed humps and chicanes designed to encourage speeds under 20 mph (32kph)[A]. In contrast 20 mph (32kph) limits contained signs and road markings only. This distinction is reflected in the evidence contained in this review, although since 2011 the requirement for UK schemes to be exclusively one or the other type has been lifted and schemes tend to be a mixture of the two. Examining evidence for the two different approaches to lower speed does though provide some insight into the relative benefits achievable in relation to the extent of the intervention being made. In some UK implementations areas or streets with low speed limits and traffic calming elements are also part of 'Home Zones', in which roads are (re)designed to facilitate greater and safer use by pedestrians and cyclists[B].

6.1.2 Low emission zones (LEZ)

These are intended to reduce levels of emissions from traffic. The principle dangers in these emissions are negative effects on human health, particularly increased risk of respiratory and cardiovascular disease (Invernizzi et al. 2011, p.3522, Panteliadis et al. 2014). Emissions that are of concern include particulate matter (PM_{10}, $PM_{2.5}$, PM_1, $PM_{0.1}$ and black carbon/soot) (Invernizzi et al., 2011, Cyrys et al., 2014, Panteliadis et al., 2014) and nitrogen oxides, or NOx (NO and NO_2)(Morfeld et al., 2014, Panteliadis et al., 2014).

In Europe, there is an additional economic incentive for LEZs in as much as they may enable compliance with EU regulations, and thus potentially avoid attendant fines for non-compliance. LEZs can also have the benefit of reducing traffic volume. In 2010 there were 152 cities with LEZs in the EU. Germany in particular has focused on them. In 2010 The EU 'Clean Air Directive' (2008/50/EC) was among the strictest legislation about PM_{10} in the world. For this reason many European cities have started to implement schemes to reduce PM_{10} (Wolff & Perry, 2010).

Different countries have different specifications for which vehicles they restrict in LEZs. In Germany, for example, most cars with catalytic convertors are allowed into the zones. Most petrol cars in Germany have these, so the zones restrict mostly diesel cars. However, different LEZs in Germany have different restrictions for what vehicles can enter (Cyrys et al., 2014).

6.2 Extent and Sources of Evidence

Eleven items were reviewed in total: three examine 20 mph zones, two examine 20 mph limits, five examine LEZs and one examines a traffic restriction zone. All 11 studies are taken from countries in the EU. However there is a focus on the UK and Germany. Five of the studies are on UK schemes and four are based on German schemes. This reflects the literature available. Germany is of particular relevance to LEZs due its widespread adoption of that scheme type. The other two studies are based on data from the Netherlands and Italy.

Nine of the 11 studies reviewed were published within the last five years, and three of these were published in 2014. This suggests that environmental zones are a topic receiving ongoing research and that the scheme types and findings discussed in this review are generally up to date.

Eight of the studies are journal papers, likely to have been written by academic authors. Two of the studies are consultancy reports. The remaining study is by a local council reporting on its own scheme (Bristol City Council, 2012). However this report shows a good degree of transparency, providing negative as well as positive findings in relation to their 20 mph limit scheme.

[A] Traffic calming is further discussed in Measure No.23

[B] Home zones are also discussed under Measure No.23

Five of the studies used case studies of single environmental zones. Some of the other studies looked at data combined from a number of zones in one country. Webster & Layfield (2003), Grundy et al. (2009) and Peters & Anderson 2012) all looked at a collection of 20 mph zones across London, UK. Morfield et al. (2014) looked at LEZs in 17 German cities, Cyrys et al. (2014) examine several German LEZs and Wolf and Perry (2010) discuss a more general policy context, although also including a specific focus on Germany. The studies reviewed provide a good level of primary data.

6.3 What the Evidence Claims

Evidence is presented against the classifications introduced above: engineered low speed zones, signed-only low speed limits and low emission zones.

6.3.1 Low speed zones

Two studies reviewed examined 20 mph zones in London (Webster & Layfield, 2003, Grundy et al., 2009). Webster & Layfield found that mean speeds on treated roads were reduced to 17 mph, a reduction of about 9 mph. Every 1 mph reduction of speed is likely to lead to a 5% reduction in collisions causing injury. Hence an important result of this reduction in speed is a reduction in collisions. The zones reduced injury frequency by about 42% and collision frequency by about 53% (Webster & Layfield, 2003). As well as reducing the frequency of collisions the seriousness of injury was also reduced. The zones led to reductions of killed or seriously injured casualties of about 57% (Webster & Layfield, 2003) and the ratio of such incidences to all collisions fell from 0.17 to 0.13. The frequencies of killed or seriously injured casualties were reduced for pedestrians, cyclists, powered two wheelers and car occupants.

Grundy et al. (2009) found that the greatest reduction in road casualties from the zones was amongst young children. They conclude that 20 mph zones are more effective in reducing severity of injury from collision than the total number of collisions. Traffic flows were also reduced by 15% in the zones (Webster & Layfield, 2003).

One concern surrounding 20 mph zones is that they can lead to collision migration. The fear is that drivers simply reroute in order to avoid the slower zones, and will thus have collisions on neighbouring roads instead. However, Webster & Layfield (2003) and Grundy et al. (2009) found there was little if any collision migration onto neighbouring roads.

6.3.2 Low speed limits

Two reports examining low speed areas in Bristol, UK (Bristol City Council, 2012) and Portsmouth, UK, (Atkins, 2010) were considered by the review. Because these 20 mph limits did not include traffic calming measures, it is to be expected that the reductions in speed they lead to will be less than for zones (although potentially providing benefits over a wider area). Bristol City Council (2012) report mean average reductions of 1.4 mph in one pilot area and 0.9 mph in the other. Atkins (2010) reported a mean average reduction of speed across the whole scheme in Portsmouth of 1.3 mph. However, speeds in Portsmouth were already generally low prior to implementation (the mean average speed for roads covered by the 20 mph limits was 19.8 mph, before implementation). In both cities there were greater reductions of speed on roads that had previously had mean average speeds greater than 24 mph. Such roads, in the Portsmouth scheme saw reductions of 6.3 mph (Atkins, 2010).

Both Bristol City Council (2012) and Atkins (2010) report that it was hard to be confident that the 20 mph limit schemes had reduced collisions and casualties. This was simply because the number of collisions within the areas was small and fluctuated. Whether the limits led to more walking and cycling, in turn leading to physical, mental and social benefits is debateable. Bristol City Council (2012) report walking counts increasing by figures ranging from 10 to 36%. Cycling counts increased between 4% and 37%. Atkins (2010) report that the limits in Portsmouth had little apparent impact on modal share.

20 mph limits can have holistic community benefits. The 20 mph limits were generally well accepted by residents and had posi-

tive impacts on their perceptions of their area. Bristol City Council (2012) found that after implementation 83% of residents supported the limits. This was an increase from 67% before implementation. 40% of respondents in Portsmouth felt the scheme had led to decreased speeds Atkins (2010). The Bristol scheme was popular in terms of addressing speeding in residential areas which is perceived by residents as one of the most widespread antisocial behaviours (Bristol City Council, 2012).The scheme type can also engender favourable perceptions of greater community: 18% of respondents thought that since limits had been introduced people spent more time in the streets. Similarly, respondents in Portsmouth felt there was a safer environment following implementation.

This evidence suggests that 20 mph zones are more effective than 20 mph limits in reducing speed (Atkins, 2010). However 20 mph limits are less expensive to implement on an area-wide basis. The geographical extent of 20mph limits may be important: If they are consistently applied across a large area than this conveys the message that 20mph is a suitable, normal speed in residential areas. However if they are only applied in small areas, so that a cross city trip encounters a number of different speed limits, than the same message will not be conveyed.

6.3.3 Low Emission Zones (LEZ)

Five studies reviewed related to LEZs and a sixth examined a traffic restriction zone that also had the aim of reducing emissions. These studies found that LEZs reduced air quality pollutants of relevance to human health.

The LEZ in Amsterdam, The Netherlands, led to reductions of traffic contributions to concentrations of pollutants (Panteliadis et al.2014). Contributions to NO_2 levels were decreased by 4.9%, NOx by 5.9%, PM_{10} by 5.8%, Absorbance (a soot proxy) by 7.7% and EC (a soot proxy) by 12.9%.

A study into the LEZ in Munich, Germany, found that the zone led to reductions of POC (particulate organic compounds – a component of PM) concentrations (Qadir et al. 2013). The contribution of traffic to the concentrations was decreased by about 60%. However the overall decrease of POC was limited due to other sources of the pollutant type.

An examination of 17 LEZs in Germany found that there was a statistically significant but small (<4%) reduction of NO2, NO and NOx concentrations associated with the zones (Morfeld et al., 2014). The study concluded that the effectiveness of LEZs in tackling such concentrations was still 'under debate' (p.2). The study does not focus on PM levels. However it does comment that PM_{10} mean values had been found to be reduced by the LEZ in Munich by 1 % at most.

Cyrus et al. (2014) examined German LEZs in Cologne, Berlin and Munich. Using modelling They estimated reductions of PM10 mass concentrations of up to 10%. However, LEZs were also associated with decreases in traffic-related soot (an important risk to health) of 52%, and decreases of diesel particle emissions of 63%. There were also important reductions of 60% in traffic related elements of PM2.5 in Munich. The study implies reductions of PM10 levels might be affected by meteorology. The study concluded that benefits of LEZs for human health are significant and greater than had been realised when only PM_{10} mass concentrations were monitored.

A policy based study, with a focus on Germany (Wolff & Perry, 2010), reported that LEZs have been a popular way amongst local authorities and governments for dealing with air pollution concentrations. Germany in particular has implemented many LEZs, and has seen national average PM_{10} concentrations fall from 24.4 ug/m3 in 2005 to 21.2 ug/m3 in 2008. The number of German cities exceeding the European Limit Values for PM_{10} fell from 36 in 2005 to 18 in 2008.

Invernizzi et al. (2011) report on a traffic restriction zone in Milan, Italy, that sought to reduce harmful emissions in the city centre area. Traffic restriction zones aim to improve both air quality vehicular congestion. Other European examples are in London and Stockholm. The Milan zone means that drivers wishing to enter have to purchase a ticket, unless their vehicle meets the Euro four standard. The zone differs from a pedestrianised zone as vehicles that are compliant, can enter. Invernizzi et al. (2011) report that PM_{10}, PM2.5 and PM1 concentrations had been found to be unaffected by the zone. However black carbon results suggested that the black carbon contribution to PM_{10} decreased by 47% and 62% in the traffic restricted zone and pedestrian zone respectively. The study considers that the absence of effect on overall PM_{10} may be due to the small size of the restricted zone. However, local traffic generally only makes a minor contribution to overall PM_{10} concentrations (see for example Querol et al., 2004).

In conclusion, as the term suggests, the main aim of low emission zones is to reduce emissions of harmful pollutants. Four of the six studies reviewed suggest that such zones can be successful in this aim. Invernizzi et al. (2011) and Morfield et al. (2014) were less positive in this respect. The prime benefit of reducing pollutants is to reduce threats to human health. Panteliadis et al. (2014) found that the reductions of pollution caused by the zone they studied led to a reduction in EC that would lead to increased life expectancy of around 2 months for those living close to the road measured. However the health benefits of LEZs can be unevenly distributed as concentrations of pollutants such as PM10 can vary greatly even within a small urban area (Cyrys et al., 2014). It is possible thought the greatest benefits from LEZs will be enjoyed by those suffering the worst air quality impacts, thus making the distribution of benefits a fair one.

6.3.4 Nature of Methods

Most of the studies relating to 20 mph zones and limits drew on 'before and after' data. The main outcomes measured in these studies were traffic speeds, collision frequency and seriousness of injury from collisions. Bristol City Council (2012) taking a more holistic approach also made walking and cycling counts, noise and air quality assessments, conducted doorstep questionnaires and monitored bus performance. Similarly Atkins (2010) drew on traffic volume data and qualitative surveys investigating support for a 20 mph limit scheme.

A common weakness amongst the methodologies investigating 20 mph zones and limits is that often only two or three years of collision data after implementation are available. This is not a serious drawback when a large number of zones are being examined together (as in Webster & Layfield, 2003 and Grundy et al., 2009) but is more problematic when only one area is being researched as collision numbers are likely to be small and to fluctuate. Bristol City Council (2012) and Atkins (2010) concede that they cannot reach confident conclusions about the effect of 20 mph limits on collision and casualty numbers. The traffic count data used by Atkins (2010) is also questionable, as the data provides a before and after comparison but no control roads (although the 20 mph limit areas are compared with national averages). Hence, Atkins concede that factors such as the economic downturn may have affected the results. For instance, they note that during the time period studied, traffic volumes fell by a greater degree in another UK city, Southampton, than they did in the 20 mph limit area being investigated.

Of the studies examining 20 mph limits and zones, the evidence regarding effects on collision numbers provided by Webster & Layfield (2003) and Grundy et al. (2009) is particularly strong as it covers a large time period and aggregates figures from a number of zones (for instance Grundy et al. covered from 1986-2006, and used data covering 119,029 road segments, a road segment being a stretch of road between junctions) with non-zoned roads acting as controls. Grundy et al. found that their results were robust under sensitivity analysis. The London studies used police data that tends to under-report road injuries, but this under-reporting remains consistent between 20 mph zones and non-zone roads (Grundy et al. 2009).

Two studies comment on the possibility of regression to the mean in relation to understanding the impact of 20 mph zones on numbers of collisions and casualties (Webster & Layfield, 2003, Grundy et al. 2009). This is the idea that if zones are implemented in areas that have experienced unusually high numbers of collisions, it is likely due to natural fluctuation that these numbers would decline in the following years even without the intervention. However both studies conclude that regression to the mean did not affect their findings. In support of this Webster & Layfield point to the fact that many zones they studied were not selected because of high collision rates and the long periods of time after implementation that the data covered.

As mentioned above amongst studies investigating 20 mph zones and limits, Bristol City Council (2012) and Atkins (2010) took a more holistic approach to evaluating success by including qualitative surveys. Good sample sizes were achieved for these, with 1,066 responses being gained to a questionnaire and 1,838 doorstep surveys being completed for Bristol City Council and 1,445 qualitative interviews being conducted for Atkins (2010). For the latter interviews, the sample was stratified by age, gender and ethnicity.

With the exceptions of the German policy focused study (Wolff & Perry, 2010) and Cyrys et al. (2014), the LEZ studies chosen for review used actual data of air pollution measurements rather than modelling. A range of different technologies was used to record the measurements of the different pollutants that the different studies measured. Some of the studies used measurements from the same location, before and after implementation of the LEZ (Panteliadis et al., 2014 – four years of data in total, Qadir et al., 2013 – three years of data in total). However Panteliadis et al. did not have traffic count data for before the intervention and so state they could not discount the possibility of the reported decreases in air pollution being attributable to decreases in traffic volumes in the area, potentially resulting from the economic downturn for example.

Others did not use before and after measurements but compared simultaneous readings from within and without the LEZ (Invernizzi et al., 2011). Panteliadis et al., 2014 used one measurement station as a control to compare the roadside data against. However, whilst this station indicated background levels as opposed to roadside readings, they concede that it was also in the LEZ and so their findings may have underestimated the effect of the zone. Morfeld et al. (2014) used both before and after measurements (four years of data in total) and also measurements from inside and outside the LEZ, and can be considered a strong methodology in this respect.

A problem commonly reported amongst the studies in accurately assessing the effectiveness of LEZs is isolating the impact of traffic specifically on air quality. This is difficult as pollutant concentrations can be affected by the weather (Panteliadis et al., 2014, Cyrus et al., 2014) including wind (Panteliadis et al., 2014, Invernizzi et al. 2011). The studies generally sought to control for the weather conditions during the measurement period (Morfeld et al., 2014). Season also has an influence on pollution. Winter tends to see higher levels of pollutants than summer (Invernizzi et al., 2011). The effects of traffic also have to be separated out from other sources of air pollution. These can include local sources such as cooking and solid fuel combustion (Qadir et al., 2013), as well as transboundary pollution that originates from sources outside the local area.

Other potential factors that can obscure LEZs effect on air pollution include, ozone concentrations (which reduce concentrations of NO_2 independently of any reduction in total NOx), school holidays and other temporal variations in traffic, the evolution of lower emission vehicles in general (Morfeld et al., 2014, Panteliadis et al. 2014), residential and business heating (Invernizzi et al., 2011) and construction work and associated heavy goods traffic (Qadir et al., 2013). One of the studies conducted positive matrix factorisation in order to separate out traffic from other sources of pollutants (Qadir et al. 2013). Other studies sought to place the air quality instruments in such places as would minimise the effect of non-traffic sources of pollution (Invernizzi et al., 2011).

The LEZ studies applied a variety of statistical tests to their data including linear regression, multivariate and sensitivity analysis (Panteliadis et al. 2014), positive matrix factorisation (Qadir et al. 2013) and multiple linear and log-linear fixed-

effects regression modelling (Morfeld et al., 2014). Morfeld et al. in particular used very thorough statistical methods.
A gap that remains in the evidence regard LEZs is the existence of a number of studies measuring the same specific pollutants: the different studies reviewed focused on a range of different pollutants, so that the overall picture of the effect of LEZs on each specific pollutant lacks corroboration by multiple papers. Such evidence may be available however, with further investigation.

6.4 Lessons for Successful Deployment of this measure

6.4.1 Low speed zones and limits

There are some issues surrounding the transferability and generalisability of the findings of some of the 20 mph studies. Three of the studies into 20 mph zones are based on data from London. London is by far the largest city in Europe and therefore may not be representative of the traffic conditions in other European cities. However, Grundy et al. (2009) suggest that their evidence from London is relevant to other major cities. They found that the effect of 20 mph zones was similar in inner and outer London areas, and conclude from this that the success of the intervention is little modified by area type.

The transferability of the evidence on 20 mph limits in Portsmouth is questionable. This is because many roads in the city had mean average speeds under 20 mph even before implementation (Atkins, 2010). Average speeds on roads before implementation would be important for authorities in other cities to consider when exploring the use of 20 mph limits. In general, careful consideration and good data should be used when deciding what streets to include in a 20 mph limit area (Bristol City Council, 2012).

The studies examined give some indications of economic aspects of implementing 20 mph zones or limits. Zones, which include traffic calming are more expensive than limits, which only require signage. 20 mph zones could be very expensive to implement on an area wide basis.

Peters & Anderson (2012) focus specifically on the economic impacts of 20 mph zones. They assessed the economic benefits and costs of such zones using two methods: cost benefit analysis (CBA) and cost utility analysis (CUA). These two assessment measures take account of different sets of costs and benefits, including quality adjusted life years as a result of injury, police, local government costs, etc. The main economic benefit of 20 mph zones is in reduction of casualties. Webster & Layfield report that in 2003 each serious casualty in the UK was valued at £134,000 by the Department for Transport.

Peters & Anderson (2012) conducted one-way, threshold and probabilistic sensitivity analyses. They found that in areas of high numbers of casualties, implementation of 20 mph zones was found to be cost effective according to CBA but not by CUA. With CBA the net present value was -£25,500. In low casualty areas neither assessment method found 20 mph zones to be cost effective. Peters & Anderson (2012, p.40) note that their findings should be treated with caution due to the 'quality, age or absence of reliable data for many parameters'. In addition the UK in general has relatively low numbers of traffic casualties (Grundy et al. 2009). This may affect how representative the UK studies are for other European countries, as calculations of the cost effectiveness of 20 mph zones depends partly on the background rate of collisions (Peters & Anderson, 2012).

The impact of 20 mph limits may be increased if accompanied by supporting measures aimed at generating public support for, and adherence to, the limits. These include communication campaigns, asking businesses and other employers of drivers to encourage compliance and other awareness strategies (Bristol City Council, 2012, Atkins, 2010). Bristol City Council (2012) suggest that for 20 mph limits to be effective, there should be partnership between stakeholders including the local council, the police, local businesses, motoring organisations and cycling and walking organisations etc.

Atkins (2010) report a number of practicalities that should be addressed when implementing 20 mph limits. Challenges encountered in Portsmouth, UK, included limited resources for the design of the scheme, vandalism of the signs and signs 'cluttering' some junction. The report also comments that the Portsmouth 20 mph limits were intended to be self-enforcing. It is unlikely that police will be able to enforce area wide 20 mph limits.

6.4.2 Low emission Zones (LEZ)

One political and economic driver of implementation of LEZs comes from the European Union's Air Quality Directive (Cyrys et al. 2014). (The degree of response to this driver has differed greatly amongst European countries, however, with many countries still violating EU air quality limits.) The directive addresses air quality with some of the strictest legislation in the world (Wolff & Perry, 2010). It requires measurement of PM_{10} on an hourly basis. There are potential fines for countries failing to meet the air quality limit values. This can result in individual cities facing fines. For instance Leipzig, a city in Germany, faced a potential penalty of 700,000 Euros per day, for failing to comply with limits (Wolff & Perry, 2010). To set against the savings of avoiding fines are the costs involved in implementing and then enforcing the zones (Cyrys et al., 2014). Zones can be enforced by a traffic camera system that reads licence plates and automatically issues fines (Panteliadis et al., 2014).

The extensive uptake of LEZs, particularly in Germany suggests that the zones can be implemented on a widespread basis. In 2010, 41 German cities had LEZs (Wolff & Perry, 2010). Countries with high concentrations of air pollution are likely to have air quality plans which provide a helpful context for implementing LEZs (Panteliadis et al, 2014). Thus an obvious driver of LEZ implementation is if a city consistently breaks air quality limit values. For instance Milan, Italy, implemented a traffic restriction zone in response to long periods of high PM concentrations, sometimes reaching daily means of more than 75 μg/m3 (Invernizzi et al. 2011).

This review has in part focused on LEZs, one of the strategies within air quality plans. However air quality plans can also include other complementary measures including 'traffic regulation, stimulation of public transport usage, ring road utilisation, traffic flow improvement (and) speed limit reduction' (Panteliadis et al. 2014, p.113).

Some studies highlight issues with public acceptance of LEZs (Wolff & Perry, 2010, Invernizzi et al., 2011). There can be particular issues with inconvenience for residents and businesses located within the zones (Wolff & Perry, 2010). Cyrys et al. (2014) suggest that LEZs can limit some people's mobility, with some commercial and private vehicles being excluded from the zones (Wolf & Perry, 2010).

LEZs can encourage city residents and businesses to buy vehicles compliant with the LEZ requirements. This means the zones can have an additional benefit for air quality, even outside the boundaries of the zone. However, it does raise issues around fairness as it may be those who cannot afford to buy a new car that are penalised for entering the zones.

6.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for Environmental Zones in promoting sustainable mobility:

- *Road safety:* Reducing traffic speeds creates a better street environment, where it is safer for children to play.
- *Health benefits:* these arise from increased walking and cycling due to perceptions of (and actual) improvements to road safety.
- *Environmental benefits – Air Quality:* The main gains from lower pollution in LEZs are for human health, although these can be unevenly distributed as concentrations of pollutants such as PM10 can vary even within a small urban area. It is possible however, that the greatest benefits from LEZs will be enjoyed by those suffering the worst air quality impacts, thus making the distribution of benefits a fair one.
- *Environmental benefits - Noise:* Reduced traffic speeds could reduce local noise levels.

6.6 Summary

One strength of the studies reviewed is that they relate to specific case studies, in specific cities for instance, and generally use real world data and measurements. The contemporary nature of the evidence is also a particular strength. As discussed a significant proportion of the studies reviewed used before and after data and/or control data.

Conversely, the small number of studies from countries other than the UK and Germany is a slight weakness in the evidence presented. A gap in the evidence on LEZs is that the studies reviewed did not greatly investigate issues surrounding enforcement of the zones. Another gap in the evidence is that the studies did not tend to discuss the economic aspects of the schemes in detail. The two main economic points that were made are that LEZs can help compliance with European limit values and thus avoid fines, and that 20 mph zones may be cost effective in areas with high numbers of casualties but were not found to be cost effective in areas of low casualties.

The studies present strong evidence that 20 mph zones can reduce vehicular speeds and the attendant injuries and fatalities. The studies did not find evidence of collision migration. 20 mph limits are much less expensive to implement on an area wide basis than zones, but lead to far smaller reductions in average speed albeit this will be over a larger area. The reduction in speed will depend, to a substantial degree, on the average speeds on a road, prior to implementation. 20 mph limits can be considered a way to achieve holistic benefits for an area, both in terms of traffic conditions, and quality of life. The evidence suggests that because of these benefits 20 mph limits can be viewed quite positively by residents. There is a weakness with the evidence of the effect of 20 mph limits on collisions and casualty numbers, due to the small and fluctuating numbers of these in the treated areas. Hence the safety benefits of 20 mph limits, whilst logical given the reduction in vehicle speeds, have not been evidenced with certainty.

Four of the six studies on LEZs suggest that they can be beneficial in reducing emissions of harmful pollutants. These studies had strong methodologies and so this finding can be given some credibility. The other two studies suggested LEZs may not be so effective. One problem with concluding on the effects of LEZs on pollutant concentration is the very localised nature of such concentrations, and the existence of other sources for them, besides motor vehicles. Hence measurements taken in two different places within the same LEZ can yield different results. As discussed weather and season can also influence measurements, although some studies controlled for these factors. Evidence suggests that there can be some issues surrounding public acceptance of LEZs. They have been a strategy that arguably been popular with local authorities. Although take up outside of Germany has not been very widespread. In addition there has been debate about whether citywide or countrywide frameworks can best achieve the aims and deployment of LEZs.

In conclusion, the evidence reviewed suggests that all three types of environmental zone, 20 mph zones, 20 mph limits and LEZs can be viable and beneficial schemes to implement, although the caveats about the evidence reviewed, as discussed above, should be considered.

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