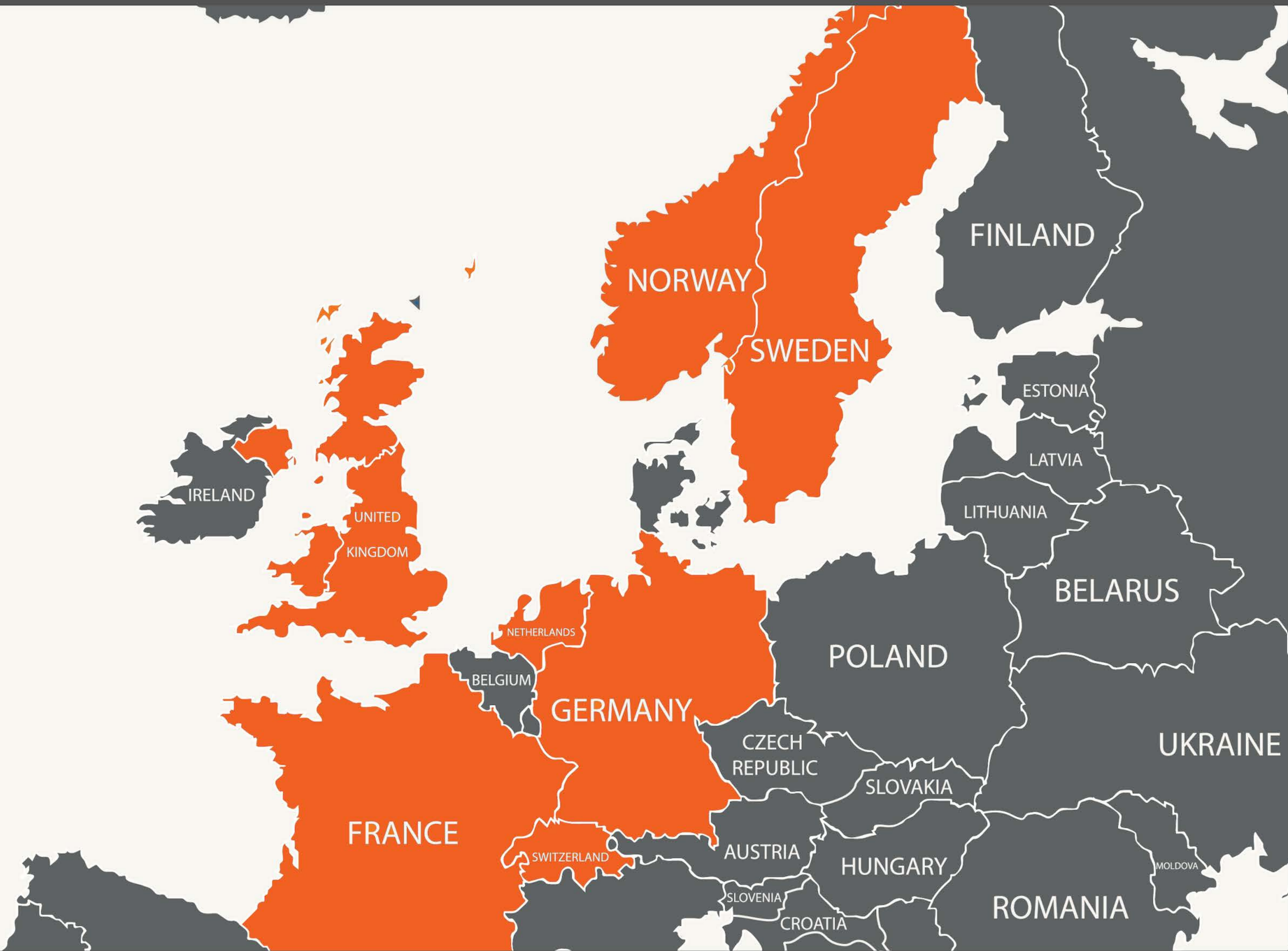
MAY 2023

LUSTRE:
LOWER URBAN SPEED LIMITS IN EUROPE

WHAT DOES THE EVIDENCE SHOW?



PROJECT TEAM:

PACTS, LOUGHBOROUGH UNIVERSITY, LUND UNIVERSITY (SWEDEN), INSTITUTE OF TRANSPORT ECONOMICS (NORWAY) AND ETSC.

PROJECT FUNDED BY

THE ROAD SAFETY TRUST
Making Roads Safer

PROJECT PUBLISHED BY

PACTS
Parliamentary Advisory Council for Transport Safety

LUSTRE

Lower urban speed limits in Europe. What does the evidence show?

May 2023

A report in three parts:

Project overview report, incorporating

- Development of UK policy on 20 mph speed limits, by PACTS (Evan Webster, David Davies and Margaret Winchcomb)
- Summary of European speed limit case studies, by Christer Hydén, Lund University, Sweden

Paper assessing the methodological quality of studies evaluating low speed limits by Dr Rune Elvik, TOI, Norway. (Appendix 1.)

Meta-analysis of the effect of 20 mph speed limits in the UK by Loughborough University (A Theofilatos, M. Quddus and M Feng). (Appendix 2.)

Project team: The Parliamentary Advisory Council for Transport Safety (PACTS), Loughborough University, Lund University (Sweden), Institute of Transport Economics (Norway) and the European Transport Safety Council (ETSC).

Principal contacts:

- margaret.winchcomb@pacts.org.uk;
- rune.elvik@toi.no;
- m.quddus@imperial.ac.uk;
- christer.hyden@tft.lth.se

Funded by The Road Safety Trust

Published by The Parliamentary Advisory Council for Transport Safety (PACTS)
Buckingham Court
78 Buckingham Gate
Westminster
London SW1E 6PE
UK

Contents

Executive Summary

Lower urban speed limits

Lower speed limits in urban areas (typically 20 mph in place of 30 mph in the UK, and 30 km/h in place of 40 or 50 km/h in mainland Europe) have been introduced since the 1990s. These usually covered relatively small areas. Graz, Austria was the first to embrace a whole city. It was seen as a matter for local policy makers, often within constraints set by central government. This has now changed.

Policy support for 20 mph limits

There is now high-level support for widespread use of lower speed limits (20 mph / 30 km/h) in urban areas, to improve road safety and to support other policy objectives. Lower urban speed limits were endorsed by the UN General Assembly in 2020 and have been adopted in many countries and major cities, including for example Spain and Brussels. In 2023, 20 mph limits will become the default on minor roads in Wales. Many towns or cities have implemented 20 mph limits, usually in particular areas but sometimes citywide.

Safe speed

Excessive or inappropriate speed is a major contributory factor to road casualties. Setting and enforcing speed limits is a well-established part of road safety policy.

The increasing adoption of Vision Zero and Safe System has brought about a new approach to speed limit setting. In this context, a safe speed is one at which the road user can withstand a collision without suffering death or life-changing injury. This will depend on the safety performance of the vehicle, the infrastructure, the nature of the collision and other factors.

20 mph is now generally accepted as the safe speed for streets used by pedestrians and cyclists. At 20 mph a pedestrian is likely to survive an impact with a motor vehicle whereas at 30 mph the pedestrian is significantly more likely to be killed. Traffic speeds of around 20 mph are also more conducive to walking and cycling.

20 mph zones

20 mph speed limits are not new in the UK. In the 1990s a number of 20 mph **zones** were introduced in the UK on streets with 30 mph limits. A condition of introducing the 20 mph limit was that it should be self-enforcing and speed humps and other traffic calming measures were installed where necessary. These schemes were independently assessed and found to substantially reduce vehicle speeds and casualties.

20 mph limits

In 2013 the UK Department for Transport's speed limit setting guidance was made more flexible. Local authorities were given the freedom to introduce 20 mph **limits** based on average speeds and the requirement for self-enforcing physical measures was eased. As a result, 20 mph limit speed limits are now generally introduced with few if any physical measures. This has made it much easier, less contentious and less costly for local authorities to install 20 mph limits over wider areas.

Evidence of outcomes

Research has established that speed and casualty reductions from introducing 20 mph zones (with self-enforcing physical measures) are greater than for 20 mph limits where no physical measures are installed. That does not mean to say, however, that no change or benefit follows but the research into the size of speed and casualty reductions for 20 mph limits is less robust and estimates of change have been less clear and more varied.

LUSTRE

Lower Urban Speed Limits in Europe. What does the Evidence Show? (LUSTRE) has sought to address the question in the project name - *What does the evidence show?* In particular, the outcomes of speed limits **without** physical measures. It has done so by gathering data from UK studies and reviewing reports from six other European countries which have similarities to the UK, either in terms of size or road safety performance. The research was funded by The Road Safety Trust.

The team

PACTS initiated the project and assembled an international team to undertake it. The University of Loughborough (UK) employed sophisticated statistical techniques in a meta-analysis to evaluate the UK data. Christer Hyden, University of Lund (Sweden) used his knowledge and contacts to assemble and evaluate the results of studies from six countries, with input from the European Transport Safety Council. Unfortunately, due to restrictions of Covid 19, the planned visits to these countries were not possible. Dr Rune Elvik, TUI, (Norway) assessed the UK studies for methodological quality and provided overall advice and quality assurance to the project. PACTS coordinated the final report.

Different approaches in different countries

Different countries have taken different approaches to introducing 30 km/h limits. France, originally, introduced 30 km/h limits in some cities and backed this with a programme of speed enforcement cameras. However, monitoring data is sparse.

Germany has taken different approaches in different states. Sometimes physical measures were used to support lower limits but not necessarily. Netherlands has tended to establish 30 km/h limits only where the infrastructure encourages drivers to comply. Where drivers would naturally adopt speeds above 30 km/h speed limits are less likely to be reduced. Norway has lowered speed limits to 30 km/h on many minor roads. Most of these are enforced by speed humps and speeding fines are high. Sweden has introduced lower speed limits extensively since 1998. Some of these are supported by physical measures. Switzerland has a clearly defined and well accepted model for speed limits, known as the 30/50 model. The proportion of zones without any physical measures is very small. The UK, as noted above, has shifted from self-enforcing 20 mph zones, which generally cover small areas, to area-wide and sometimes citywide 20 mph limits which tend not to have many self-enforcing physical measures.

Limitations of the studies

The quality of studies assessing the outcomes of 20 mph limit is variable. Few take account of background trends, regression to mean or changes in traffic flow or composition. These aspects can be difficult for local authorities which are not research specialists and operate on limited budgets. Because of the variation in the standards of research, the estimates of the outcomes of speed limit reductions vary widely. It is hard to compare studies as methods, before speeds, scheme conditions and other factors also vary. Despite these limitations, the conclusions and direction of change are reasonably consistent. These show a downward movement in speeds and casualties where lower limits are introduced. It is the scale of the movement that is harder to assess.

Findings

The magnitude of the results of individual studies varies, both within countries and between them. However, there is enough commonality to draw the following findings, based on the UK and six European case studies.

- 20 mph limits without physical measures result in modest speed reductions – typically 1-2 mph where before speeds are approximately 25 mph, and reductions of 3-5 mph where before speeds are approximately 30 mph.
- 20 mph limits without physical measures result in approximately 11% fewer casualties than before in the UK.
- For the European case studies, there were approximately 18% fewer casualties after 30 km/h limits were introduced but this figure was for all schemes, including some with physical measures. There were too few studies of sign only schemes to provide an average.
- Some 20 mph limits would have been accompanied by other measures, such as cycling infrastructure which might have contributed to any casualty reductions.
- Compliance with 20 mph limits without physical measures is poor.
- 20 mph limits with physical measures have substantially greater speed and casualty reduction effects than those without.
- Very few studies have attempted to assess the outcomes in relation to other goals set, such as increasing walking and cycling, air quality, noise etc. If speeds did not reduce by perceptible amounts, it seems unlikely that there would be any significant change in other behaviours. It may be that these goals were achieved as a result of complementary measures, such as cycling infrastructure, to which the lower speed limit contributed.

New directions

Lower urban speed limits are being introduced in many countries and covering larger areas, sometimes city-wide. These are backed, to varying degrees, by a range of measures to encourage and enforce driver compliance, including physical changes to the streets, speed cameras, police enforcement and publicity.

In the UK, London now has 20 mph limits on most minor roads and substantial lengths of major roads. Edinburgh has introduced a 20 mph limits across much of the city and Wales will make 20 mph the default in 2023. In Spain, the limit on urban roads with one lane per direction has been reduced to 30 km/h. City-wide schemes have been recently adopted in Brussels and other European cities.

It has not been possible within the scope of LUSTRE to properly consider these more recent schemes, their features or study methodologies. The reported speed reductions are broadly consistent with those found in LUSTRE but the reported casualty reductions are greater. It may be that 20 mph limit reductions introduced at scale have a greater impact. In addition, it seems that schemes incorporating main road have greater casualty reductions. This may be due to better public awareness, supporting measures, or both.

Given public and policy support for lower speed limits, it seems highly likely that they will be adopted in more areas. It will be interesting to see if larger-scale schemes achieve greater speed reductions.

Expectations from lower limits seem to be changing. Some advocates seem to now accept modest speed reductions (1-2mph), rather than the bigger reductions achieved by physical measures. From the perspective of casualty and danger reduction, the main issue will be the extent to which the lower limits are backed by speed reducing measures, of whatever kind.

It is notable that some highway authorities now see in-vehicle technologies and regulations as important to delivering actual reductions in speed and casualties. Intelligent Speed Assistance (ISA) is seen as having significant potential to encourage compliance with the lower limits. Since July 2022, ISA has been required in new vehicle models in the EU (and Northern Ireland), under the revised General and Pedestrian Safety Regulations. However, advisory ISA will moderate speeds less than mandatory ISA would; and it will take many years to significantly penetrate the vehicle fleet. Great Britain has yet to update its safety standards. Autonomously-driven vehicles will almost certainly be required to comply with speed limits.

Perhaps in future it will be the vehicles themselves, not external factors, that contribute most to compliance with speed limits. Whether the limits are set at safe speed levels, in accordance with Safe System principles, will be a matter for national and local governments and highways authorities.

1 Introduction

Vision zero, reducing road casualties, promoting active travel, healthy streets, improved public realm and other sustainability programmes are increasingly high on the agendas for world cities and smaller towns.

Lower urban speed limits (20 mph/ 30 km/h) are often promoted as a key policy element. Indeed, since starting on this project, policy support for widespread application of these speed limits in urban areas has greatly increased. It has been endorsed in the 2020 UN Road Safety Declaration and the Welsh Government will implement 20 mph as the default speed limit for minor roads in Wales from September 2023.

20 mph speed limits are not new in the UK. They have applied to some minor roads since the 1990s. They are now being adopted much more widely by some local authorities.

Changing speed limits alone, however, does not necessarily change the speed at which drivers will drive. The objective of this project is to review the evidence of the impacts of 20 mph speed limits (30 km/h) in the UK and in other parts of Europe, particularly where they are not supported by physical measures. It is intended to provide a clear, factual statement of the outcomes from setting lower speed limits, 20 mph in urban areas and villages in the UK and 30 km/h in mainland Europe. This report has sought to bring together as many studies of UK 20 mph speed limits as possible. Appendix 1 provides an analysis of their methodological strengths and weaknesses. The report goes on to describe the history and effects of 30 km/h speed limits in six case studies: the Netherlands, Switzerland, Sweden, Norway, France and Germany. It summarises the European experience, referencing outcomes of studies of 30 km/h speed limits conducted in these countries. The report then highlights the lessons that can be learnt for the UK. Appendix 2 provides an advanced statistical analysis of the effects of 20 mph in the UK, based on the results of 24 previous studies of 20 mph.

The results are relevant for road safety professionals and other considering how and whether to introduce 20 mph at a national, regional and local level.

2 Project Method

Studies were gathered from the UK and mainland Europe with the main purpose of investigating the impacts of 20 mph (30 km/h) speed limits, primarily those implemented as 'sign only', with additional physical measures, on driven speeds, collisions, and casualties.

Six countries in mainland Europe were selected as case studies to provide a variety of circumstances and evidence on the impacts of reduced urban speed limits (30 km/h).

Published evidence, including "grey" literature, was collected from a variety of sources. This focused mainly on quantitative data on:

- Speeds
- Collisions
- Casualties

We were prepared to review data on other possible impacts, such as air quality or modal share. However, we did not find any significant information on these other factors.

We also gathered information on the legal/planning framework and policy development regarding urban speed limits.

2.1 UK study

Having described the development of 20 mph limits in the UK, a number of scientific papers and reports on the impact of lower speed limits in the UK were used to examine data to determine overall trends, known as carrying out **meta-analyses**. These studies were retrieved by means of a **systematic literature survey** and were discussed, evaluated, and rated according to their scientific and methodological quality and validity.

A methodology to assess the quality, suitability and validity of published reports and articles was developed and is included in Error! Reference source not found.. The g uidelines formed the basis of a formal quality scoring system for studies that have evaluated the effects of 20 mph speed limits on road safety.

Following assessment of the available data, additional studies and reports were added resulting in a **total of 24 studies/reports** being utilised to provide the basis for meta-analysis of the effects of 20 mph speed limits in the UK.

Each of the studies contained one or more estimates of the effects on collisions and/or personal injuries. These estimates of the effect were combined by means of the log-odds method of meta-analysis (e.g. Fleiss, 1981; Elvik, 2003), it being the common method to analyse the effects employed in the before and after studies. The results of the analysis are included in **Appendix Two: Meta-analysis of the effects of 20 mph speed limits in the UK**.

2.2 European Case Studies

In parallel to the UK study, a review was conducted of research covering 30 km/h speed limits made in six mainland European case study countries: France, Germany, the Netherlands, Norway, Sweden, , and Switzerland . Information was provided by various research institutions and the European Transport Safety Council (ETSC). Considering the scale of implementation, the number of studies available was found to be surprisingly scarce. All the data available was prioritised with relation to the sophistication of the study, its volume and quality of measurable outcomes and its extent, for example, documentation of inclusion or exclusion of engineering or enforcement, in addition to the speed limit.

3 Development of 20 mph speed limits in the UK

Since 1991, under the Road Traffic Regulation Act (1984) local authorities had been able to set speed limits below 30 mph. With an amendment to those regulations in July 1999, the Road Traffic Regulation Act 1984 (Amendment) Act Order 1999, traffic authorities have had the powers to introduce 20 mph speed limits without first obtaining the consent of the Secretary of State. The Department for Transport (in its various guises) has also issued guidance on where 20 mph speed limits are appropriate and how they should be implemented. Guidance which is relevant for 20 mph speed limits has been included in the Traffic Advisory Leaflet 09/99, “20 mph Speed Limits and Zones”, Department for Transport (DfT) Circular 01/06, “Setting Local Speed Limits” and DfT Circular 01/2013, “Setting Local Speed Limits”. Broadly, these documents have become more supportive of 20 mph speed limits and reduced the requirements (such as traffic calming, distance between signs etc.) for the introduction of 20 mph speed limits. It should be noted that although 20 mph zones still require physical traffic calming measures, 20 mph limits do not.[1] [2] Of these changes, the 2013 guidance (first announced in 2011) marked the greatest change in policy.

Speed limit setting is a devolved matter across the four nations of the UK. In 2019, the Welsh Government announced its intention to make 20 mph the default limit in place of 30 mph limits on “restricted streets” (mainly residential streets) for Wales. Research, consultation and legislation followed with national implementation planned for 2023.[3]

The setting of **20 mph speed limits** may also be influenced by other legislation. This includes:

- the **Traffic Management Act 2004**, which places a duty on local authorities to balance the needs of all road users in securing the expeditious movement of traffic;
- the **Health and Social Care Act 2012**, which gives local authorities public health responsibilities;
- the **Equality Act 2010**, which requires local authorities to provide equality of opportunity between people who share a protected characteristic and those who

[1] https://www.rospa.com/rospaweb/docs/advice-services/road-safety/drivers/20-mph-zone-factsheet.pdf
[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/63975/circular-01-2013.pdf
[3] Proposal to reduce speed limit to 20 mph on residential streets: summary of responses [HTML] | GOV.WALES

do not (of particular relevance to 20 mph speed limits are children, older people, people with disabilities and women, who are less likely to have access to a car);
- the **Traffic Signs Regulations** and **General Directions 2016**, and;
- in Wales, the **Wellbeing of Future Generations (Wales) Act 2015**, which requires public bodies to think more in the long term and work more with communities.[4]

Since the introduction of the **first 20 mph speed limit in the UK** in Tinsley in Sheffield in 1991, their use has increased across the UK. Following Tinsley, 20 mph zones were introduced in Kingston-Upon-Thames and Norwich and by 2000, a total of 450 20 mph speed limits (mostly in zones) had been introduced.[5]

Portsmouth City Council became the first local authority to implement an extensive 20 mph speed limit scheme in 2007. 20 mph speed limits (generally without physical traffic calming measures) have since become the most common approach taken by local authorities. This is because limits, which do not involve physical traffic calming, generally face less opposition and are cheaper to implement than zones which do involve physical traffic calming measures.[6]

In 2011, the DfT announced that it intended to ease restrictions on 20 mph limits and reduce the need for speed humps by expanding the list of permitted traffic calming measures.[7] This change came about following the initial assessment of the Portsmouth scheme. It was also part of broader political changes under the 2010 Conservative-Liberal Democrat coalition government whereby local authorities were given more powers and discretion over local priorities and national road safety targets were eliminated.

In 2016, the DfT asked all local authorities to provide details of the length of road with a permanent 20 mph speed limit in their area. 39 responded and reported the length of 20 mph road as 2975 miles (4787 km) in 2015, a 225% increase from 2010. This number is an underestimate as PACTS is aware of 64 local authorities which have introduced 20 mph speed limits or zones.[8]

---

[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/757307/20 mph-headline-report.pdf
[5] https://www.rospa.com/rospaweb/docs/advice-services/road-safety/drivers/20-mph-zone-factsheet.pdf
[6] https://webarchive.nationalarchives.gov.uk/20120215031359/http://www2.dft.gov.uk//pgr/roadsafety/speedmanagement/20 mphPortsmouth/pdf/20 mphzoneresearch.pdf
[7] https://www.bristol20 mph.co.uk/wp-content/uploads/2016/06/Cabinet-Report-26th-July-2012.pdf
[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/757307/20 mph-headline-report.pdf

The **2006 Speed Limit Circular** had advised against the implementation of 20 mph speed limits over a larger number of roads. However, the **2013 Speed Limit Circular** stated that it 'should be considered where mean speeds at or below 24mph are already achieved over a number of roads.' The same document states that traffic authorities can, over time, introduce 20 mph speed limits or zones on:

- **major streets** where there are – or could be - significant numbers of journeys on foot, and/or where pedal cycle movements are an important consideration, and this outweighs the disadvantage of longer journey times for motorised traffic, and;
- **residential streets** in cities, towns and villages, particularly where the streets are being used by people on foot and on bicycles, there is community support and the characteristics of the street are suitable. Where they do so, general compliance needs to be achievable without an excessive reliance on enforcement.[9]

The DfT advises that 20 mph zones and limits should be self-enforcing with the existing conditions of the road alongside additional traffic calming, signage, and publicity leading to a mean traffic speed compliant with the speed limit. It states that there should be no expectation on the police to provide enforcement beyond their routine activity.[10]

3.1 Regulations for 20 mph zones

20 mph *zones* are distinguishable from 20 mph *limits* as zones typically require a higher level of road engineering. The requirements for 20 mph zones were eased in 2011 to facilitate them and reduce their cost - for example the lighting of regulatory signs is now optional.[11]

At least one traffic calming feature must be used at least every 100 m in 20 mph zones. Traffic calming features are defined as: a road hump; traffic calming works (chicanes, gateways, rumble strips etc.); a refuge for pedestrians; a variation of the relative widths of the carriageway or any footway; a horizontal bend in the carriageway through which all vehicular traffic turn by no less than 70 degrees; a 20 mph repeater sign and; a 20 mph speed roundel road marking.[12] A 20 mph zone must include at least one traffic

[9] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/63975/circular-01-2013.pdf
[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/63975/circular-01-2013.pdf
[11] http://www.roadsafetyknowledgecentre.org.uk/downloads/20 mph-reportv1.0-FINAL.pdf
[12] For full details on the requirements for each feature see https://tsrgd.co.uk/pdf/tsm/tsm-chapter-03.pdf

calming feature that is not a sign or speed roundel road marking.[13] The DfT also states that traffic authorities must carefully consider the implications for compliance of using signs and road markings as traffic calming features.[14]

The DfT suggested that changes to requirements for 20 mph zones would also allow traffic authorities to incorporate wider areas into zones by allowing them to sign 20 mph on distributor roads where physical traffic calming features are not suitable and on small individual roads or stretches of roads where mean speeds are already at or below 24mph.[15]

Official guidance is that 20 mph zones should be used around shops, markets, playgrounds and other areas with high pedestrian or cyclist traffic. They should not be used on roads where motor vehicle movement is the primary function. Finally, it is recommended that generally, 20 mph zones should be imposed over an area consisting of several roads.[16]

3.2 Regulations for 20 mph limits

20 mph limits do not require any features, such as physical traffic calming measures, beyond those required for any other speed limit. As limits often cover larger areas than 20 mph zones, they require relatively fewer signs. This generally makes them cheaper to implement than 20 mph zones.[17] 20 mph limits must be indicated by terminal and repeater signs, as is the case for all other defined limits.[18]

Traffic authorities also have the power to introduce 20 mph limits which apply only at certain times of day. These limits are generally located outside schools where a full time 20 mph limit is not deemed suitable (for example on major through roads). They are often indicated by an advisory part-time 20 mph limit sign with flashing school warning lights.[19]

The DfT suggests that **average speed cameras** may be a useful tool for enforcing compliance with urban speed limits and also states that enforcement with fixed speed

[13] https://tsrgd.co.uk/pdf/tsm/tsm-chapter-03.pdf
[14] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/63975/circular-01-2013.pdf
[15] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/63975/circular-01-2013.pdf
[16] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/63975/circular-01-2013.pdf
[17] http://www.roadsafetyknowledgecentre.org.uk/downloads/20 mph-reportv1.0-FINAL.pdf
[18] https://tsrgd.co.uk/pdf/tsm/tsm-chapter-03.pdf
[19] http://www.roadsafetyknowledgecentre.org.uk/downloads/20 mph-reportv1.0-FINAL.pdf

cameras is possible.[20] In some cases, local authorities have provided funding for police enforcement of 20 mph limits (such as in Calderdale), though this is not routine. Ancillary publicity is usually undertaken alongside the implementation of 20pmh schemes. However, it is not required and behaviour change campaigns to encourage compliance generally have not formed a core part of 20 mph schemes.[21] Some areas have set aside project funding to be used to introduce targeted traffic calming following the implementation and initial assessment of 20 mph limits, though this is unusual.[22]

3.3 Objectives of 20 mph limits

Initially, 20 mph limits were introduced largely to reduce risk to road users, particularly vulnerable road users, by reducing vehicle speeds. This remains a key objective of 20 mph limits.

Over time, local authorities have broadened the objectives of 20 mph limits. These now encompass a variety of **social, environmental, health and road safety objectives**. Many 20 mph schemes have the objective of increasing cycling and walking (often among young people) by reducing people's perception of risk. Other 20 mph schemes have the objective of improving air quality, placemaking and easing congestion (including by reducing car use). Many of these objectives are framed in terms of public health (air quality, active travel and road casualties). This is significant as local authorities were handed public health responsibilities in 2012.

Speed reduction is often cited as an objective in its own right and as the means by which other objectives are reached. 20 mph schemes are often introduced as part of broader strategies with road safety, environmental or social objectives.[23]

The 2018 Atkins report for DfT outlines key motivations for implementing 20 mph limits as reproduced below.**[24]**

[20] http://www.roadsafetyknowledgecentre.org.uk/downloads/20 mph-reportv1.0-FINAL.pdf
[21] http://www.roadsafetyknowledgecentre.org.uk/downloads/20 mph-reportv1.0-FINAL.pdf
[22] http://www.roadsafetyknowledgecentre.org.uk/downloads/20 mph-reportv1.0-FINAL.pdf
[23] http://www.roadsafetyknowledgecentre.org.uk/downloads/20 mph-reportv1.0-FINAL.pdf
[24]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/757307/20 mph-headline-report.pdf

FIGURE 1: PRIMARY MOTIVATIONS FOR IMPLEMENTING 20 MPH SPEED LIMITS (SOURCE ATKINS, AECOM AND MAHER, M. (2018), 20 MPH RESEARCH STUDY. ATKINS)

There has also been a more positive attitude towards enforcing 20 mph speed limits in policing guidance, though the default position is still that 20 mph should be self-enforcing. 20 mph schemes have had a wide range of objectives, reflecting the wide range of responsibilities held by local authorities and the range of benefits they can provide.

Regardless of the type or number of objectives for 20 mph limits, it is important that the schemes are effective and deliver on at least some of them. Speed reduction seems to be essential to achieving them all.

3.4 Latest UK policy on 20 mph limits

The UK government endorsed the 2020 Stockholm and UN road safety declarations but it has not endorsed widespread or default 20 mph limits. Its 2019 Road Safety Statement makes little reference to 20 mph limits and the DfT’s position is to leave it to local authorities.

By contrast, the Welsh government has passed legislation to make 20 mph the default limit on minor roads previously 30 mph. This will come into effect in 2023. Scotland’s Framework for Road Safety 2021 recognises the importance of lower speeds. The Scottish government has not endorsed a 20 mph default but Edinburgh Council has been introduced 20mph across much of the city. In England, substantial areas of London, Bristol, Oxford and other towns and cities also now have 20 mph limits.

4 Development of 30 km/h speed limits in mainland Europe

Studies from six countries (France, Germany, the Netherlands, Norway, Sweden and Switzerland) were sought with the aims of finding the best evidence of the effect of 30 km/h limits and of understanding how European experience and practice differs from that in the UK. An emphasis was placed on establishing measurable outcomes, to understand what role the change to 30 km/h limits has had in terms of actual change of speeds. Studies which were included investigated a variety of different speed limits:

i) schemes (with and without physical measures),
ii) schemes without physical measure (sign only) and
iii) schemes with physical measures.

Sources of studies included government agencies, academia, police, and road safety and active travel bodies. References which were provided were sifted to focus on those with the highest validity and sophistication (i.e. that analysis differentiated between before and after scenarios and between the method of limiting speeds). Studies with measurable outcomes in terms of driven speeds, collisions, and casualties were prioritised. It should be noted that there was a wide variety in the quality and number of reports within and between the countries studied therefore comparisons are difficult. The length of time which 30 kmph limits have been used in a country, their location (urban, rural, residential), their extent and also method for defining them differs between countries and therefore has an impact on the outcomes of the studies.

4.1 France

The setting

In 1972 the number of road victims in France reached its highest level, with over 18,000 deaths and nearly 400,000 injuries. A real awareness of the issues linked to road collisions then emerged. Gradually, measures have been put in place and over the years, several decrees have been issued.

On 29 November 1990, a decree was published regulating three strategic points including the creation of the “zone 30” concept. In 2006 the "street code approach" brought together the State and associations of elected officials, professionals and users. It aimed to raise awareness of the current regulations of the Highway Code in urban areas, as well as to develop this code to take into account changes in the practice of public spaces, such as the development of alternative modes to private vehicles. It is also intended to promote the safety of vulnerable users and the use of active modes. This approach led to another major step, with the decree of 30 July 2008 specifying the rules relating to zone 30 and pedestrian areas. The introduction of 30 km/h limits has changed the balance between motorised traffic and other modes, and also presents a new balance between “local” interest and “circulation” interests.

Since 2015 it has been possible for local authorities to set speed limits below 50 km/h for all or parts of the road network of a municipality. In January 2016 Grenoble became the first large French city to introduce a blanket 30 km/h zone across the city. Since then Lille, Nantes, Montpellier and most recently Paris, have joined with almost all roads in these conurbations limited to 30 km/h by the end of August 2021.

Changes in speed

Although lower speed limits have been introduced in many French cities, we found very few studies of the impacts on speeds or casualties.

One major study available in France is for the city of Grenoble.[25] This found there was a decrease in mean speeds of 4.2 km/h, resulting in a mean speed a little above 30 km/h. In neighbouring areas around Grenoble, the mean speed increased 0.5km/h to 39.2 km/h.

[25] Grenoble Métropole Apaisée Evaluation du dispositif "villes et villages à 30 km/h". Cerema Juillet 2020.

Almost no physical measures had been installed. The installation of an informative radar improved compliance with the speed limit at first. Compliance then decreased over time, although excessive speeding changed little.

As part of the implementation of the new speed limit, significant effort was made to inform the city's population through media campaigns and communication signs on routes, however, few physical measures were installed. A survey carried out in three places with people driving and riding cycles, identified that the knowledge rate (those who knew the speed limit was 30 km/h) was 90% in one location, but as low as 65% and 69% in the two others. This 'head knowledge' did not result in reduced speeds as the rate of compliance with the authorised speed limit was around 35% in the daytime, decreasing to less than 20% at night.

Changes in collisions and casualties

The study identified a nearly 30% reduction in the number of collisions and nearly 20% reduction in victims recorded annually with a corresponding decrease of at least 20% in the proportion of victims killed or seriously injured.[26]

Other changes

We did not find any studies of other changes as a result of the speed limit reductions.

[26] Grenoble Métropole Apaisée Evaluation du dispositif "villes et villages à 30 km/h". Cerema Juillet 2020.

4.2 Germany

The setting

In 1957 a general speed limit of 50 km/h within built-up areas was introduced and in 1983, the first pilot project for Tempo-30-zone was opened in Buxtehude. Since then, most cities have developed and executed quite comprehensive plans for 30 km/h in 'smaller, residential streets'.

Many cities are now working to reduce speed limits on larger streets (state or district roads) helped by changes made by the Federal Government in 2015. Improved environmental conditions (reducing noise and emissions) as well as increased road safety are the main drivers. Physical measures to ensure "low enough" speeds are proposed as "30-zones should always be designed so that the drivers get the impression of a special situation ("slow driving street")". Narrowing the cross-section of the carriageway by marking parking spaces or adding "30" to the road are included in these measures.

In the summer of 2021, seven German cities pressed for a new legal requirement, enabling them to change their speed limits flexibly and based on location. The drivers for this change include increased safety, as well as reduction of air and noise pollution.

Overall, 30 km/h limits are fairly common today in Germany. Physical measures have been used to a relatively small degree while there has been more focus on enforcement and communication.

Changes in speed

We found only a limited number of assessments of their impact. In 2016 a paper was produced by the German Department for Environment and Transport gathering findings of the effects of 30 km/h limits in the country. [27] This found that "in the majority of the cases examined, 30 km/h on major roads has a speed-lowering effect even without accompanying measures. Above all, the high speeds decrease. The longer the speed limit is 30 km/h, the better the speed control is maintained." There were very large fluctuations in the range of average speed reductions with decreases of up to 16km/h (without speed controls) and up to 18 km/h (with speed controls). The top speeds drop

[27] Wirkungen von Tempo 30 an Hauptverkehrsstraßen. Editor: Umweltbundesamt, Umwelt und Verkehr. Dessau-Roßlau. info@umweltbundesamt.de

more than the average speeds. Accompanying measures such as dialogue displays or radar surveillance over several days result in lowering average speeds further.[28]

A study in 2017 in the city of Münster found that speeds within the city reduced from 35.6km/h to 31.3km/h after a 30 km/h limit was applied to a number of major roads in the city centre.[29]

A common feature is that, although average speeds fall, the non-compliance rate is most often well beyond 50% and it is not unusual that it is as high as 80%.[30]

Changes in collisions and casualties

In the city of Schwerin the total number of collisions reduced from 50 to 24, though the result is not very strong statistically. Regarding collisions resulting in injury, the number of injured and killed went from 11+1 with 50 km/h, to 4+0 with 30 km/h, thus a reduction of almost 70%.[31] Findings from 1994 of limits in Hamburg assessed that the total number of collisions in speed limited zones went down by 10% and that collisions involving injury or death decreased by 16%.[32]

Other changes

One study assessed the associated benefits of reduced speeds. This found that speeds of 30 km/h instead of 50 km/h reduce the average noise level by around 3 decibels (dB), which corresponds to a halving of traffic volumes.[33] Reductions in air pollution and improvements in well-being were also measured.

[28] Wirkungen von Tempo 30 an Hauptverkehrsstraßen. Editor: Umweltbundesamt, Umwelt und Verkehr. Dessau-Roßlau. info@umweltbundesamt.de

[29] Evaluierung des Geschwindigkeitskonzepts MünsterZusammenfassung, Auftraggeber: Stadt Münster, Amt für Grünflächen, Umwelt und Nachhaltigkeit, April 2020

[30] Wirkungen von Tempo 30 an Hauptverkehrsstraßen. Editor: Umweltbundesamt, Umwelt und Verkehr. Dessau-Roßlau. info@umweltbundesamt.de). Case 1d: Erfurt

[31] Wirkungen von Tempo 30 an Hauptverkehrsstraßen. Editor: Umweltbundesamt, Umwelt und Verkehr. Dessau-Roßlau

[32] Proceedings of the Third International Conference on Safety and the Environment in the 21st century: lessons from the past, shaping the future, November 7-10, 1994, Tel Aviv, Israel (https://trid.trb.org/view/415895)

[33] Strassenverkehr: Besser schlafen dank Tempo 30 (Road traffic: sleep better thanks to speed 30) 29.05.2019

4.3 The Netherlands

The setting

Since 1957 a general speed limit of 50 km/h has been in place within built-up area in the Netherlands, unless otherwise indicated.[34] However, during the 1970s with the increase in motorised traffic casualty rates increased among people walking or cycling, particularly the young and elderly. Initiatives were developed to try to improve safety for road users and from these 'woonerf', or living streets, were created. These gained legal status in residential areas in 1976 and in shopping areas and villages in 1988.[35] Woonerf are areas where traffic is restricted to walking pace as it travels through space entirely shared with other road users (for example, there are no pavements). Their implementation, however, is expensive.

In the meantime, it was agreed that the speed of traffic within residential areas would have to fall significantly below the legal 50 km/h limit. 30 km/h was chosen because of the reduced likelihood of serious injury to a vulnerable road user in the event of a collision.

In 1984, a new road category, the Zone 30, was created as a means to improve safety for vulnerable road users, especially cyclists. This enabled Dutch municipal authorities to institute a maximum speed of 30 km/h road in zones within built-up areas. Although speed limits on these roads were reduced to 30 km/h, changes were not always supported with any alterations to the road infrastructure. To guide local authorities in their choice of speed-restricting physical measures a 'Handbook for 30 km/h measures' was published in 1984, presenting 50 designs.[36]

In 1991 the Administrative Provisions for Road Traffic Order (BABW) was introduced. Elements of the BABW Implementing Rules on Road Signs, chapter II(4) states that "The maximum speed to be set shall be in accordance with the road image on site. This means that, where necessary, the circumstances have been adapted in such a way that the intended speed reasonably results from the nature and layout of the road in question and of its surroundings."

---

[34] Traffic Rules and Signs Regulations 1990 – RVV 1990
[35] Safety effects of 30 km/h zones in the Netherlands. Vis, A.A.; Dijkstra, A.; Slop, M.Accident Analysis & Prevention 24 (1), Pagina's 75-86 1992 (1/)

[36] V&W Hankboek 30 km/h mattregelen 's-Gravenage: Ministerie van Verkeer en Waterstaat: 1984

During the 1990s the Sustainable Safety Vision was developed with the aim 'to practically eliminate the chances of severe injury'.[37] The implementation of Sustainable Safety in road safety policy commenced in 1998 with the Start-up program Sustainable Safety. Over the next ten years urban roads with 30 km/h limits increased, from 45% early in 2003 to 70% of in 2008.[38] Development was fast because, as in the 1980s, the implementation of the new 30 km/h zones was often very simple and the national government also subsidised 50% of the costs. Zone 30 signs alone were installed with speed reducing measures constructed only at 'dangerous' locations. Many of these 'sign only' 30 km'h zones remain in residential areas. SWOV, the Dutch Institute for Road Safety Research, recommends that new zones should include methods to physically enforce lower speeds.[39]

Concerns over speeds in wider urban areas and the safety of vulnerable road users outside Zone 30s, remain. Most recently SWOV published a report recommending that, 30 km/h distributor roads, known as the GOW30, should be constructed where it is not possible to provide segregated space for cyclists. [40]

Changes in speed

Interpretation of the impact of 30 km/h speed limits on urban roads in the Netherlands is difficult as we have not been able to identify almost any study where speeds before the introduction of limits were measured. Furthermore, there are no specific studies on the impact of speed limits defined by signs only.

Two studies were carried out, in Eindhoven and Rijswijk, to evaluate the impact of different physical measures. These were instigated in the late 1970s and evaluated a decade later. Assessing areas where physical measures were constructed, there was a reduction of both traffic volume and speed. Both these effects had a dose-response pattern: the more physical measures, the larger the effects. The physical measures constructed were humps, elongated humps and axis realignments. In areas where

[37] W Weijermars & F Wegman, ten Years of Sustainable Safety in the Netherlands, An Assessment, Transportation Research Record: journal of the Transportation Research Board, No 2213, 2011, DOI: 10.3141/2213-01
[38] SWOV (2019). Sustainable Road Safety. SWOV Fact sheet, March 2019. The Hague.
[39] https://www.swov.nl/feiten-cijfers/factsheet/30 kmuur-gebieden

[40] (https://www.swov.nl/publicatie/naar-een-algemene-snelheidslimiet-van-30-kmuur-binnen-de-bebouwde-kom, with access to the report Dijkstra, A .; Petegem, J.W.H. Naar een algemene snelheidslimiet van 30 km/uur binnen de bebouwde kom? Publicatie/rapport R-2019-24 (Towards a general speed limit of 30 km / h in built-up areas?). 2019 (SWOV)).

woonerf measures were constructed, average speeds and the volume of motorised traffic fell further.

In the late 1980s the Ministry of Transport and Public Works encouraged 15 municipalities to implement a 30 km/h zone and to design an evaluation of the safety effects of these zones. A study was carried out in the late 1990s of these 15 experimental projects.[41] The basis of the study was that 30 km/h limits could ‘be justified only if such a speed would be a natural choice given the road environment’. The presumption was made based on ’everyday practice’ that the maintenance of a maximum speed of 30 km/h cannot be expected without support from physical measures. Each of the sites therefore included 30 km/h signs with some form of physical alteration to the road layout (eg humps, narrowings, axis realignments). The study found that the 85% speed value (the speed below which 85% of the vehicles travelled) reduced from just over 40 km/h to about 25km/h.

Changes in collisions and casualties

The evaluation of the 15 municipalities was coordinated by the SWOV Institute for Road Safety Research. In their report of 1991 results show that the total number of collisions after the introduction of the 30 m/h zone measure had dropped by 10-15%.[42] With respect to the number of casualties, there were indications that the reduction may have amounted to double that figure. However, due to the limited scale of this study, the effects demonstrated a large spread.

A follow-up study was therefore conducted. Vis & Kaal analysed 150 30 km/h zones without through traffic and with sufficient speed-reduction measures (including road humps).[43] Over the period of the study 660 injuries were recorded. After correcting for effects not associated with the installation of the speed reduction measures, the average decrease in the number of injuries was calculated as 22% (+/- 13%). However, there were large differences in effect between zones related to differences in zone size, degree of urbanization, nature of the speed-reduction measures and the changes in traffic volume that occurred.

---

[41] Effecten Van Inrichting Tot 30 km/uur Zone in 15 Experimentele Gebieden, AAVis, Leidschendam 1991, SWOV recovered from https://www.swov.nl/sites/default/files/publicaties/rapport/r-91-81.pdf, (summarised in English in Safety effects of 30 km/h zones in the Netherlands. Vis, A.A.; Dijkstra, A.; Slop, M. Accident Analysis & Prevention 24 (1), Pagina's 75-86 1992 (1/))

[42] Effecten Van Inrichting Tot 30 km/uur Zone in 15 Experimentele Gebieden, AAVis, Leidschendam 1991, SWOV recovered from https://www.swov.nl/sites/default/files/publicaties/rapport/r-91-81.pdf, (summarised in English in Safety effects of 30 km/h zones in the Netherlands. Vis, A.A.; Dijkstra, A.; Slop, M.Accident Analysis & Prevention 24 (1), Pagina's 75-86 1992 (1/))

[43] https://trid.trb.org/view/381787

More recently, results from the evaluation of the implementation of Sustainable Safety, estimate that in 2008 the construction of 41,000 km of 30 km/h roads prevented approximately 51 to 77 fatalities.[44] That is an approximate 11.6 to 17.5 % reduction on 1998 fatalities. However, it should be noted that the introduction of speed limits was just one of a number of facets of the programme including changes to the road infrastructure, education and enforcement.

Since 2005, it has been possible to use data from the National Road Register to determine the total road length for roads with a certain speed limit. Using this data changes in crash and casualty volumes per speed limit can, under certain assumptions, be determined. A study compared the numbers of casualties during the period 1998-2008 with results showing little change in the accident density on stretches of road or at intersections.[45]

Where 'frugal' 30 km/h limits have been constructed, and zones are indicated with entrance gates but no physical measures, casualty numbers recorded have been above zones with physical measures. In 2009 a study found that if all 30,000 km of 30 km/h access roads (including roads within Zone 30 areas) were to have appropriate physical measure such that the 'intended speed reasonably results from the nature and layout of the road in question and of its surroundings' there would be 200 fewer serious injuries per year.[46]

Other changes

We did not find any studies of other changes as a result of the speed limit reductions.

---

[44] V Tien jaar Duurzaam Veilig Verkeersveiligheidsbalans 1998-2007, R-2009-14 Dr. ir. W.A.M. Weijermars & drs. I.N.L.G. van Schagen (red.) Leidschendam, 2009 Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV

[45] De relatie tussen snelheidslimiet en verkeersveiligheid Ontwikkeling van de verkeersonveiligheid op 50- en 80 km/uur-wegen vergeleken met die op 30- en 60 km/uur-wegen, D-2013-6 Dr. ir. L. Braimaister, drs. N.M. Bos, ing. V. Kars & dr. H.L. Stipdonk Leidschendam, 2013 Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV - https://www.swov.nl/sites/default/files/publicaties/rapport/d-2013-06.pdf

[46] De veiligheid van voetgangers en fietsers op 30 km/uur-erftoegangswegen Dr ir E m Berends & drs H l Stipdonk, Leidschendam 2009, SWOV

4.4 Norway

The setting

In 2005, the Norwegian Public Roads Administration issued new guidelines for speed limits in urban areas. The use of speed limits of 30 or 40 km/h was encouraged. In most cases there are humps if the speed limit is 30 km/h.

The default speed for built up areas in Norway is 50 km/h, and speeding can result in a fine nearly 14 times that given in Germany. In 2018 the Norwegian Road Administration further encouraged the use of 30 and 40 km/h limits, stressing that "they are important in areas where there are many pedestrians and bicyclists".

Many roads in urban areas in Norway have a 30 km/h speed limit. For example, in Oslo, around 75% of the road length has a 30 km/h speed limit.

Changes in speed

We have not been able to find any specific studies of the effects on speeds of introducing speed limits of 30 and 40 km/h in Norway.

Changes in collisions and casualties

A study made by the Institute of Transport Economics in 2015 (Bjørnskau and Amundsen 2015) attempted to evaluate the effect on accidents of an increased use of the speed limits of 30 and 40 km/h. The results were not very clear, but an indication that increasing use of speed limits of 30 or 40 km/h may reduce the number of injury accidents was found by comparing municipalities that stated that they complied with the 2005 guidelines to municipalities that stated they did not comply with the guidelines. The guidelines were not mandatory; it was up to each municipality to decide whether to lower speed limits to 30 or 40 km/h or not. Figure 3 shows the trend in the number of injury accidents from 2000 to 2013 in municipalities that applied the guidelines compared to municipalities that did not apply them (and presumably did therefore not introduce the lower speed limits).

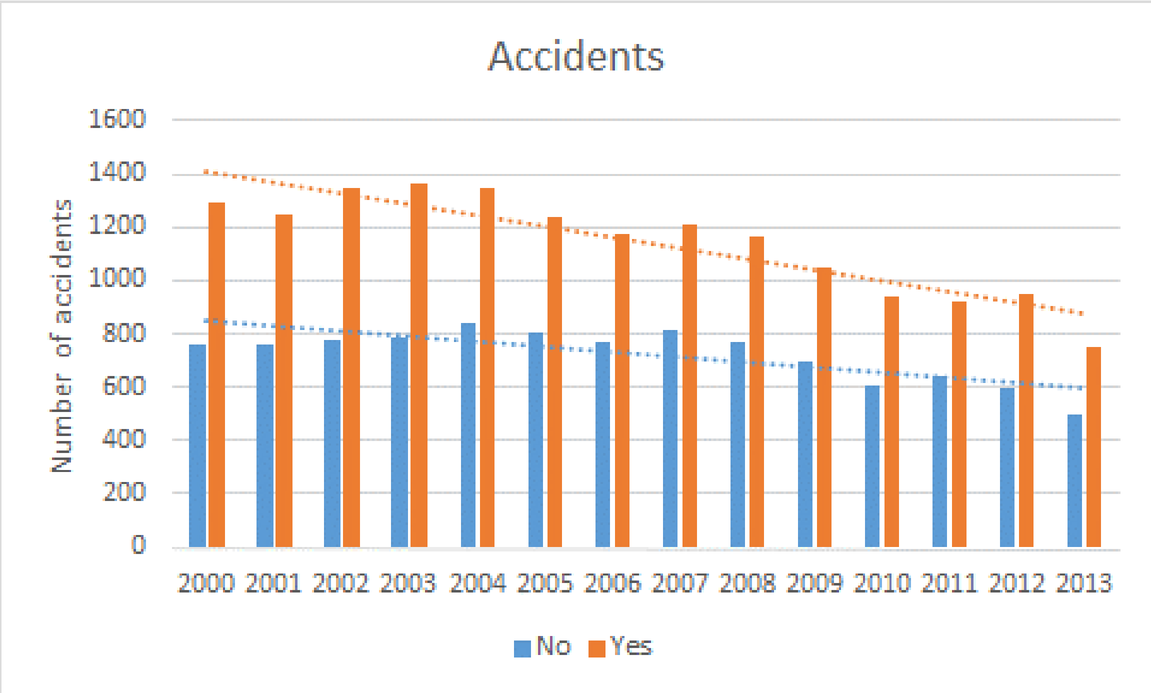


FIGURE 2: TRENDS IN THE NUMBER OF INJURY ACCIDENTS IN MUNICIPALITIES IN NORWAY INTRODUCING SPEED LIMITS OF 30 OR 40 KM/H (YES) AND MUNICIPALITIES NOT DOING SO (NO)

The downward trend is slightly stronger in municipalities that lowered speed limits than in municipalities that did not do so.[47] The data do not distinguish between areas with or without physical measures. However, 30 km/h is most likely on streets with physical measures; 40 km/h limits are more likely to have signs only but sometimes also physical measures.

Other changes

We did not find any studies of other changes as a result of the speed limit reductions.

[47] Bjørnskau, T., Amundsen, A. H. 2015. Bruk av reduserte fartsgrenser i byer og tettsteder. Rapport 1401. Oslo, Transportøkonomisk institutt

4.5 Sweden

The setting

The 30 km/h limit has been in use, in urban areas, in Sweden since 1972, within a speed limit system built on 20 km/h-increments: 30, 50, 70, 90 and 110 km/h. Since 1998, municipalities have been able to implement the 30 km/h limit themselves. This has resulted in extensive use and up to 3,000 km of 30 km/h roads in the country.

With the advent of Vision Zero (adopted by the Swedish parliament in 1997) speeds were reviewed and a 10 km/h-stepped system introduced. Almost every city in Sweden then made a thorough investigation of its entire network to decide on an appropriate speed for every part of the system. One of the results was a lively discussion over the choice between 30 or 40 km/h. Interviews conducted with members of the public as well as professionals found that 30 km/h was favoured for its improved safety (meeting Vision Zero and increasing the safety for pedestrians and cyclists), while 40 km/h was considered better (by car drivers, politicians and planners) because it was easier to adapt the environment to 40 km/h and there was a belief that compliance would be better.

Transport Analysis, a Swedish agency for transport policy analysis, proposed, in 2017, a five-year implementation period, giving municipalities time to conduct studies, repost speed limits, and make street scene adaptations. [48] It recommended a new default speed limit of 40 km/h be implemented in built-up areas. This was, however, not accepted by the decision makers. At the same time the Transport Analysis stated that, in a number of cases, a speed limit of 30 km/h would yield greater positive effects in terms of traffic safety.

Changes in speed

A study in 2008 investigated changes in speed associated with a lowering of the speed limit from 50 to 30 km/h. The reduction of the mean speed, with the reduced limit, was little more than 2km/h, to 32.2km/h in the new 30 km/h zone.[49] The report did not include any cases of reductions in speed limits from 40 km/h to 30 km/h.

Comparing daytime and night-time speeds showed that night-time speeds were much higher.

---

[48] rapport-2017_16-sankt-bashastighet-i-tatort.pdf (trafa.se)/summary-report-2017_16.pdf (trafa.se)

[49] Hydén, C., Jonsson, T., Linderholm, L., & Towliat, M. (2008). Nya hastighetsgränser i tätort - Resultat av försök i några svenska kommuner. (Bulletin 240 A / 3000; Vol. Bulletin 240 A / 3000). Lund University Faculty of Engineering, Technology and Society, Transport and Roads, Lund, Sweden.

Changes in collisions and casualties

According to the Power model of the relationship between the mean speed of traffic and the number of fatalities, the reduction from 34.6 to 32.2 km/h found when speed limit was reduced from 50 to 30 km/h would be expected to lead to a 25% reduction in the number of people killed in motor vehicle related collisions and 10-15% reduction in the number injured (depending on the severity of the injuries). However, no measurement of the actual changes in casualties was made. Reducing the speed limit from 50 to 40 km/h on local streets or on residential roads which originally had lower speeds, had less impact.[50]

Other changes

We did not find any studies of other changes as a result of the speed limit reductions.

[50] Hydén, C., Jonsson, T., Linderholm, L., & Towliat, M. (2008). Nya hastighetsgränser i tätort - Resultat av försök i några svenska kommuner. (Bulletin 240 A / 3000; Vol. Bulletin 240 A / 3000). Lund University Faculty of Engineering, Technology and Society, Transport and Roads, Lund, Sweden

4.6 Switzerland

The setting

Switzerland has a very clearly defined and well accepted model for speed limits, known as the 30/50 model. These limits were introduced with the Signalization Ordinance in 1989 and supplemented with zone signing (knowns as Tempo 30) in 1991. Both 30 and 50 km/h limits apply in built-up areas as well as, since 2002, 20 km/h in 'encounter zones' (similar to the Dutch 'woonerf'). In planning terms, a distinction is made between basic network roads with 50 km/h limits and roads of the complementary network limited to 30 km/h.

Speed limits are signed but enhanced with use of the principle of 'self-explanatory streets'. This means that road users should be able to perceive the current speed limit unambiguously at all times via the appearance of the road.

The number of implemented zone signs in Switzerland increased by 219%, from 167 to 533 in only four years (between 1993 and 1997).[51] The proportion of 30/50 zones rose from almost 60% to around 69%. According to information from the Swiss local authorities, measures have been implemented in practically all 30/50 zones, predominantly a combination of physical and traffic engineering-related (80.4%).[52] The proportion of zones without any physical measures is 3.6%.

Changes in speed

In December 1994, the Administrative Commission of the Road Safety Fund approved co-financing of a study 'Assessment of the Effects of zone signalling in residential areas (30 km/h) on road safety'. From this 48 zones were found to have complete before/after assessments enabling the effect of the Tempo 30 zone to be analysed and assessed.[53] Overall, results showed that in the Tempo 30 zones average speeds reduced by around 18% to 32km/h in areas with physical measures compared with a 5% reduction, to 37km/h, in areas which were 'sign only'. A second study shows similar results.[54]

---

[51] Swiss Council for Accident Prevention BFU surveys of 1993 and 1997

[52] Auswirkungen von Zonensignalisationen (Tempo 30) in Wohngebieten auf die Verkehrssicherheit [1] H.P. Lindenmann, Th. Koy, Institut für Verkehrsplanung, Transporttechnik, Strassen- und Eisenbahnbau (IVT) – ETH Zürich Fachartikel VSS – Strasse und Verkehr, Heft 9 /2000

[53] Auswirkungen von Zonensignalisationen (Tempo 30) in Wohngebieten auf die Verkehrssicherheit [1] H.P. Lindenmann, Th. Koy, Institut für Verkehrsplanung, Transporttechnik, Strassen- und Eisenbahnbau (IVT) – ETH Zürich Fachartikel VSS – Strasse und Verkehr, Heft 9 /2000

[54] Lindenman HP: The Effects on Road Safety of 30 Kilometer-Per-Hour Zone Signposting in Residential Districts, ITE Journal 2005

Changes in collisions and casualties

The impact of the implementation of Tempo-30 zones on casualty numbers has been assessed in two notable studies, one by the Institute for Transport Planning and Transport Systems IVT of the ETHZ and the other by the Traffic Technical Department of the Cantonal Police Zurich.[55] [56]

The conclusion of the first study found that the number of casualties decreased by around 15% in urban areas, and in rural areas by almost 50%. The severity of the collisions also decreased significantly. It was found that the proportion of cyclists and moped drivers involved in collisions fell markedly after the introduction of Tempo 30, however, there was a slight increase in collisions involving pedestrians.[57]

In the other study, by Zurich police, there was a decrease in collisions of 27.5% and of injuries by 28.8%. A meta-analysis by Elvik shows that speed 30 zones reduced the number of injured by an average of 27% (Error accuracy: +/- 3%).[58]

This significant rate of reduction in annual collisions was echoed in the 1994 report which found the average annual number of collisions before and after the introduction of a 30 km/h zone of 28.7% for rural areas, although only 3.8% for urban areas.[59]

Other changes

We did not find any studies of other changes as a result of the speed limit reductions.

---

[55] Bfu-Massnahmenkatalog Infrastruktur–Sicherheitsmassnahmen im Strassenraum Bfu. Bern 2017
[56] Lindeman HP: The Effects on Road Safety of 30 Kilometer-Per-Hour Zone Signposting in Residential Districts, ITE Journal 2005
[57] Bfu-Massnahmenkatalog Infrastruktur–Sicherheitsmassnahmen im Strassenraum Bfu. Bern 2017)
[58] Elvik R, Bjørnskau T. Safety-in-numbers: A systematic review and meta-analysis of evidence. Safety Science. 2// 2017;92: 274-82. http://www.sciencedirect.com/science/article/pii/S0925753515001812. DOI: http://dx.doi.org/10.1016/j.ssci.2015.07.017
[59] Kanton Basel-Landschaft: Pilot Project (Pilotprojekt), Justis- und Polizeidirektion, Liestal, 1994

4.7 Conclusions from European case studies

Implementation of 30 km/h limits

The six European countries studied have had different approaches to implementing speed limits. For example, in Germany physical measures are less likely to be constructed while in Switzerland they are widespread.

Road classification

As far as we are able to tell, in the six countries studied, a high proportion of residential areas have 30 km/h limits. Almost all streets that have 30 km/h today are small residential streets.

In some of the countries a speed limit of 20 km/h, or lower, has been introduced and is used in central areas of cities, and specific areas such as at schools, retirement homes and some residential streets. Use of 20 km/h limits is not widespread and no studies were found about its impact.

However, main arteries in built-up areas, carrying the majority of motor traffic and the biggest burden in terms of collisions and injuries, retain 40 or even 50 km/h limits. In Sweden, politicians have agreed that 40 km/h was a reasonable speed limit, combining the driver's desire for shorter journey times with improved safety of vulnerable road users and the well-being of residents. However, it was decided to retain the 50 km/h limits. Introducing 30 km/h on those streets could result in the biggest safety gain, if the compliance rate was high.

Speed

As shown by the figure below, there is a distinct difference between the impact of speed limits accompanied by physical measures and those implemented with 'signs only'. The latter represents by far the largest group of studies and although 'signs alone' produce a reduction in speed, it is, on average, quite small. The effect of accompanying 'sign-only' schemes with education and campaigns has little further impact and, in practice, enforcement is too difficult to employ on a large scale.

Physical measures led to a greater reduction in mean speeds. The optimal design of any physical measures has not been studied for this report.[60]

[60] Safety effects of 30 km/h zones in the Netherlands. Vis, A.A.; Dijkstra, A.; Slop, M.Accident Analysis & Prevention 24 (1), Pagina's 75-86 1992 (1/)

It has also been found that the initial average speeds on a road, regardless of the speed limit, impact the average speeds after the new limit has been implemented. Where average speeds before a new limit is introduced are close to the new speed limit, there is no or very small changes to the average speed.

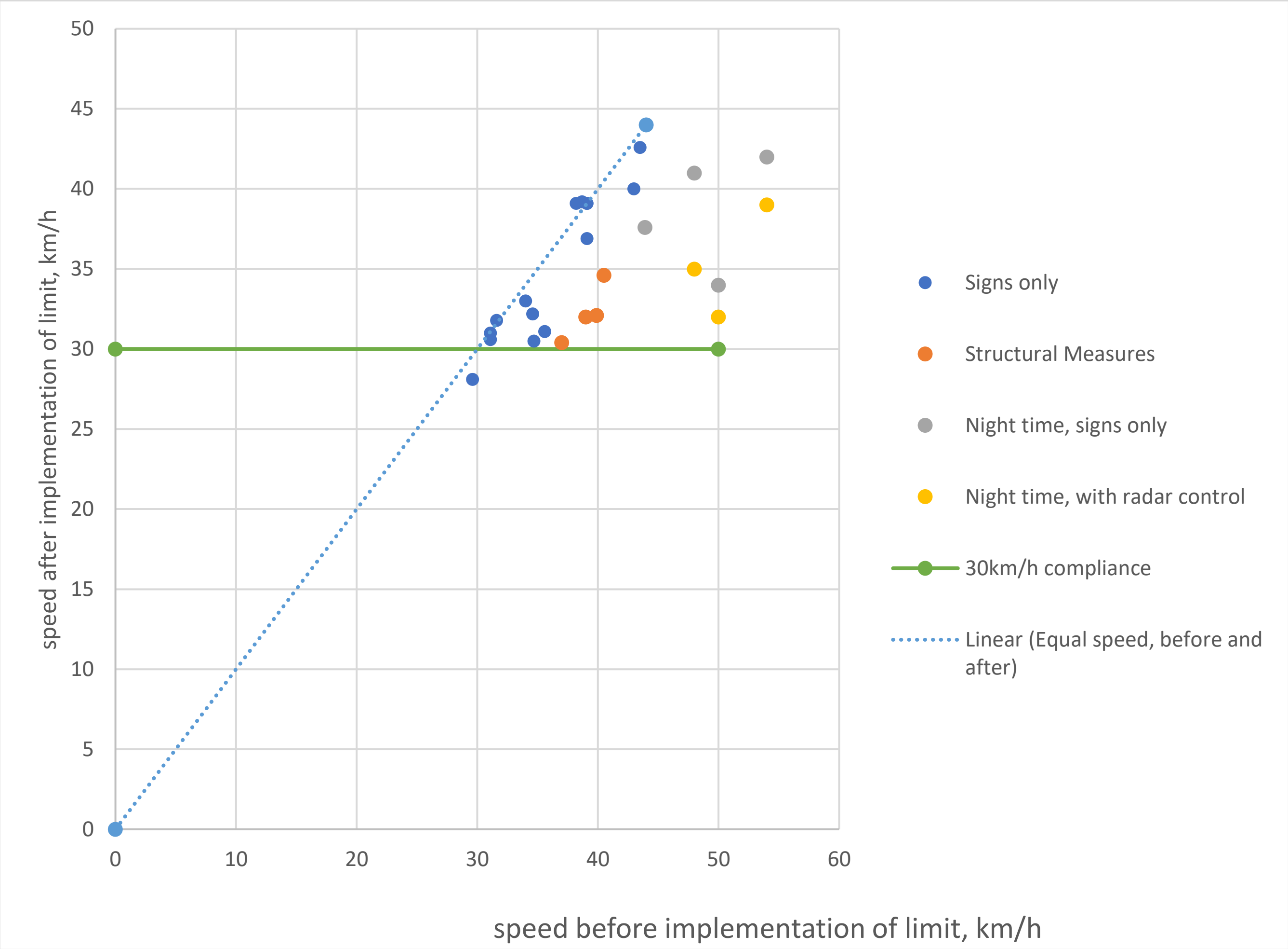


Figure 2 Speeds before and after the implementation of 30 km/h limits in European locations
Note: Closer proximity to the diagonal trend line indicates smaller reduction in speed, closer proximity to the horizontal trend line indicates compliance with the 30 km/h limit

Collisions and casualties

The available studies showed that following the implementation of 30 km/h speed limits there were median reductions in casualties within urban areas of 18%. Insufficient details are available in the studies to distinguish between sites with physical measures and those which are sign-only.

Where 30 km/h limits are linked to additional measures – physical, enforcement and communication – significant reductions in speed may result. Without physical measures the effect is a reduction of 0-4 km/h which corresponds to minimal reductions in collisions and injuries.

Scope and quality of assessments

The lack of available assessment studies has limited the depth of this report and comparison between countries has been difficult. There is a wide variety in the quality of documentation recording the effect 30 km/h limits on speeds, collisions and casualties in each of the six countries studied. Some countries, such as the Netherlands, have undertaken studies and assessed outcomes which has influenced their policy. Others, such as Norway, appear to have implemented lower limits quite widely but undertaken little assessment.

The studies of effects on accidents quoted for the Netherlands, Switzerland, Sweden, Germany and France are all simple before-and-after studies that did not control for any confounding factors. This means that the studies all score lowest for methodological quality according to the scoring system presented in the Appendix to this report.

However, there was consistency in the general findings. The studies in the Netherlands, Switzerland, Germany and France all found reductions in speed. One would expect these reductions to be associated with a reduction in the number of accidents, in particular those resulting in fatal or serious injury. This was found in, for example, Germany. Therefore, despite the lack of control for confounding factors in these studies, it is reasonable to believe that at least part of the decline in the number of accidents is attributable to the reduction in speed.

The study in Sweden also found a reduction in speed, but accident data were only available for the before-period. Therefore, expected effects were estimated by applying the Power Model of the relationship between changes in speed and changes in the number of accidents. This should result in unbiased estimates of expected effects, but actual effects were not studied.

The study in Norway did not include speed data. Therefore, the changes seen in the number of accidents cannot be related to changes in speed. There was a downward trend, and this trend was stronger in municipalities that introduced lower speed limits than in municipalities that did not do so. The length of the time-series means that regression-to-the-mean is not an issue in these data.

Other results

The non-compliance rate across the case studies was very high, thereby negating some of the possible safety benefits. it seems that where drivers consider that the limit is ‘too low’ and there are neither physical measures nor effective enforcement, the consequence is less respect for the speed limits.

Speed limit reductions have increasingly been introduced on the basis of wider objectives, e.g. to increase walking and cycling. Very few studies attempted to measure the outcomes for such objectives. It is possible that they succeeded but we could find no evidence. It seems likely that, where they did, it was as a component of a wider set of measures rather than on their own.

One study, in Germany, recorded lower levels of traffic noise.

Studies have shown that fuel consumption and emissions increase on roads that have speed humps. The increase is mainly attributable to deceleration and acceleration when passing the humps. We did not find any studies that assessed changes in emissions from speed limit reductions without physical measures.

5 Effects of 20 mph limits in the UK

Studies of the effectiveness of 20 mph speed limits in the UK vary by their contexts, analysis methods and data, study quality, built environments (urban vs rural), types of scheme (with physical measures and enforcement, sign only), types of impact (collisions, casualties and speed changes) as well period of assessment from the 1990s to 2019.

An assessment of the overall effectiveness of 20 mph speed limits was made by Loughborough University for LUSTRE, carrying out a meta-analysis on 24 studies. This provided insights and evidence on the safety impacts of 20 mph speed limits in the UK (driven speeds, collisions, and casualties).[61]

Although the primary interest was to estimate the impact of 20 mph speed limit without physical measures (i.e. sign only), the impact for: (i) all schemes (with and without physical measures), (ii) schemes without physical measure (sign only) and (iii) schemes with physical measures was also compared.

The results indicate that the introduction of 20 mph speed limits (**sign only**) was found to reduce mean speed by **1.76 mph.**

In terms of the number of casualties, the introduction of a 20 mph speed limit resulted in a reduction of 23% (all severities) for all schemes. For those with physical measures casualties (all severities) reduced by 40**%** whereas this was **only 11%** for the schemes with **sign only**.

The results for casualties are consistent with other studies; the results for collisions indicate larger effects than other studies have found and that one would expect based on the changes in the number of casualties. Usually, percentage changes in collisions are smaller than percentage changes in casualties.

Unfortunately, the number of studies for sign-only schemes was small and some results, e.g. changes in casualties by severity, must be treated with caution. The full results are included in Loughborough's paper, published in full later in this report.

As anticipated, it can therefore be concluded that there is a greater reduction in the number of collisions and casualties from the introduction of a 20 mph speed limit which incorporates physical measures than when it has no physical measures (i.e. sign only).

[61] Meta-analysis of the effects of 20 mph speed limits in the UK, A. Theofilatos, M. Quddus, M Feng, R Elvik, 2021

The results are also consistent with existing studies. For instance, Elvik[62] found that studies of speed humps resulted in a mean reduction of the number of injury collisions by 30% which is not significantly different from the 26% collision reduction (for the schemes with physical measures) found in this study. Since the sample size for some estimates are low, the findings should be interpreted with care.

[62] Elvik R. (2020). Assessing the methodological quality of studies evaluating the effects of 20 mph zones. Working paper 51621, Oslo 04.05.2020, 4873 LUSTRE project

6 Summary and Conclusions

6.1 Lower urban speed limits

Lower speed limits in urban areas (typically 20 mph in place of 30 mph in the UK, and 30 km/h in place of 40 or 50 km/h in mainland Europe) have been introduced since the 1990s. These usually covered relatively small areas. Graz, Austria was the first to embrace a whole city. It was seen as a matter for local policy makers, often within constraints set by central government. This has now changed.

6.2 Policy support for 20 mph limits

There is now high-level support for widespread use of lower speed limits (20 mph / 30 km/h) in urban areas, to improve road safety and to support other policy objectives. Lower urban speed limits were endorsed by the UN General Assembly in 2020 and have been adopted in many countries and major cities, including for example Spain and Brussels. In 2023, 20 mph limits will become the default on minor roads in Wales. In the UK, many towns or cities have implemented 20 mph limits, usually in particular areas but sometimes citywide.

6.3 Safe speed

Excessive or inappropriate speed is a major contributory factor to road casualties. Setting and enforcing speed limits is a well-established part of road safety policy.

The increasing adoption of Vision Zero and Safe System has brought about a new approach to speed limit setting. In this context, a safe speed is one at which the road user can withstand a collision without suffering death or life-changing injury. This will depend on the safety performance of the vehicle, the infrastructure, the nature of the collision and other factors.

20 mph is now generally accepted as the safe speed for streets used by people walking, cycling or wheeling. At 20 mph a pedestrian is likely to survive an impact with a motor vehicle whereas at 30 mph the pedestrian is significantly more likely to be killed. Traffic speeds of around 20 mph are also more conducive to walking and cycling.

6.4 20 mph zones

20 mph speed limits are not new in the UK. In the 1990s a number of 20 mph **zones** were introduced in the UK on streets with 30 mph limits. A condition of introducing the 20 mph limit was that it should be self-enforcing and speed humps and other traffic calming measures were installed where necessary. These schemes were independently assessed and found to substantially reduce vehicle speeds and casualties.

6.5 20 mph limits

In 2013 the UK Department for Transport's Speed limit setting guidance was made more flexible. Local authorities were given the freedom to introduce 20 mph **limits** based on average speeds and the requirement for self-enforcing physical measures was eased. As a result, 20 mph limit speed limits are now generally introduced with few if any physical measures. This has made it much easier, less contentious and less costly for local authorities to install 20 mph limits over wider areas.

6.6 Evidence of outcomes

Research has clearly established that speed and casualty reductions from introducing 20 mph zones (with self-enforcing physical measures) are greater than for 20 mph limits (where no physical measures are installed). That does not mean to say, however, that no change or benefit follows but the research into the size of speed and casualty reductions for 20 mph limits is less robust and estimates of change have been less clear and more varied.

6.7 Different approaches in different countries

Different countries have taken different approaches to introducing 30 km/h limits

- France, originally, introduced 30 km/h limits in some cities and backed this with a programme of speed enforcement cameras. However, monitoring data is sparse.
- Germany has taken different approaches in different states. Sometimes physical measures were used to support lower limits but not necessarily.
- Netherlands has tended to establish 30 km/h limits mainly where the infrastructure encourages drivers to comply. 30 km/h speed limits are less likely to be reduced where drivers would naturally adopt higher speeds.
- Norway has lowered speed limits to 30 km/h on many minor roads. Most of these are enforced by speed humps and speeding fines are high.
- Sweden has introduced lower speed limits extensively since 1998. Some of these are supported by physical measures.
- Switzerland has a clearly defined and well accepted model for speed limits, known as the 30/50 model. The proportion of zones without any physical measures is small.
- The UK, as noted above, has shifted from introducing self-enforcing 20 mph zones, which generally covered small areas, to area-wide and sometimes citywide 20 mph limits which tend not to have self-enforcing physical measures.

6.8 LUSTRE findings

Table 1. Summary of changes in speeds, collisions and casualties.

	Before speeds **(30-40 or 40-50 km/h)**	**After (with physical measures) – Previous research and LUSTRE** (Column C)	**After (without physical measures) – LUSTRE** (Column D)
Typical average speeds (km/h)	For lower before speeds, 30-40 km/h[63]	• 24.0 • 25.6 • 26.7 • 27.4 • 32.1	• 29.8 • 30.1 • 30.5 • 32.2 • 39.1 • 39.2
Typical average speeds (km/h)	For higher before speeds, 40-50 km/h[64]	• 37.7 • 41.2 • 44.1	• 33.6 • 36.0 • 36.2
Typical change in casualties – UK (%)	For all before speeds[65]	• 40	• 11
Typical change in casualties (%)	For lower before speeds, 30-40 km/h[66]	Fatal: • -82 • +5 • -35 Serious: • -70 • -55 • -47 Slight: • -58 • -44 • -36	Fatal: • -11 • -35 Serious: • -4 • -16 Slight: • +8 • -9
Typical change in casualties (%)	For higher before speeds, 40-50 km/h	No estimates available	No estimates available

For sources, see footnotes.

Table 1 above summarises the quantitative findings from LUSTRE. It shows:

- When a speed limit of 30 km/h (20 mph) is introduced *with physical measures*, often humps, speed is normally reduced to less than 30 km/h, provided it was less than about 40 km/h before the measures were implemented.
- When the driven speed was above 50 km/h before a limit of 30 km/h is introduced with physical measures, it tends to remain above 40 km/h even with physical measures.
- When a speed limit of 30 km/h is introduced *without physical measures*, the mean speed of traffic changes very little and in most cases remains above 30 km/h.
- The meta-analysis of UK data by Loughborough University found that the introduction of 20 mph speed limits (sign-only) reduced average speed by **1.76 mph** (with the 95% confidence intervals: -2.73 mph; -0.8 mph). Sign-only limits reduced the total casualties (all severities), on average, by 10.9% (with the 95% confidence intervals: -18.3%; -3.5%). Larger changes were found for limits with physical measures.
- The mean speeds given without physical measures (33.6; 36.0; 36.2) are all lower than those with physical measures, but in all these cases mean speed in the before-period was lower (around 40-44 km/h) and the reduction of speed from before to after was smaller than where physical measures were used.
- The effects on collisions and casualties given in the Table are based on the same studies as those quoted above for changes in speed. In general, larger reductions are found when physical measures are used than when they are not used. There

[63] The first four numbers listed in Column C (24.0; 25.6; 26.7; 27.4) are all from British studies (respectively Baguley 1982; Webster 1996, 2007; Grundy et al. 2009). The fifth number (32.1) is from a Swiss study (Lindemann 2005). The first two figures in Column D (29.8 and 30.1) are from the studies summarised in the meta-analysis in Appendix 2 of this report (mean speeds before were, respectively, 31.9 and 31.5 km/h). The next (30.5) is from Grenoble in France (mean speed before 34.7 km/h) (Cerema 2020). 32.2 km/h is from Sweden (mean speed before 34.6 km/h) (Hydén et al 2008). 39.1 is from Switzerland (Lindenmann 2005) and 39.2 again from France (Cerema 2020).

[64] The numbers 41.2; 44.1 in Column C are from Ewing (1999) and 37.7 from Mountain et al. 2005. (Sun 2018; Bornioli et al. 2019; Unweltbundesamt 2016).

[65] See Meta-analysis of the effects of 20 mph speed limits in the UK, A. Theofilatos, M. Quddus, M Feng, R Elvik, 2021

[66] See Meta-analysis of the effects of 20 mph speed limits in the UK, A. Theofilatos, M. Quddus, M Feng, R Elvik, 2021

are also larger percentage reductions in fatal or serious injuries than in slight injuries.

6.9 Limitations of the studies

The quality of studies assessing the outcomes of 20 mph limit is variable. Few take account of background trends, regression to mean or changes in traffic flow or composition. These aspects can be difficult to address for local authorities which are not research specialists and operate on limited budgets. In Appendix 1, Dr Rune Elvik suggests practical ways in which studies could be improved.

Because of the variation in the standards of research, the estimates of the outcomes of speed limit reductions vary widely. It is hard to compare studies as methods, before speeds, scheme conditions and other factors vary widely.

Despite the lack of robust assessments, the conclusions and direction of change are reasonably consistent. These show a downward movement in speeds and casualties where lower limits are introduced. It is the scale of the movement that is much harder to assess.

6.10 Conclusions

The following conclusions can be drawn from the studies and data analysis in LUSTRE.

- 20 mph limits without physical measures result in modest speed reductions – typically 1-2 mph where before speeds are approximately 25 mph, and reductions of 3-5 mph where before speeds are approximately 30 mph.
- 20 mph limits without physical measures result in approximately 11% fewer casualties than before in the UK.
- For the European case studies, there were approximately 18% fewer casualties after 30 km/h limits were introduced but this figure was for all schemes, including some with physical measures. There were too few studies of sign only schemes to provide an average.
- Some 20 mph limits would have been accompanied by other measures, such as cycling infrastructure which might have contributed to any casualty reductions.
- Compliance with 20 mph limits without physical measures is poor.
- 20 mph limits with physical measures have substantially greater speed and casualty reduction effects than those without.

- Very few studies have attempted to assess the outcomes in relation to other goals set, such as increasing walking and cycling, air quality, noise etc. If speeds did not reduce by perceptible amounts, it seems unlikely that there would be any significant change in other behaviours. It may be that these goals were achieved as a result of complementary measures, such as cycling infrastructure, to which the lower speed limit contributed.

Lower urban speeds are important to delivering casualty reductions and associated objectives such as increasing active travel. Lower speed limits (20 mph limits / 30 km/h) help to reduce driven speeds and casualties. The extent to which they deliver actual speed and casualty reductions depends on the extent to which schemes are supported by other measures.

6.11 Is bigger better?

Lower urban speed limits are being introduced in many countries and covering larger areas, sometimes city-wide. These are backed to varying degrees by measures to encourage and enforce driver compliance – physical changes to the streets, speed cameras, police enforcement and publicity. Mainly, however, they do not include substantial physical measures.

In the UK, Brighton introduced 20 mph limits in the city centre and some of the surrounding residential area. Here the reduction was 19% in casualties with a main road reduction of 23.7%. This contrasted with the other areas analysed in the Atkins study which found little or no reductions beyond the background trends.[67]

London now has 20 mph limits on most minor roads and Transport for London (TfL) has introduced these limits on a substantial length of the main road network. A further 65km is planned for late 2023.[68] This has been backed by a range of measures and TfL has reported significant casualty reductions.

Edinburgh has introduced 20 mph limits across much of the city. A major study found that mean speeds reduced by 1.34 mph with main roads showing a slightly higher reduction of 1.79 mph. The reported overall casualty reductions were 39%, substantially higher than studies of most other areas have found. However, in Belfast, where 20 mph

[67]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/757307/20 mph-headline-report.pdf
[68] 20mph limits: “the facts are clear” (roadsafetygb.org.uk)

limits were introduced on a more limited area, there was no change in speeds and only a 2% reduction in casualties.[69]

Wales has reported success with 20 mph limits in pilot areas and will replace 30 mph limits with 20 mph across the country in September 2023, except for those roads exempted.[70]

In Spain, the limit on urban roads with one lane per direction has been reduced to 30 km/h. Brussels has introduced a city-wide 30 km/h limit and reported a significant reduction in fatalities.

It has not been possible within the scope of LUSTRE to properly consider these more recent schemes, their features or study methodologies. The reported speed reductions are broadly consistent with those found in LUSTRE but the reported casualty reductions are greater. It may be that 20 mph limit reductions introduced at scale have a greater impact. In addition, it seems that schemes incorporating main roads have greater casualty reductions. This may be due to slightly larger reductions in speeds on these faster roads, better public awareness or other supporting measures.

6.12 New directions

It is notable that the highway authorities now see in-vehicle technologies and regulations as important to delivering actual reductions in speed and casualties. Intelligent Speed Assistance (ISA) is seen as having significant potential to encourage compliance with the lower limits. Since July 2022, ISA has been required in new vehicles models in the EU (and Northern Ireland), under the revised General and Pedestrian Safety Regulations. However, advisory ISA will moderate speeds less than mandatory ISA would; and it will take many years to significantly penetrate the vehicle fleet. Great Britain has yet to update its safety standards. Autonomously-driven vehicles will almost certainly be required to comply with speeds limits.

Ironically, in future, it may be the vehicles themselves, not external factors, that ensure compliance with speed limits. Whether the limits are set at safe speed levels, in accordance with Safe System principles, will be a matter for national and local governments and highways authorities.

---

[69] Developing and implementing 20-mph speed limits in Edinburgh and Belfast: mixed-methods study (nihr.ac.uk)
[70] New data 'shows benefits of driving at 20mph' (roadsafetygb.org.uk)

7 Acknowledgements

PACTS thanks The Road Safety Trust for funding this project. Particular thanks go to Grants and Impact Director Louise Palomino for her patience and support; and to Heather Ward, Trustee and Chair of Road Safety Initiatives Committee, for providing valuable technical advice.

The project team would also like to acknowledge the assistance of the following people who were primary contacts for case studies. We are grateful for their help and advice. Responsibility for the contents of this report lies with the authors.

1. France
    - Lucie Bruyere - CEREMA/DTecTV/VOI/SUD
    - Dr Sylvain Lassare; FFSTAR and the Université Gustave
2. Germany
    - Professor Regine Gerike, Fakultät Verkehrswissenschaften „Friedrich List“, Technishe Universität Dresden. Regine Gerike
    - Professor Professor Jürgen Gerlach. Bergishe Universität Wuppertal.
    - Professor Jürgen Follman
    - Dr Marek Junghans; German Aerospace Center (DLR), Department of Traffic Management.
3. The Netherlands
    - Mr Rob Methorst, Emeritus Researcher at Road Safety Institute SWOV, and Senior Advisor @ RWS Water, Traffic, Environment.
4. Norway
    - Dr Guro Ranes, Norwegian Road Administration
    - Dr Arild Ragnöy. Norwegian Road Administration
    - Dr Rune Elvik. Institute of Transport Economics.
5. Sweden
    - Dr Anna Vadeby. VTI-Swedish National Road and Transport Research Institute.
    - Dr Anna Niska, VTI-Swedish National Road and Transport Research Institute.
    - Dr Maria Krafft. The Swedish Transport Administration. (Not explicitly involved, but responsible for traffic safety in Sweden and interested in the topic.)
6. Switzerland
    - Swiss Council for Accident Prevention BFU
7. CTCT, International Committee on Theories and Concepts in Traffic Safety

LUSTRE

Lower urban speed limits in Europe. What does the evidence show?

Appendix One: Guidance on evaluating the effects of changes in low speed limits.

Paper by Dr Rune Elvik, TOI, Norway

September 2022

Contents

1. Introduction

The purpose of this document is twofold:

- to provide guidelines for those undertaking evaluations of the effects of changes in low (urban) speed limits;
- to assess the methodological quality of studies evaluating the effects on road safety of 20 miles per hour (mph) speed zones.

These guidelines serve as the basis for a formal quality scoring system for studies that have evaluated the effects on road safety of 20 mph speed zones.

In addition to the quality of studies, the completeness of reporting is addressed. To be included in formal research synthesis and meta-analysis, a study at least needs to report the best estimate of the change in the number of collisions and the standard error of the estimate, or information permitting the standard error to be computed. These statistics are needed to assign a statistical weight to a study, reflecting the precision of its estimate of effect. A study of otherwise high methodological quality may have to be omitted from a meta-analysis if the results are not reported in sufficient detail to determine its statistical weight.

2. What is the methodological quality?

The methodological quality of a study is the extent to which it controls for potential sources of bias and confounding that may influence its results. The number of collisions, and their severity, is influenced by very many factors. To conclude that a change in the number of collisions was caused by a road safety measure, like a 20 mph zone, it must be ruled out that the change was caused by something else. The only way of ensuring this, is to do a randomised controlled trial (experiment), in which the road safety measure is introduced at random to ensure that there are no systematic differences between the treated group and the control group. Randomised controlled trials are rare in road safety research. A common design for an observational (non-experimental) study is a before-and-after study with or without a comparison group. No observational study can control for all potentially confounding factors, but the most important confounding factors in before-and-after studies are known.

The three most important potential confounding factors in before-and-after studies evaluating the effects of road safety measures are:

1. Regression-to-the-mean
2. Long-term trends in the number of collisions
3. Exogenous changes in traffic volume

A fourth factor which has been found to be relevant in evaluations of 20 mph zones is:

4. Collision migration

Figure 1 depicts the relationship between variables that are relevant in evaluations of 20 mph zones.

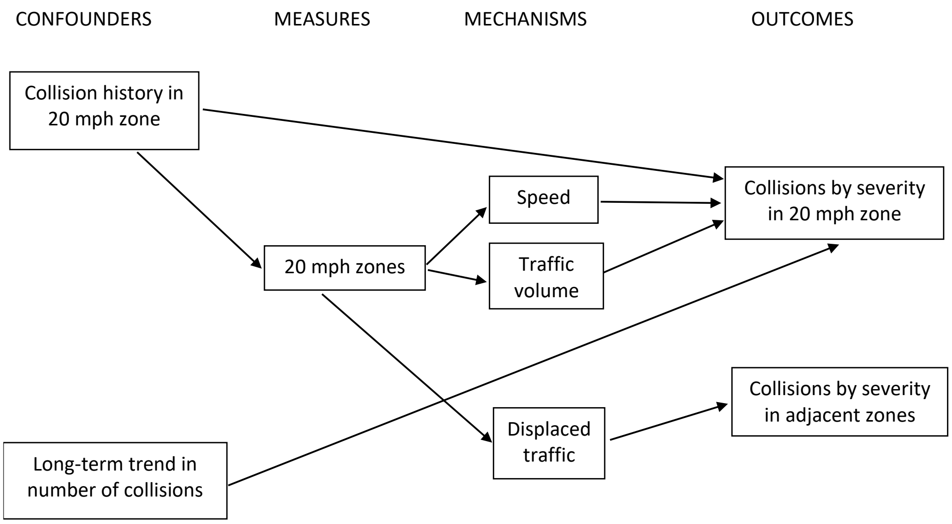


FIGURE 1: RELEVANT VARIABLES IN STUDIES EVALUATING EFFECTS ON ROAD SAFETY OF 20 MPH SPEED ZONES

Regression-to-the-mean refers to the tendency of an abnormally high, or abnormally low, number of collisions to return to a value closer to the long-term mean number of collisions per unit of time. There is random variation in the number of collisions; as a result of this, there may be a higher-than-normal number of collisions during a period that may last at least a few years. The number of collisions may then go down, even if no road safety measure is introduced. In Figure 1, the source of regression-to-the-mean is referred to as collision history of the 20 mph zone.

The collision history of a zone may be one of the reasons for introducing a 20 mph zone, but even if it is not, a good study will always check if regression-to-the-mean is likely to confound the results, and, if so, control for it. There are many ways of controlling for regression-to-the-mean, but the Empirical Bayes (EB) method is widely regarded as the best method (Hauer 1997).

The number of collisions may have a long-term trend towards increase or decline. To detect such a trend, data for at least five years in the before-period is needed. A long-term trend can only be reliably detected in a large data set, preferably recording at least a few hundred collisions per year. In smaller data sets, random fluctuations will make the detection of any long-term trend unreliable.

Exogenous changes in traffic volume is not listed separately as a confounder in Figure 1. By exogenous is meant that the changes in traffic volume were not caused by the implementation of the 20 mph zone, but would have occurred all the same. If a 20 mph zone is located in an area of rapid development, traffic volume might be expected to increase. The reason it is not listed separately in Figure 1, is that in an evaluation study, we are usually not interested in changes in traffic volume *per se*, but in the effects changes in traffic volume have on the number of collisions. If a study includes a large comparison group, the effects on collisions of exogenous changes in traffic volume will be captured by the long-term trend in the number of collisions in the comparison group. A reliably estimated long-term trend in a comparison group includes the effects of everything producing that trend.

The road safety measure of principal interest in this project is 20 mph zones, both those without physical measures and those that include physical measures like humps.

A 20 mph zone influences collisions by influencing risk factors that are associated with collisions. These are referred to as mechanisms in Figure 1. The principal risk factor it is intended to influence is speed. However, studies (Baguley 1982, Webster and Mackie 1996) have found that traffic volume sometimes goes down in 20 mph zones.

The treatment of changes in traffic volume in an evaluation study depends on whether a decline in the number of motor vehicles in a 20 mph zone is the result of displacing traffic to adjacent streets or the result of a change in the modal split of travel in the 20 mph zone. In the former case, there really has not been any decline in traffic volume; traffic has just moved to other streets. In that case, the effects on collisions of increased traffic volume in the adjacent area should be interpreted as an effect of the 20 mph zone, and the evaluation of the effects on collisions should include changes both in the 20 mph zone and in the adjacent area. In the latter case, the evaluation of effects on collisions can be based on data just for the 20 mph zone. It is known that low speed limits discourage driving (Elvik 2018) and make walking or cycling more attractive. Therefore, a decline in the number of motor vehicles in a 20 mph zone need not imply that these vehicles now take a different route. They could simply have disappeared, and people living in the 20 mph zone have taken up walking or cycling instead of driving. The effects on collisions of such changes in modal split within the 20 mph zone would be reflected in collision data for the zone.

A correct interpretation of changes in traffic volume clearly requires quite detailed data that are not always available. An indirect way of evaluating the effects of changes in traffic volume, in particular of traffic displaced to adjacent areas, is to rely on collision data only. If the number of collisions in the adjacent area did not increase, controlling for long-term trends, that suggests that there was no displaced traffic, at least not enough to lead to an increase in the number of collisions.

3. The importance of controlling for confounders

Which of the potential confounding factors is the most important to control for? Which can have the largest influence on study results?

To shed light on these questions, Elvik (1997) compared the results of studies evaluating the safety effects of treating hazardous road locations, often referred to as black spot treatment. Figure 2 shows some of the results.

In simple before-and-after studies, not controlling for any confounding factors, an impressive collision reduction of 55 % was found. In studies controlling for one confounding factor, either changes in traffic volume, long-term trends, or regression-to-the-mean, effects varied between 26 % and 39 % collision reduction. Controlling for long-term trends or regression-to-the-mean both reduced estimates of effect to less than half the value (55 %) found when these factors were not controlled for.

In studies controlling for two confounding factors, estimates of effect varied between 2 % and 33 % collision reduction. Controlling for long-term trend and regression-to-the-mean was found to have the greatest influence on estimate of effect. Finally, in studies controlling for long-term trend, regression-to-the-mean and collision migration, the estimate of effect was zero. It is notable that no study had controlled for all the four potential confounding factors considered.

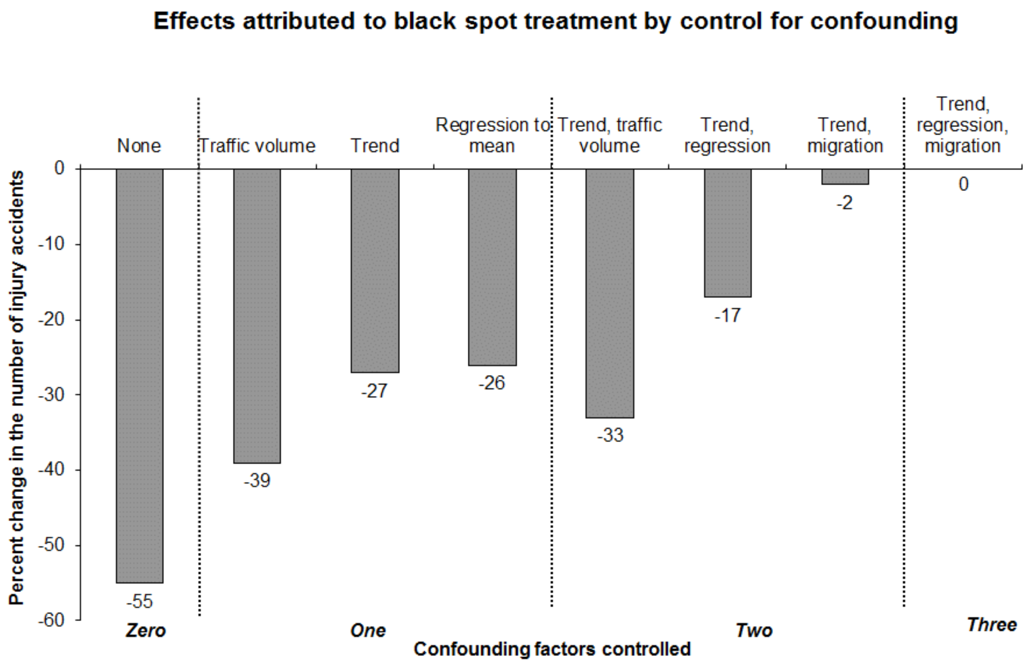


FIGURE 2: ESTIMATED CHANGES IN THE NUMBER OF COLLISIONS ATTRIBUTED TO BLACK SPOT TREATMENT AS A FUNCTION OF CONTROL FOR CONFOUNDING FACTORS

Long-term trends and regression-to-the-mean are the two most important confounding factors. Controlling for changes in traffic volume is less important, both because changes in traffic volume tend to be small during a period of 5-10 years, and because by using a large comparison group, changes in the number of collisions in the comparison group will reflect the effects of changes in traffic volume on the number of collisions.

4. A quality scoring system

This section proposes a numerical quality scoring system for the methodological quality of studies evaluating the effects on road safety of 20 mph zones. The scoring system is presented in Table 1.

TABLE 1: QUALITY SCORING FOR METHODOLOGICAL QUALITY OF STUDIES EVALUATING THE EFFECTS ON ROAD SAFETY OF 20 MPH ZONES

Aspect of study quality	Score
Study controls for regression-to-the-mean or shows that the count of collisions in the before-period was an unbiased estimate of the long-term mean	4
Study controls for long-term trends or shows that there was no long-term trend in the number of collisions	3
Study specifies both changes in speed and in traffic volume and shows whether changes in traffic volume involved displacing traffic to other routes or not	3
Study specifies changes in speed but not in traffic volume	1
Study evaluates collision migration by use of a large comparison group	1

Controlling for regression-to-the-mean is the most important aspect of study quality. A study controlling for regression-to-the-mean and long-term trends, while specifying changes in speed and traffic volume, and documenting whether the changes in traffic volume involved displacing traffic to alternative routes, or were confined to the 20 mph zone, will score 10 points (4 + 3 + 3).

A study controlling for regression-to-the-mean and long-term trends, and providing data on speed, but not on traffic volume, will score 8 points (4 + 3 + 1). If the study tests for collision migration to an adjacent area, using a large comparison group, it will score an additional point, for a total of 9.

Use of the quality scoring scale will be illustrated by means of examples in later sections of this paper.

5. Quality of study presentation and plausibility of results

The scoring system for study quality is based on how well a study controls for confounding factors and how well it specifies the mechanism, principally changes in speed, producing changes in the number of collisions. Scoring studies for quality by means of this system deliberately disregards study findings. The reason for this is that experience shows (Rosenthal 1991) that the assessment of study quality is often influenced by knowledge of study findings. "Bad studies tend to be those whose results we do not like".

Nevertheless, the findings of a study may be more or less well-presented and more or less plausible in view of other knowledge. If a study found a large reduction in speed and a large increase in the number of collisions, we would regard the finding as implausible. It is therefore relevant to define criteria for assessing the quality of presentation and the plausibility of results. Table 2 proposes a scoring system for quality of presentation and plausibility of results.

TABLE 2: SCORING STUDIES FOR PRESENTATION AND PLAUSIBILITY OF FINDINGS

Aspect of presentation or results	Score
Study presents at least two estimates of effect referring to different levels of collision severity and states the standard error of each estimate or information permitting the standard error to be computed	5
Study presents a single estimate of effect referring to a specific level of collision severity and its standard error or information permitting standard error to be computed	3
Results presented enable an assessment of either a dose-response relationship between (a) the "dose" of the measure and the size of the effect, or (b) the size of the change in speed and the size of the change in the number of collisions, or both	5 (a+b) 2 (a) 3 (b)
Study gives an imprecise presentation of some of the items above	1

The first item on the list is proposed because the effect of changes in speed on the number of collisions is known to vary according to collision severity (Elvik 2019). A given change in speed will have the largest effect on fatal collisions, a smaller effect on serious injury collisions, and a still smaller effect on slight injury collisions. If estimates of effects are available for different levels of collision severity, it becomes possible to assess the plausibility of findings according to general knowledge about the gradient of the relationship between changes in speed and changes in collision severity.

If a study presents only one estimate of effect, it is still possible to synthesise the estimate with other estimates in a meta-analysis if the standard error of the estimate is known and if collision severity is specified.

The plausibility of the findings of a study can be assessed in terms of two types of "dose-response" relationships. The first type refers to the "dose" of the measure. If a 20 mph zone includes physical measures, the more there are of these – the shorter the distance between each speed hump – the larger is the dose of the measure. All else equal, one would expect an extensive use of physical measures to be associated with a larger effect on speed and collisions than a sparser use, or no use, of physical measures.

Even if a 20 mph zone does not include any physical measures, it still makes sense to talk about different doses of the measure. Thus, reducing speed limit from 35 mph to 20 mph is a larger dose of treatment than reducing the speed limit from 30 to 20 mph.

The second type of dose-response relationship refers to the relationship between changes in speed and changes in the number of collisions. If there is a large reduction in speed, one would expect a larger reduction in the number of collisions than if there is a small reduction in speed.

A study permitting an assessment of both types of dose-response relationship scores 5 points for this item. If the study also reports estimates of effect for at least two levels of collision severity, it will get 10 points in total, which is the maximum score. A study scoring 5 points for estimates referring to different levels of collision severity, but allowing only for assessing the speed change-collision change relationship will score 8 points (5 + 3).

Formal scales of the kind proposed here have been criticised for being arbitrary and subjective (Greenland 1994). This criticism is correct, but the scales are transparent, easy to use, and replicable. Their value resides in their discriminatory performance: do the scales enable good and bad studies to be identified, or do all studies score the same? In the first case, not everybody will agree about the scores assigned to specific studies, but a discussion about how to score a study may at least refer to commonly accepted criteria. In the latter case, the scores can be dispensed with, as they add no information. The next section illustrates use of the scales by discussing a sample of studies of 20 mph, or 30 km/h, speed zones.

6. Assessing the quality of a sample of studies

The studies presented in this section are a selection of studies only, and does not aim to include all studies that have evaluated the effects of 20 mph or 30 km/h speed zones. Studies will be discussed in chronological order.

Baguley 1982

Baguley (1982) summarises the results of evaluations of nine zones where speed humps were installed. All evaluations were before-and-after studies using collisions in local community as comparison group. For the nine zones combined, an collision reduction of 64 % was found. There was a reduction both of speed and of traffic volume. Some of the traffic was displaced to adjacent routes. In the adjacent area, an increase in the number of collisions of 6 % was found. For the treated roads and adjacent roads put together, there was an collision reduction of 4 %, showing that collision migration can reduce the overall impact considerably.

Mean speed before and after is stated for five of the nine zones. 85 percentile speed is stated for all nine zones. If mean speed is weighted by the length of the roads, and treated as representative of all zones, mean speed declined from 41.6 km/h to 24.1 km/h.

Can the contributions from reduced traffic volume and reduced speed to the decline in the number of collisions on the roads where humps were installed be identified? It is stated that the mean reduction of traffic volume was 31 %. The number of collisions is not strictly proportional to traffic volume. For injury collisions, multivariate statistical models (Høye 2014, 2016) tend to find a collision elasticity for injury collisions of around 0.9, i.e. when traffic volume increases by 1 %, the number of collisions increases by 0.9 %. However, the models rely on cross-sectional data and the relationship between changes in traffic volume and changes in the number of collisions over time is not necessarily the same as the cross-sectional relationship. Data for 20 bypass road projects in Norway (Elvik et al. 2001) indicate a collision elasticity of 0.84. If this is applied, we get:

Contribution from reduced traffic volume = $0.69^{0.84} = 0.732$

This is a collision reduction of close to 27 %. The collision reduction attributable to reduced speed would then be 50 %. The expected number of collisions in the after-period was 33. The recorded number was 12. Reduction of traffic volume contributed to a reduction from 33 to 24.1. Speed reduction explained the further reduction from 24.1 to 12 collisions. If the exponential model of the relationship between changes in speed and changes in the number of collisions is applied (Elvik 2019), this implies a coefficient of 0.04, which is the value Elvik (2019) recommends for slightly injured road users. The results are thus consistent with general knowledge about the relationship between changes in speed and changes in road safety.

The study did not control for regression to the mean, but it is stated that only three of the nine roads had an abnormally high number of collisions in the before-period. Based on this, the study is classified as having controlled quite well, but not completely for regression-to-the-mean.

Data for five years, four before and one after, were used. This is a bit too short to control for long-term trends. In Table 1 of the paper presenting the study, a set of "control-ratios" is presented. These ratios are the number of collisions in comparison group in the after-period (1 year) divided for the number of collisions in the before-period (4 years). If no trends existed, these ratios should all be close to 0.25 (1/4). They vary between 0.199 and 0.314, suggesting that trends differ and that the results reflect these differences. The study is therefore classified as having controlled for long-term trends.

In terms of methodological quality, the study scores 3 (out a maximum of 4) for control for regression-to-the-mean, 3 for control for long-term trends, and 3 for specifying the mechanisms producing effects. Total score is 9 out 10, or 0.9 on scale in the 0-1 range.

With respect to quality of presentation and plausibility of results, the study presented the number of collisions on the treated roads and adjacent roads, but not the number of collisions in the comparison groups. Although statistical weights can be estimated based on the information provided, they will not be strictly correct, as the number of collisions in the comparison groups is not included. The study is assigned a score of 3 with respect to the quality of statistical details reported.

Figure 2 of the paper presenting the study shows that the more densely humps were spaced, the lower was the mean speed midway between a pair of humps. This documents a dose-response relationship between the dose of the measure, indicated by the number and spacing of humps, and the size of the effect on speed. It was not possible to test for a dose-response relationship between changes in mean speed and changes in the number of collisions. The study scores 2 for the assessment of dose-response relationships. Total score for presentation and plausibility of results is 5 out 10. Total score for both scales is 14 out of 20, or 0.70 if the range of the scale is converted to the 0-1 interval.

Brilon and Blanke 1990

Brilon and Blanke (1990) present an evaluation of traffic calming schemes in six German cities. The evaluation was a before-and-after study using comparison group. The before-periods varied in duration from 16 months to 3 years, too short to determine long-term trends. The after-periods were equally short.

Most results are presented as changes in collision density, i.e. changes in the number of collisions per kilometre of road. Maps of the study areas are provided, but without scale. Hence, it is not known how long the streets were, and the number of collisions per kilometre cannot be converted into a total number of collisions. Stating effects per kilometre of road would make sense if the length of the streets changed, but if it did not, effects might just as well have been stated in terms of the total number of collisions.

The information given does not permit the estimation of statistical weights, except for the whole areas studied; these weights would not be relevant, as each area was divided into smaller areas with different treatments. Few details are given about the measures implemented, but one the measures was a 30 km/h speed zone. It is not clear if these zones were introduced by a speed limit sign only or included engineering measures as well. However, the classification of measures used in the paper suggests that the only measure implemented was to reduce the speed limit.

No data are provided on speed, but relying on collisions per kilometre of road, a couple of estimates of effect can be extracted from the paper. Thus for Charlottenburg, using Moabit as comparison group, the estimate of effect is (22.5/31.9)/(25.2/28.2) = 0.789, or an collision reduction of 21 %. For Buxtehude, the corresponding estimate is (5.9/5.8)/(8.7/6.9) = 0.807, or an collision reduction of 19 %. Statistical weights cannot be assigned to these estimates, but they can be compared to the results of other studies.

There is no mention of regression-to-the-mean in the paper. Presumably this means that this factor was not considered and not controlled for. Therefore, the study did not control for regression-to-the-mean, did not control for long-term trends and did not specify any mechanisms (changes in speed and /or traffic volume) generating effects. It scores 0 for methodological quality, i.e. the study is worthless as it impossible to know what caused the changes in the number of collisions.

Turning to the quality of presentation and the plausibility of results, it has already been noted that it is not possible to determine statistical weights for including the study in a meta-analysis. There are no data on speed or traffic volume or any other data permitting the assessment of dose-response relationships. The only weak hint that changes in speed may be one of the factors producing changes in the number of collisions, are Tables showing a tendency, albeit not entirely consistent, for the number of seriously injured road users to go down more than the number of slightly injured persons and in turn more than the number of property-damage-only collisions. Based on this, the study is assigned a score of 1 for the quality of presentation and the plausibility of results. The total score is 1 out 20, or 0.05 for a scale with a range from 0 to 1.

Vis, Dijkstra and Slop 1992

Vis, Dijkstra and Slop (1992) present a study evaluating 30 km/h zones in the Netherlands. 15 zones were included. All zones had physical measures, most commonly humps. Effects were evaluated by means of a before-and-after study using either all of the Netherlands or municipalities in which the 30 km/h zones were implemented as comparison groups. Changes in the 85th percentile speed were shown by means of diagrams.

Effects on collisions are shown in two Figures (Figures 11 and 12 of the paper). Only percentage changes are shown, not the number of collisions underlying the percentages. Percentages are shown for the years from 1983 to 1989, but it is not clear which years belong to the before-period and which years belong to the after-period. The number of injury collisions shows a minimum value in 1986 of a little more than 60 % of the 1983 value. The number then increased in 1987 and 1988, reaching about 80 % of the 1983 value in 1988. There is evidence of a downward trend in the number of collisions in the municipalities where the 30 km/h zones were implemented.

The paper does not explain whether the study controlled for regression-to-the-mean or long-term trends. Presumably, the study did not control for these confounding factors; it is reasonable to assume that if it had, it would have stated so explicitly. It is stated that: "Roughly speaking, the traffic intensity fell by 5 % to 30 %". It is not made clear if traffic was displaced to alternative routes, or if it was just a local decline confined to the 30 km/h zones. It must therefore be assumed that the study did not control for collision migration.

Speed data are only given as 85 percentile values, while almost all other studies provide data on mean speed. No attempt is made to relate changes in speed to changes in the number of collisions, although it is evident that the changes in speed varied substantially between zones. It would have been useful to learn whether larger declines in the number of collisions were found in zones with a large reduction in speed than in zones with a small reduction in speed.

On the whole, the study appears to be methodologically weak. It does not satisfy any of the criteria of methodological quality specified in Table 1. It therefore scores 0 for methodological quality, i.e. it is a completely worthless study in terms of its methodological rigour. We cannot know if the observed changes in the number of collisions were caused by regression-to-the-mean, long-term trends, exogenous local changes in traffic volume, collision migration, or the safety measures. The results are, in other words, completely un-interpretable.

The presentation is also very weak. None of the details needed for including the study in a meta-analysis are provided. The only weak hint of a dose-response relationship one can find in the study, is that there was a larger percentage decline in the number of injury collisions than in the total number of collisions (which presumably includes property-damage-only collisions in addition to injury collisions). This is what one would expect to find when speed goes down. The study can therefore be assigned a score of 1 with respect to presentation and plausibility of results.

The maximum total score for methodological quality and presentation and plausibility is 20 (10 + 10). This study scores 1, which on a scale ranging from 0 to 1 corresponds to a value of 0.05.

Grundy et al. 2009

Grundy et al. (2009) present a controlled interrupted time-series analysis designed to evaluate the effects on collisions of 20 mph zones in London. 385 of 399 20 mph zones established between 1991 and 2007 were included in the study.

Roads were divided into three groups: (1) Roads in 20 mph zones; (2) Roads in adjacent zones, i.e. roads within a perimeter of 150 metres from a 20 mph zone; (3) Other roads. Other roads was by far the largest group both in terms of road length and in terms of the number of injured road users. In the time-series analysis, the case groups were either the 20 mph zones or the adjacent zones. The comparison group was in both cases other roads.

The analysis relied on data for 1986-2006, meaning that the before-period was at least five years (for 20 mph zones established in 1991), but in most cases around ten years. This period is long enough to reliably determine a long-term trend, given the large annual number of injured road users on other roads (more than 20,000 per year).

No data on traffic volume are presented, but it is stated that the mean speed of traffic in the 20 mph zones was reduced from 26 mph to 17 mph. The following estimates of effect are presented (95 % confidence intervals in parentheses):

All injured road users:	-41.9 % (-36.0 %; -47.8 %)
Killed or seriously injured road users:	-46.3 % (-38.6 %; -54.1 %)
Killed road users:	-35.1 % (+1.9 %; -72.0 %)

This information can be used to estimate the standard error of each estimate of effect and determine statistical weight for inclusion in a meta-analysis. Assuming that all estimates of effect can be stated as odds ratios, which is reasonable given the fact that changes in the 20 mph zones were adjusted for changes on other roads, the statistical weight of the estimate for all injured road users can be obtained as follows:

Statistical weight (all injured road users) = $\frac{1}{\left(\frac{\ln(0.640)-\ln\,(0.522}{3.92}\right)^{2}}$

Ln (0.640) is the natural logarithm of the lower 95 % estimate of effect (36.0 %; corresponding to an odds ratio of 0.64). Ln (0.522) is the natural logarithm of the upper 95 % estimate of effect (47.8 %). Conversion to natural logarithms is needed because odds ratios in natural units have a lognormal distribution. By taking natural logarithms, the distribution becomes a standard normal distribution to which all inferential statistics can be applied. A 95 % confidence interval spans plus or minus 1.96 standard deviations; the sum is 3.92. Thus, dividing the 95 % confidence interval by 3.92 gives an estimate of the standard error. Statistical weight in meta-analysis is inversely proportional to the squared standard error (i.e. inversely proportional to variance), hence standard error is squared and its inverse value taken. The resulting statistical weight is 369.966.

Applying the same procedure, the statistical weights of the estimates of effect for killed or seriously injured road users and for killed road users were estimated to, respectively, 181.531 and 9.209. Except for the estimate of effect on the number of killed road users, these estimates are not statistically independent. The estimate for killed or seriously injured road users comprises both groups, and the estimate for all injured road users includes both killed, seriously injured and slightly injured road users.

In a meta-analysis, estimates of effect should ideally speaking be statistically independent. However, based on the statistical weights and estimates of effect, it is possible to obtain three independent estimates of effect: one for killed road users, one for seriously injured road users, and one for slightly injured road users. From the statistical weight applying to killed or seriously injured road users, one subtracts the statistical weight applying to killed road users. The resulting statistical weight applies only to seriously injured road users.

The estimate of effect for each level of injury severity is the exponential of the product of the statistical weight and the natural logarithm of the estimate of effect, divided by the statistical weight:

Estimate of effect (killed road users) = $e^{[(\ln(0.649)\cdot 9.209)/9.209]}$

The estimate of effect for killed or seriously injured road users was obtained the same way. By subtracting the product of the natural logarithm of the estimate of effect and the statistical weight of the estimate for killed road users (i.e. ln(estimate) · weight) from the same product for killed or seriously injured road users, an estimate of effect applying to seriously injured road users only was obtained. The estimate was an injury reduction of 46.8 %, slight larger than the estimate of 46.3 % reported above, as one would expect, since the estimated effect for killed road users indicated a smaller effect than for killed or seriously injured road users combined.

Repeating the procedure for slightly injured road users produced an estimate of effect of 37.3 % injury reduction, a little less than the originally reported estimate of 41.9 % for all levels of injury severity combined.

For the adjacent areas, an collision reduction of 8 % was estimated. This is after controlling for the general trend, and thus shows that safety improved more in the areas adjacent to the 20 mph zones than in London in general. It is therefore concluded that there was no collision migration to adjacent areas.

With respect to regression-to-the-mean, the models were run by removing the data for the last three, four or five years before a zone was implemented. The idea was that if there was a high number of collisions during these years, the effect estimated when including them would be larger than the effect estimated when excluding them. No evidence of such a tendency was found. Based on this, the study is classified as having controlled for regression-to-the-mean.

By reference to Table 1, the study scores 4 for control for regression-to-the mean, 3 for control for long-term trends, 1 for specifying changes in speed (but not traffic volume), and 1 for controlling for collision migration. Total score is 9 out of 10 points (0.9 on the 0-1 scale).

For quality of presentation and plausibility of results, the study scores 5 for presentation of estimates of effect referring to different levels of injury severity and providing data to estimate the statistical weights of these estimates of effect. The adjusted estimates of effect, see above, was 35.1 % reduction of fatalities, 46.8 % reduction of seriously injured road users, and 37.3 % reduction of slightly injured road users. The plausibility of these findings can be assessed by reference to the exponential model of the relationship between speed and traffic injury recommended by Elvik (2019). The recommended values of the coefficients of that model are 0.08 for fatal injury, 0.06 for serious injury and 0.04 for slight injury. The coefficients refer to speed stated in kilometres per hour.

Applying these coefficients, and converting the change in speed to kilometres per hour, reductions of 68.6 % in fatal injury, 58.1 % in serious injury and 44.0 % in slight injury is predicted. The estimated reductions are in all cases smaller than these values. However, the reduction in serious injury is consistent with a coefficient of about 0.043. The reduction in the number of slightly injured road users is consistent with a coefficient of about 0.032. Both these values are within the range of values found in the literature.

The study scores 3 for dose-response pattern, for a total of 8 for presentation and plausibility of results. Total score is 17 out of 20, or 0.85 on the 0-1 scale.

Bornioli et al. 2019

Bornioli, Bray, Pilkington and Parkin (2019) present an evaluation of 20 mph speed limits in Bristol. The speed limit was introduced between 2010 and 2015 in seven stages. The before-periods vary in length from 34 months to 93 months, but are at least 72 month for six of the seven stages of introducing the speed limit. This period is long enough to determine a long-term trend. The after-periods vary in length between 15 months and 74 months.

A negative binomial regression model was fitted in order to estimate the effects on traffic injury of the 20 mph speed limit. The speed limit was introduced by traffic signs only; there were no engineering measures. For the 20 mph speed limit zones, a decline in fatal injury of 35 %, a decline in serious injury of 16 % and a decline in slight injury of 9 % was found. The mean speed of traffic was reduced from 27.1 to 22.5 miles per hour (43.6 to 36.2 kilometres per hour).

The paper states that regression-to-the-mean was not considered an issue, as the new speed limit was introduced on the majority of the city's roads, not just on those that had a bad collision record. This is a relevant point. In support of it, the data show no relationship between when a 20 mph speed limit was introduced and its effect on injuries. Had collision history been a criterion for selecting where first to introduce the speed limit, one would have expected to see a larger decline in injuries in the first 20 mph speed limit zones than in the zones that were the last to get this speed limit. The study is therefore classified as controlling for regression-to-the-mean and long-term trends.

Changes in speed are stated, but not changes in traffic volume. Collision migration is, like regression-to-the-mean, unlikely to be an issue, since the 20 mph speed limit was introduced on most roads in Bristol, reducing the availability of alternative routes with a higher speed limit. Moreover, data show that speed was reduced even on roads that retained a speed limit of 30 mph.

Nevertheless, the absence of detailed data regarding traffic volume and collision migration means that the study cannot be assigned the top score for specifying the mechanism producing the effects, but is assigned a score of 2. Total score for methodological quality is 9 out of 10, or 0.9 on the 0-1 scale.

Confidence intervals are provided for all estimated effects, permitting statistical weights to be computed. The confidence intervals show that the changes in the number of injured road users are far from statistically significant. This is not unusual in road safety evaluation studies, and is one reason why formally synthesising studies by means of meta-analysis is useful, as it increases statistical power to detect small effects.

The study provides estimates of effect for three levels of injury severity and statistical weights can assigned to these estimates. The study therefore scores 5 for presentation of details needed for inclusion in meta-analysis.

Changes in the number of injured road users show a pattern consistent with lower speed, i.e. the largest reduction in fatalities, a smaller reduction in serious injury and a still smaller reduction in slight injury. Applying the coefficients of 0.08 (fatal), 0.06 (serious), and 0.04 (slight) of the exponential model (Elvik 2019), predicted effects are 45 % reduction of fatalities, 36 % reduction of serious injuries and 26 % reduction of slight injuries. The observed reductions were smaller and are consistent with coefficients of, respectively, 0.058, 0.023 and 0.013. This indicates, like the study by Grundy et al. (2009), a weaker relationship between speed and traffic injury at low speeds than at high speeds.

Overall, the study scores 8 out of 10 points for presentation and plausibility of results. Total score is 9 +8 = 17 out of 20, or 0.85 on the 0-1 scale.

Fridman et al. 2020

Fridman et al. (2020) present an evaluation of the effects on pedestrian-motor vehicle collisions of lowering the speed limit from 40 to 30 kilometres per hour in parts of Toronto, Ontario, Canada. Streets in Toronto that retained the 40 km/h speed limit were used as comparison group.

Poisson regression was used to estimate the effects of the speed limit reduction. Key results are presented in Table 3.

TABLE 3: RESULTS OF EVALUATION OF 30 KM/H SPEED LIMIT IN TORONTO (FRIDMAN ET AL. TABLE 1)

Group	Period	Collisions	Km-months	Collisions per 100 km-months	Adjusted incidence rate ratio	Crude incidence rate ratio
Test	Before	245	12286	1.994		
	After	137	9600	1.427	0.72	0.72
Comparison	Before	151	10428	1.448		
	After	141	10437	1.351	0.93	0.93

The adjusted incidence rate ratio is the number of collisions per kilometre per month adjusted for seasonal effects. As can be seen from Table 3, this adjustment had no effect on the incidence rate ratios, as the crude (non-adjusted) values are identical to the adjusted values.

The function of a comparison group is normally to indicate "what would otherwise have happened", i.e. the changes in the number of collisions that would have been expected to occur if the safety measure had not been introduced. However, in this study, the comparison group is not used for this purpose. Had it been, the best estimate of effect would have been:

Estimate of effect = (1.427/1.994)/(1.351/1.448) = 0.767

This is the ordinary odds ratio estimate of effect, indicating an collision reduction of 23 %. The statistical weight assigned to it would be (for the logarithm of the odds ratio):

Statistical weight = $\frac{1}{\left(\frac{1}{245}+\frac{1}{137}+\frac{1}{151}+\frac{1}{141}\right)}$

The statistical weight is 39.848.

However, the paper by Fridman et al. (2020) provides confidence intervals for the incidence rate ratios. Can statistical weights, comparable to the log odds inverse variance statistical weight estimated above be derived from these confidence intervals?

The standard error of each adjusted incidence rate ratio was estimated from the confidence interval. To obtain the standard error of the odds ratio estimator of effect, the following approximation was applied:

Standard error of odds ratio estimator of effect = $\sqrt{SE_T^2 + SE_C^2}$

SE_T^2 is the squared standard error of the adjusted incidence rate ratio for the test group and

SE_C^2 is the squared standard error of the adjusted incidence rate ratio for the comparison group.

The statistical weight for the odds ratio estimator of effect was estimated to 29.577, which is slightly less than the above estimate (39.848), but in the same order of magnitude. Thus, the odds ratio estimate of effect is 0.767 with a statistical weight of 29.577.

Similar estimates of effect were obtained for slight and serious pedestrian injury. For slight injury, the odds ratio estimate of effect was 0.757, or 24 % reduction of the number of slightly injured pedestrians. Statistical weight was 24.901. For serious injury, the odds ratio estimate if effect was 0.478, or 52 % reduction of the number of seriously injured pedestrians. Statistical weight was 2.999.

The study relied on data for two years before and two years after introduction of the 30 km/h speed limit. As these data span the period from 2013 to 2018 (six years), the study is classified as controlling for long-term trends. Regression-to-the-mean is not mentioned, and the study has apparently not controlled for it. The fact that the number of injured pedestrian per kilometre per month in before-period was higher on streets where the speed limit was reduced (1.994) than on streets where the speed limit was not reduced (1.448) suggests that that estimates of effect can be confounded by the lack of control for regression-to-the-mean.

The study did not provide data on changes in speed or traffic volume, but the fact that there was a larger reduction in the number of seriously injured pedestrians than in the number of slightly injured pedestrians is consistent with a reduction of speed. The study is assigned a score of 4 for methodological quality (0.4 on the 0-1 scale).

As for the quality of presentation and plausibility of results, the study stated effects for two levels of injury severity, and it was possible to estimate statistical weights associated with these estimates. Furthermore, the difference in the size of the effect between serious and slight injuries is consistent with a reduction of speed. The study is assigned a score of 6 for quality of presentation and plausibility of results. Total score is 10 out of 20, or 0.50 on the scale ranging from 0 to 1.

7. Discussion and conclusions

Controlling for at least the most important known potential confounding factors in before-and-after studies evaluating the effects of road safety measures is an essential requirement for concluding that the changes in the number of collisions, number of injured road users or severity of injuries were caused mainly by the road safety measure and not by something else. No observational study can control for all potential confounding factors, but if it at least controls for those that have been found to seriously bias study findings, one may at least provisionally conclude that the results mainly reflect the effects of the road safety measure.

However, any conclusion is provisional and may be overturned by subsequent developments in study methodology. When the first studies evaluating low speed zones and humps were made, the statistical techniques currently used to control for regression-to-the-mean had not been developed. Most of these studies therefore made no attempt to control for regression-to-the-mean. It may seem unfair to reject these studies because they did not use statistical methods that did not exist when the studies were made, but it is in the nature of scientific progress that when better methods become available, older studies must be rejected. Nobody would try to diagnose or treat an illness today using the knowledge and apparatus that was available in 1950.

The Empirical Bayes method for road safety estimation was developed during the period from 1980 to 1997. The most complete presentation of it is the 1997-book by Ezra Hauer (1997). Although the Empirical Bayes method remains widely used, one should obviously not rule out the possibility that better methods for road safety estimation will be developed, and that studies currently regarded as acceptable will be regarded as naïve or imprecise and come to be rejected.

Formal syntheses of studies by means of meta-analysis is useful when there are many studies dealing with a topic. There are many studies dealing with low speed limits. Only a few of them have been discussed in this paper, mainly for the purpose of explaining how studies can be assessed for methodological quality and the quality in presentation. Assessing studies in terms of these characteristics is useful if studies are found to vary in quality. This was clearly the case for the sample of studies used in this paper. The overall quality score, within a range from 0 to 1, varied between 0.05 and 0.85.

In general, if a study provides enough information to be included in a meta-analysis, it should be included, even if its quality score is low. Any cutoff point on a numerical scale for study quality is arbitrary; it is bad enough that a numerical scale for study quality is itself arbitrary. It would add insult to injury if, on top of introducing an arbitrary scale, one would add an arbitrary cutoff value on that scale.

The use of quality scoring is mainly for sensitivity analysis. If summary estimates of effect in a meta-analysis are strongly related to quality scores, it tells us that we should only rely on the results of the best studies. But what if there is no agreement on study quality, and some regard study A as quite good and others regard it as quite bad. Well, one of the advantages of proposing an admittedly arbitrary scoring system for study quality, is that it may facilitate a discussion about study quality. Not everybody may agree with the scales proposed in this paper. No problem. Let them propose their own scales. And let us compare how studies score according to the different scales.

It would be surprising if the items included in the scales proposed in this paper are not widely supported. Surely, everybody agrees that controlling for confounding factors is important. Surely, it is widely accepted that finding a dose-response relationship strengthens causal inference. However, the points assigned to the items are clearly more open to discussion. Again, however, it is easy to change the scores, e.g. assign 2 points rather than 4 for controlling for regression-to-the-mean and then see what happens.

Close-up reading of papers and careful attention to details in them is needed to assess study quality. Unfortunately, many papers do not state explicitly whether, for example, the study controlled for regression-to-the-mean. In such cases, my recommendation is that one should never give studies the benefit of doubt. If regression-to-the-mean is not mentioned, then most probably the authors of the study are unaware of the phenomenon, or, if aware of it, completely in the dark about how to control for it. There are many ways of controlling for regression-to-the-mean. One does not have to apply the Empirical Bayes method. Even in cases where the Empirical Bayes method cannot be applied, a creative researcher ought in many cases to be able to control for regression-to-the-mean in other ways.

8. References

Baguley, C. 1982. Evaluation of the safety of speed control humps. In: Seminar on short-term and area-wide evaluation of safety measures. Proceedings, 246-250. SWOV Institute for Road Safety research.

Bornioli, A., Bray, I., Pilkington, P., Parkin, P. 2019. Effects of city-wide 20 mph (30 km/hour) speed limits on road injuries in Bristol, UK. Injury Prevention, 2019-043305.

Brilon, W., Blanke, H. 1990. Traffic safety effects from traffic calming. Proceedings of road safety and traffic environment in Europe, Gothenburg, Sweden, September 26-28, 1990, 134-148. VTI Report 363A. Linköping, Väg- och Trafikinstitutet.

Elvik, R. 1997. Evaluation of road collision blackspot treatment: a case of the Iron Law of evaluation studies? Collision Analysis and Prevention, 29, 191-199.

Elvik, R., Amundsen, F. H., Hofset, F. 2001. Road safety effects of bypasses. Transportation Research Record, 1758, 13-20.

Elvik, R. 2018. How can the notion of optimal speed limits best be applied in urban areas? Transport Policy, 68, 170-177.

Elvik, R. 2019. A comprehensive and unified framework for analysing the effects on injuries of measures influencing speed. Collision Analysis and Prevention, 125, 63-69.

Fridman, L., Ling, R., Rothman, L., Cloutier, M. S., Macarthur, C, Hagel, B., Howard, A. 2020. Effect of reducing the posted speed limit to 30 km per hour on pedestrian motor vehicle collisions in Toronto, Canada – a quasi-experimental, pre-post study. BMC Public Health, 20:56.

Greenland, S. 1994. Invited commentary: A critical look at some popular meta-analytic methods. American Journal of Epidemiology, 140, 290-296, 300-302.

Grundy, C., Steinbach, R., Edwards, P., Green, J., Armstrong, B., Wilkinson, P. 2009. Effect of 20 mph traffic speed zones on road injuries in London, 1986-2006: controlled interrupted time-series analysis. BMJ Research, 339, b4469.

Hauer, E. 1997. Observational before-after studies in road safety. Oxford, Pergamon Press (Elsevier Science).

Høye, A. 2014. Utvikling av ulykkesmodeller for ulykker på riks- og fylkesvegnettet i Norge. Rapport 1323. Oslo, Transportøkonomisk institutt.

Høye, A. 2016. Utvikling av ulykkesmodeller for ulykker på riks- og fylkesvegnettet i Norge (2010-2015). Rapport 1522. Oslo, Transportøkonomisk institutt.

Rosenthal, R. 1991. Meta-Analytic Procedures for Social Research. Applied Social Research Methods Series Volume 6. Newbury Park, Ca, Sage Publications.

Vis, A. A., Dijkstra, A., Slop, M. 1992. Safety effect of 30 km/h zones in the Netherlands. Collision Analysis and Prevention, 24, 75-86.

Webster, D. C., Mackie, A. M. 1996. Review of traffic calming schemes in 20 mph zones. TRL Report 215. Crowthorne, Berkshire, Transport Research Laboratory.

LUSTRE

Lower urban speed limits in Europe. What does the evidence show?

Appendix Two: Meta-analysis of the effect of 20mph speed limits in the UK

Work Package	WP3. Systematic review and meta-analysis
Authors	A. Theofilatos, M. Quddus, M Feng, R Elvik
Acknowledgment	This project received funding from The Road Safety Trust.

Version	Final
Date of Submission	04/03/2021

Contents

1 Summary

Studies of the effectiveness of 20 mph speed limits in the UK vary by their contexts, analysis methods/data, study quality, built environments (urban vs rural), types of scheme (with physical measures and enforcement, sign only) and types of impact (collisions, casualties and speed changes). The overall impact of the effectiveness of 20 mph speed limit needs to be generalized, especially for the schemes with sign only. However, this is challenging as the quality of the studies vary significantly. Therefore, the aim of this report is to provide insights and evidence on the safety impacts of 20mph speed limits in the UK (driven speeds, collisions, and casualties). Consequently, a *meta-analysis* was applied to systematically evaluate the findings and evidence by generating a weighted overall mean effect.

Literature indicates that high quality studies should be employed as input to the meta-analyses. Such studies are however limited in the UK as studies conducted by Local Authorities (LAs) do not usually control for confounders such as: (i) regression-to-the-mean, (ii) long-terms trends in the number of collisions or casualties and (iii) changes in traffic volume. The mean score of the study quality is 0.49 on a scale of 0 to 1. Given the importance of this topic and the need to estimate quantitative evidence, all studies were considered for potential meta-analyses, regardless of their quality. The final analysis was based on 24 studies and 224 estimates of effects.

Three methods of meta-analysis were employed: (i) fixed-effects model, (ii) random-effects model and (iii) multi-level models. In addition, a meta-regression model was developed. Although the studies are methodologically weak, these provide some knowledge about the effects of 20 mph speed limits. The impact of 20mph speed limit reductions was estimated by considering reported injury-collisions, casualties, and speed changes. Although the primary interest was to estimate the impact of 20 mph speed limit without physical measures (i.e. sign only), for comparison purposes we estimated the impact for: (i) all schemes (with and without physical measures), (ii) schemes without physical measure (sign only) and (iii) schemes with physical measures.

The results indicate that the introduction of 20mph speed limits (**sign only**) was found to reduce mean speed by **1.76 mph.** For schemes with the with physical measures the mean speed reduced by 5.6 mph.

The introduction of 20mph speed limits (for all schemes – those with and without physical measures and enforcement) reduced traffic collisions involving personal injury by **26.45%** on average. For sign only schemes (without physical measures) this is **21.6%.**

In terms of the number of casualties, the introduction of a 20 mph speed limit resulted in a reduction of 22.9% (all severities) for all schemes (those with and without physical measures and enforcement). For the **sign only** schemes this was **10.9%**.

As anticipated, it can therefore be concluded that there is a greater reduction in the number of collisions and casualties from the introduction of a 20 mph speed limit which incorporates physical measures than when it has no physical measures (i.e. sign only).

The results are also consistent with existing studies. For instance, Elvik (2020) found that studies of speed humps resulted in a mean reduction of the number of injury collisions by 30% which is not significantly different from the 26% collision reduction (for the schemes with physical measures) found in this study. Since the sample size for some estimates are low, the findings should be interpreted with care.

2 Introduction

2.1. State of the problem

As shown in LUSTRE Deliverable 3.1 (assessment of study quality by Dr Elvik), key findings and evidence from a number of studies on the effectiveness of 20 mph speed limits in the UK differ significantly due to their heterogeneous contexts, scope, data availability, operational environments, types of scheme (e.g. 20 mph with traffic calming measures, 20 mph with sign only) and types of impact (e.g. speed, collision, traffic volume). Therefore, it is essential that the overall impact of the effectiveness of 20 mph speed limit is generalized but this is challenging as the quality of the studies vary significantly (see Deliverable 3.1). However, a *meta-analysis* is applied to systematically evaluate the findings and evidence by generating a weighted overall mean effect by operational environment and to identify the sources of systematic variation in individual results. This Deliverable reports the findings of meta-analysis on the impact of 20mph speed limit on both traffic collisions and personal injuries.

2.2. Aim of deliverable

The aim of this deliverable is to **provide insights and evidence on the safety impacts of the introduction of 20mph speed limits in the UK, particularly those without significant physical measures**. For that reason:

- A **systematic review** of UK relevant studies and reports was carried out and studies were coded (Deliverable 3.1)
- The **methodological framework** has been developed
- A **meta-analysis** on the effect of 20mph limits on **speed reduction** was conducted
- A **meta-analysis** on the effect of 20mph limits on **reported collisions involving injury** was conducted
- A **meta-analysis** on the effect of 20mph limits on **personal casualties** was conducted
- **Meta-regression analyses** were carried out where possible
- The **overall impact of 20mph** limits (with and without physical measures) is **evaluated** and **discussed.**

3 Materials and Methods

3.1. Data collection and pre-processing

In order to carry out the meta-analyses in the present deliverable, the scientific papers and reports on the impact on lower speed limits in the UK (see Deliverable 3.1) were utilised. Those studies were retrieved by means of a **systematic literature survey**. In Deliverable 3.1, these studies were discussed, evaluated, and rated according to their scientific and methodological quality and validity. Additional studies and reports were added where appropriate. These studies provide the basis for our subsequent analyses in Deliverable 3.2.

Ideally, only high-quality journal papers and scientific reports achieving a '*high*' score according to the project criteria (Elvik, 2020), should be employed as input to the meta-analyses. Such studies are, however, limited. Given the importance of this topic and the need to estimate quantitative evidence, **all studies were considered** for potential meta-analyses, regardless of their quality.

All relevant studies were scrutinised and coded to initially acquire the following information:

- Study ID
- Authors, Year
- County, specific location
- Presence of physical measures and/or enforcement
- Potential control for Regression-to-the-mean (RTM), trend and/or collision migration
- Period before & after the introduction
- Collision/collision or injury
- Collision numbers before & after for the control group as well as for potential comparison groups
- Level of severity
- Speeds before & after
- Traffic flows before & after

Figure 1 provides an example of the raw database[1]. In order to prepare the dataset for the meta-analyses, **additional processing** was required. The detailed steps and work carried out are presented in section *"3.2 Methodological framework"*. **A total of 24 studies/reports were finally utilised**.

[1] A full copy was uploaded on the project's respective OneDrive folder.

Study	Type	Year	Score	First Author	ID	County	Enforcement	Physical measures	Control for RTM	Control for trend	Control for migration	Period before (year)	Period after (year)	Location	Variable	Severity	before (total)_case	after (total)_case
1	report	2019	0.5	Byrne	1	Cheshire	no	no	no	no	no	3	1	residential roads, 36 schemes (year 1) + 31 schemes (year 2)	collision	total	175	28
1	report	2019	0.5	Byrne	2	Cheshire	no	no	no	no	no	3	1	residential roads, 36 schemes (year 1) + 31 schemes (year 2)	collision	fatal_serious	19	5
1	report	2019	0.5	Byrne	3	Cheshire	no	no	no	no	no	3	1	residential roads, 36 schemes (year 1) + 31 schemes (year 2)	collision	slight	156	23
1	report	2019	0.5	Byrne	4	Cheshire	no	no	no	no	no	3	1	residential roads, 36 schemes introduced in year 1	collision	total	121	14
1	report	2019	0.5	Byrne	5	Cheshire	no	no	no	no	no	3	1	residential roads, 36 schemes introduced in year 1	collision	fatal_serious	15	3
1	report	2019	0.5	Byrne	6	Cheshire	no	no	no	no	no	3	1	residential roads, 36 schemes introduced in year 1	collision	slight	106	11
1	report	2019	0.5	Byrne	7	Cheshire	no	no	no	no	no	3	1	residential roads, 31 schemes introduced in year 2	collision	total	54	14
1	report	2019	0.5	Byrne	8	Cheshire	no	no	no	no	no	3	1	residential roads, 31 schemes introduced in year 2	collision	fatal_serious	4	2
1	report	2019	0.5	Byrne	9	Cheshire	no	no	no	no	no	3	1		collision	slight	50	12
2	report	2010	0.6	Fisher	11	Warrington	yes	no	no	yes	yes	1.5	1.5	Orford - residential	collision	total	**28.2**	**17**
2	report	2010	0.6	Fisher	13	Warrington	yes	no	no	yes	yes	1.5	1.5	Orford - residential	collision	serious	**3.5**	**2**
2	report	2010	0.6	Fisher	14	Warrington	yes	no	no	yes	yes	1.5	1.5	Orford - residential	collision	slight	**24.6**	**15**
2	report	2010	0.6	Fisher	15	Warrington	yes	no	no	yes	yes	1.5	1.5	Park Road - residential	collision	total	**4.4**	**2**
2	report	2010	0.6	Fisher	18	Warrington	yes	no	no	yes	yes	1.5	1.5	Park Road - residential	collision	slight	**4.4**	**2**
2	report	2010	0.6	Fisher	19	Warrington	yes	no	no	yes	yes	1.5	1.5	Town Centre	collision	total	**21.1**	**21**

Figure 1. Example of an excerpt of the coded raw dataset used in this deliverable.

3.2. Methodological framework

3.2.1 Estimating safety effects

Before presenting the methodological framework, it is important to introduce the main method used for analysing the safety impacts of 20mph. Each of the studies in our database contained one or more estimates of the effects on collisions and/or personal injuries. It is worthwhile to note that collisions associated with 'property damage only' are not available for including in the analysis. These estimates of the effect were combined by means of the **log-odds method of meta-analysis** (e.g. Fleiss, 1981; Elvik, 2003), as it being the common method to analyse the effects employed in the before & after studies. This method is based on the assumption that each estimate of effect is stated in terms of an **odds ratio**. This is the case when before-and-after studies use a comparison group. Hence, the effects on safety in the before-and-after studies using a comparison group are normally estimated in terms of the following odds ratio:

$$Estimate\ of\ effect = \frac{\dfrac{Number\ of\ accidents\ after\ the\ measure\ (a)}{Number\ of\ accidents\ before\ the\ measure\ (b)}}{\dfrac{Number\ of\ accidents\ in\ comparison\ group\ after\ the\ measure\ (c)}{Number\ of\ accidents\ in\ comparison\ group\ before\ the\ measure\ (d)}} \quad \text{(Equation 1)}$$

$$Variance\ of\ effect = \frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d} \qquad \text{(Equation 2)}$$

where, a, b, c and d, are the four respective numbers entered in Equation 1. This variance of effect is the variance of the logarithm (vi) of the odds ratio. However, few studies have evaluated the effects of the 20mph limits by using a comparison group. A significant number of studies are basically simple before-and-after studies, which do not include a comparison group. In such cases, Equation 2 drops out numbers c and d. In total, twenty-four (24) studies and more than 260 effects (for collisions, injuries and speed) were retrieved. This means that effects nested within studies, which may indicate some correlation between the effects from the same study (i.e. within-cluster correlation). On the other hand, there might be a variation between effects from different studies/area (i.e. between-cluster variation). Therefore, a statistical model may be needed to jointly control both within- and between-cluster variations (e.g. a multilevel model).

3.2.2 General framework for safety impacts of 20mph limits

In order to carry out the meta-analyses for evaluating the impacts on collisions and injuries, the following general steps were followed. The steps are summarised in Figure 2.

Step 1: Literature search and study classification. This step was previously carried out for in Deliverable 3.1 of the LUSTRE project.

Step 2: Study coding and information extraction. See section 3.1 as presented earlier in this document.

Step 3: Adjust collision numbers for unequal before-after year. A common case was where a study periods (before & after the intervention) were unequal. To overcome this issue, collisions/injury frequencies were extrapolated to acquire equal durations, by using a 'ratio of durations' as defined by Hauer (1997), used in the development of crash modification factors in the Highway Safety Manual (Bahar, 2010) and a recent paper by Manuel et al. (2020).

According to Manuel et al. (2020), the ratio of durations is simply the ratio of the 'after' period to the 'before' period. In this case, Ra(i) is the duration of the after period of study i, whilst Rb(i) is the duration of the before period of study i.

$$r(i) = \frac{Ra(i)}{Rb(i)} \qquad \text{(Equation 3)}$$

Afterwards, the before estimate is adjusted ($B_{adj,i}$) as shown in equation (4) where Bi is the "original" collision frequency during the before study period in the treatment group.

$$B_{adj,i} = Bi * r(i) \qquad \text{(Equation 4)}$$

Step 4: Remove observations with zero collisions within the before and after periods. Estimates showing zero frequencies both for the before and after periods were not meaningful and were removed from the analysis.

Step 5: Treating observations with and without zeros. When there are non-zero collisions either before or after the implementation of the safety measure, the method to calculate the overall estimates is straightforward. In this case, the approach is to calculate the estimate and the variance according to section *"3.2.1 Estimating study safety effects"*.

However, when observations included zero collisions/injuries either the before or the after period, but no comparison group was considered, then 0.5 was added to all before and after collision/injury numbers (Elvik, 2003). Lastly, when a zero frequency was present and also a comparison group was existed, then the approach was to:

a) Exclude this observation initially
b) Calculate estimate and variance for all other observations
c) Run meta-analysis to obtain an initial estimate
d) Correct zeros by using the continuity correction method (Elvik, 2013)
e) Re-run the meta-analysis to achieve the final estimate by using the correction factors produced by the continuity correction method (Elvik, 2013)

Step 6: Final meta-analyses. Run and/or re-run meta-analyses (see previous steps) to obtain the final estimates.

Step 7: Potential meta-regression. When the number of observations were sufficient (~ at least 10 observations per variable), a meta-regression was conducted. More details on the respective section describing meta-regression is provided in Section 3.3.3.

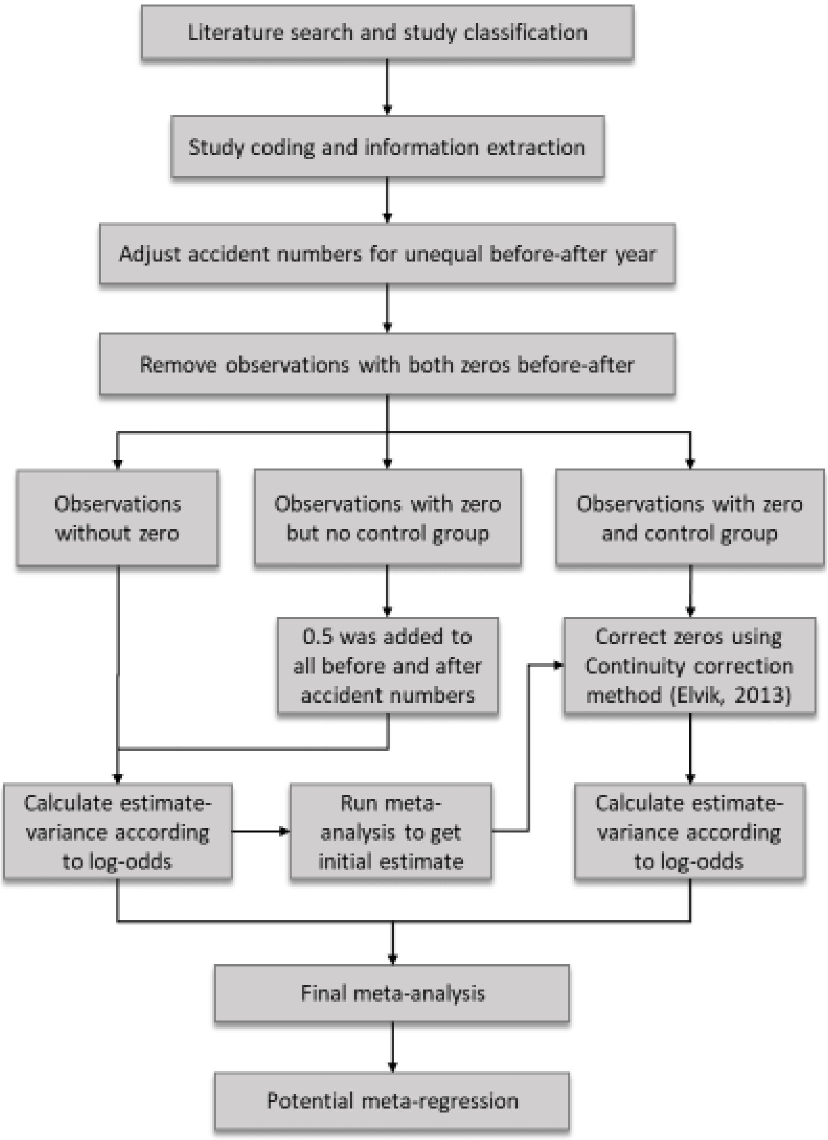


Figure 2. General methodological framework.

3.2.3 Data processing for the impact of 20mph on speed reductions

Although the main purpose is to investigate the impacts of 20mph limits on collisions and injuries, the impact on mean speeds was also examined in this deliverable. (If speeds do not reduce as a result of a limit change, it seems unlikely that collisions or casualties would change. The framework for this approach was different from the main framework for collisions.

The method used for this analysis was the **Mean Difference (MD) meta-analysis**. To perform this method, the mean value of speeds before, as well as the mean value of speeds after the implementation of the measure, across the various locations of the study, were calculated. Similarly, standard deviations (s.d.) were extracted. It is, however, noted that only a handful of studies were the candidates for this analysis. In addition, a number of assumptions were made when a study included only a single effect. Hence, the interpretation of the findings should be carefully interpreted.

3.3. Meta-analysis background

3.3.1 Fixed and random effects meta-analysis

A meta-analysis is a method of analysis of numerical research results of studies aiming to develop a weighted overall mean result and identify the sources of potential systematic variation in individual results. More details on the theoretical background can be found in several papers (e.g. Elvik and Bjornskau, 2017; Hedges and Olkin, 1985; Berkey et al., 1995; Van Houwelingen et al., 2002; Viechtbauer, 2016). The readers are referred to Elvik (2005) and Elvik (2011) for a comprehensive overview of meta-analyses when studies are few. The following information has been largely based on the aforementioned studies by Elvik and Theofilatos et al. (2017; 2018).

The summary estimate (of risk or effect) based on *n* individual estimates is:

Summary mean = $\bar{Y} = \frac{\sum_{i=1}^{n} Y_i \cdot w_i}{\sum_{I=1}^{n} w_i}$ (Equation 5)

where $\bar{Y}$ is the estimate of the weighted summary mean, based on *n* individual estimates, each of which is assigned a statistical weight equals to the inverse variance *vi*:

Statistical weight = $W = \frac{1}{vi}$ (Equation 6)

The most common approach is to use a fixed effects meta-analysis. However, variability (or heterogeneity) can be present among true effects. In such cases, one solution is to apply a random effect model to account for potential heterogeneity.

In fixed effects meta-analyses, if i=1,…,n independent effect size estimates, each is estimating a corresponding true effect size.

$y_i = \theta_i + \varepsilon_i,$ (Equation 7)

where y_i is the observed effect in the i-th study, ϑ_i is the corresponding (unknown) true effect, εi is the sampling error (ε_i~N(0,vi)). As a result, all the y_i's are assumed to be unbiased and normally distributed estimates of their corresponding true effects. However, variability (or heterogeneity) can be present among true effects.

On the other hand, the random effect model can be considered as an extension of the simple fixed effect model in a sense that it can account for potential heterogeneity. In this case, the true effect θ_i is:

$$\theta_i = \mu + u_i, \qquad \text{(Equation 8)}$$

where u_i follows a normal distribution with mean value μ and variance τ^2. If τ^2 equals zero, then the true effects are assumed to be homogenous (i.e. θ_1=θ_2=…θ_n=0).

To determine whether there is systematic between-study variation in results, the Q statistical test is performed. Q is defined as:

$$Q = \sum_{i=1}^{g} W_i \cdot Y_i^2 - \frac{\left(\sum_{i=1}^{n} W_i \cdot Y_i\right)^2}{\sum_{i=1}^{n} W_i} \qquad \text{(Equation 9)}$$

Where Q is an estimate of variance, chi-square distributed with n – 1 degrees of freedom. If the value of Q is statistically significant, then the variance between studies is larger than would be expected on the basis of the within-study variation.

For a typical random-effects meta-analysis model, the I^2 statistic is estimated as:

$$I^2 = 100\% * \frac{\hat{\tau}^2}{\hat{\tau}^2 + \tilde{u}} \qquad \text{(Equation 10)}$$

Where $\hat{\tau}^2$ was defined earlier and:

$$\tilde{u} = \frac{(k-1) * \sum w_i}{(\sum w_i)^2 - \sum {w_i}^2} \qquad \text{(Equation 11)}$$

3.3.2. Funnel plots and publication bias

A funnel plot is a very useful tool used to visualize results of exploratory meta-analyses (Elvik and Bjørnskau, 2017) in which the estimate of interest is plotted on the horizontal axis, while the standard error or the variance is plotted on the vertical axis. In addition, funnel plots are helpful to detect publication bias (Elvik and Bjørnskau, 2017). In general, if studies with non-significant or small effect are not published, an asymmetric funnel plot are generated (Sterne and Egger, 2001; Rothstein et al., 2005).

In this deliverable, funnel plot asymmetry was detected via the regression test proposed by Egger et al. (1997) as well as the Rank correlation test (Begg and Mazumdar, 1994). When publication bias is detected then, the trim-and-fill method will be applied (Duval and Tweedie, 2000a & 2000b).

3.3.1 Multi-level meta-analysis

Multilevel structures arise when the estimates can be grouped together based on some higher-level clustering variable (Metafor, 2020). In that case, *"true effects belonging to the same group may be more similar to each other than true effects for different groups"*. Consequently, multilevel meta-analysis models can be used to account for the between- and within-group heterogeneity and hence the intra-group (or intra-class) correlation in the true effects. For more details, the readers referred to Konstantopoulos (2011) and Metafor (2020) for a detailed illustration of such model, as generally, the approach is similar to classic multi-level statistical models when there are, for example, repeated measures.

3.3.3 Meta-regression

Lastly, another way to deal with potential heterogeneity is to carry out a meta-regression. In this case, the moderators, (i.e. study characteristics such as Year, location, method, etc.) are included in the model and may account for heterogeneity in the true effects

In this case, the model is:

$$\theta_i = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_{ik} + u_i \qquad \text{(Equation 12)}$$

Where x_{ij} is the value of *j-th* moderator variable in the *i-th* study. Ui is assumed to follow a normal distribution with mean value μ and variance τ^2. In meta-regression models, τ^2 is the amount of residual heterogeneity among the true effects (i.e. the variability among the true effect that cannot be explained by the moderators entered in the meta-regression model).

Meta-regressions although are useful in providing insights on how individual study results influence the overall estimate, they are meaningful when there are at least ten (10) observations for each moderator (independent variable). Consequently, this method was not widely applied in our dataset, but only when this was possible.

3.4. Qualitative evaluation of the measure

After the required meta-analyses, a final qualitative indicator was extracted so as to evaluate the overall effectiveness of the 20mph limits. This colour-code qualitative indicator was based on the concept developed in the SafetyCube project (https://www.safetycube-project.eu/). The colour-code for the effectiveness of the 20mph measure was classified as follows:

- **Green.** Effective
- **Light green.** Probably effective
- **Grey.** Unclear effect
- **Red.** Probably risky

The following table was extracted from SafetyCube Deliverable 3.3 *"Methodological framework for the evaluation of road safety measures"* (Martensen and Lassarre, 2017) and provides the classification criteria of the countermeasure:

Countermeasure	
Green	Results consistently show that the countermeasure reduces road safety risk.
Light green	There is some indication that the counter measure reduces road safety risk, but results are not consistent.
Grey	No conclusion possible because of few studies with inconsistent results, or few studies with weak indicators, or an equal amount of studies with no (or opposite) effect.
Red	Results consistently show that this measure does NOT reduce road safety risk and may even increase it.

Table 1. Effectiveness classification criteria (Source: SafetyCube Deliverable 3.3 "Methodological framework for the evaluation of road safety measures").

4 Results

4.1. Impact of 20mph speed limits on collisions

To estimate the impact of the introduction of 20mph speed limits on reported injury collision frequencies, the log-odds meta-analysis method was implemented. The following sub-sections provide an illustration of the main findings of the analyses. Initially, all studies and observations were considered, including the studies that introduced physical measures and enforcements alongside the 20mph speed limits implementation. Afterwards, separate meta-analyses were carried out, which considered only the studies without physical measures or enforcement (i.e. 20mph speed limit sign only).

In order to address potential correlation among multiple observations within the same study, a random effects multi-level meta-analysis was firstly carried out and an additional amount of variance (i.e. an additional variance component) was produced. However, in cases when the goodness-of-fit measures (AIC, BIC) of the fixed effect specification were better, and/or when the Q-statistic for heterogeneity was not significant, the fixed effects model was retained.

The findings from the meta-analysis are categorised and presented as follows:

- Impact of 20mph limits on speed reduction (**sign only**)
  - all settings (with physical measures/enforcement & sign only)
  - sign only
- Impact of 20mph limits on collisions by type
  - all settings (with physical measures/enforcement & sign only)
  - sign only
- Impact of 20mph limits on casualties by type
  - all settings (with physical measures/enforcement & sign only)
  - sign only

4.1.1 Total number of collisions (all settings)

A meta-analysis as presented in Section 3 was applied to quantify the mean effect of 20 mph speed limits. A total of 38 estimates related to total number of reported injury collisions were available. Results of the fixed effects meta-analysis indicate that the overall estimate with respect to all collisions is 0.7355, while the 95% confidence intervals are 0.6976 and 0.7734 respectively, as shown in Table 2. The p-value (<.0001) indicates a strong effect at the 99% confidence level.

Following Elvik (2003) and Manuel et al. (2020), the results can be interpreted as following: a **reduction of (1-0.7355)x100% ~ 26.45% in total collisions** is expected when 20mph limits with physical measures and enforcement are simultaneously implemented.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.7355	0.0193	<.0001	(0.6976, 0.7734)	38

Table 2. Summary results of the meta-analysis for the total number of collisions (in all settings).

The Q-test was not found to be significant (Q[df = 37] = 42.8744, p-value = 0.2338) suggesting no considerable heterogeneity among the studies is present. Moreover, the additional variance of multi-level model was found to be negligible. Hence, the fixed effects meta-analysis is preferred and there is no need to retain the multi-level model. The funnel plot is illustrated in Figure 3. The regression and rank correlation tests for funnel plot asymmetry were both not significant at a 95% level, suggesting no evidence for possible publication bias, and as such there is no need for correcting the estimates with the trim-and-fill method.

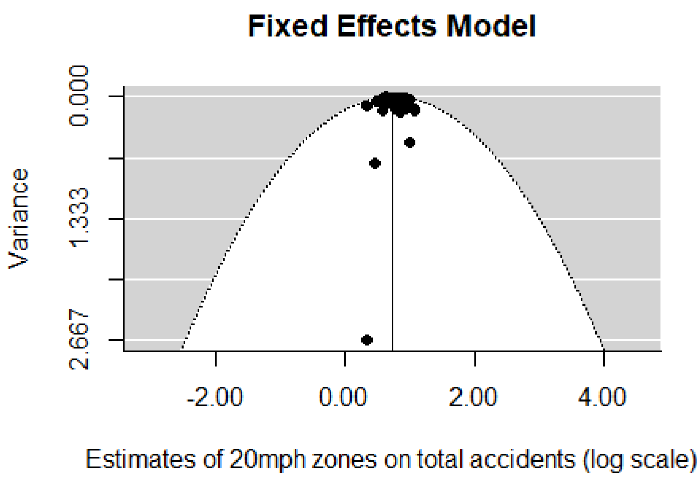


Figure 3. Funnel plot for the total number of collisions (all settings).

4.1.2 Fatal collisions (all settings)

When fatal collisions were considered (incl. physical measures/enforcements), it was found that the fixed effects model is more appropriate. This is intuitive since only two (2) estimates are included. As a consequence, the presented findings here are crude and should be interpreted with care.

Although the results of the fixed effects model indicate **a 29.75% reduction in fatal collisions**, the estimate was **not statistically significant** (p-value = 0.2285). No publication bias was detected.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.7025	0.5834	0.2285	(-0.4409, 1.8460)	2

Table 3. Summary results of the meta-analysis for fatal collisions (all settings).

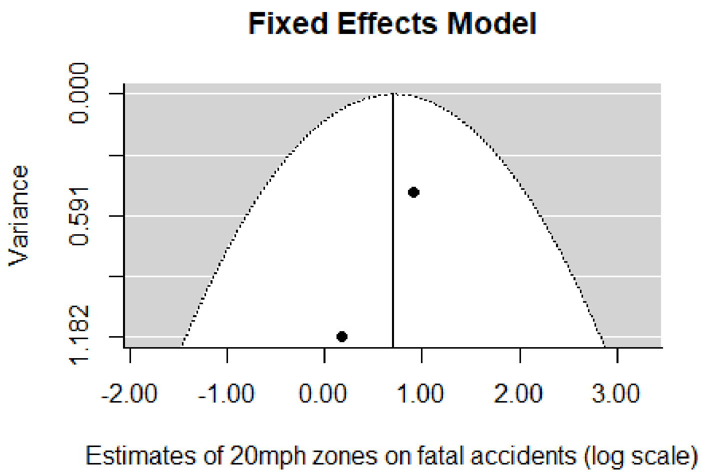


Figure 3. Funnel plot for fatal collisions (all settings).

4.1.3 KSI collisions (all settings)

When killed and seriously injured (KSI) collisions were considered, the same procedure was followed as in the previous analyses. The fixed effect model was also found to be appropriate (Q statistic = 15.3656, p-value = 0.3536). It also outperforms the multi-level model. No publication bias was present (p-value = 0.8458).

Results indicate that there is a strong **reduction of 36.29% in killed and serious injury (KSI) collisions**.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.6371	0.0550	<.0001	(0.592, 0.7449)	15

Table 4. Summary results of the meta-analysis for fatal/serious collisions (all settings).

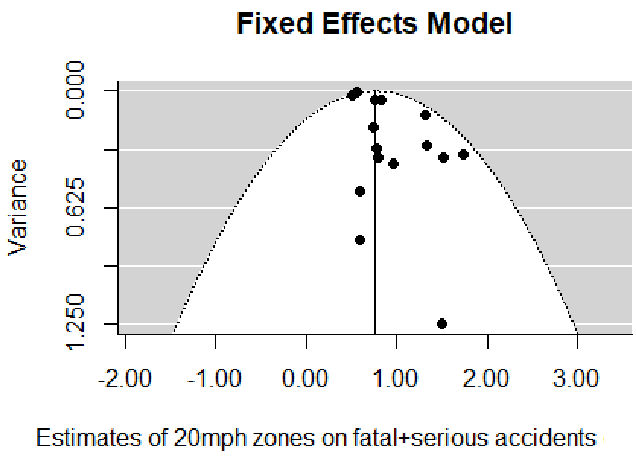


Figure 4. Funnel plot for fatal/serious collisions (all settings).

4.1.4 Serious injury collisions (all settings)

The strongest effect on collision reduction concerns the serious collisions. The results of the fixed effects meta-analysis (zero variance was found to be produced by the multi-level model) shows that there is **almost a 59.75% reduction in the serious injury collisions**. However, only four (4) estimates were available for this analysis, and hence the results come with some degree of uncertainty. Note that no publication bias was found to be present in this analysis as well as suggested by the regression test and rank correlation test.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.4015	0.1117	0.0003	(0.1826, 0.6204)	4

Table 5. Summary results of the meta-analysis for serious injury collisions (all settings).

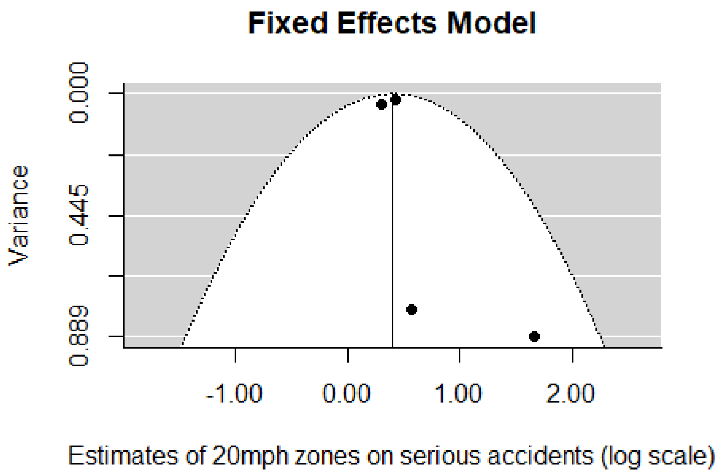


Figure 5. Funnel plot for serious collisions (all settings).

4.1.5 Slight injury collisions (all settings)

The impact of 20mph on slight injury collision frequencies seems to be high as well. In this case, the multilevel model was more appropriate (σ^2 = 0.234, Q-test = 25.9553, p-value = 0.0262). No publication bias was found to be present in this analysis suggested by the rank correlation test (p-value = 0.7662). The results suggest that **slight injury collisions are reduced by 32.4%**. Table 6 summarizes the main findings and Figure 6 provides the funnel plot.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.6760	0.0668	<.0001	(0.5452, 0.8069)	15

Table 6. Summary results of the meta-analysis for slight injury collisions (all settings).

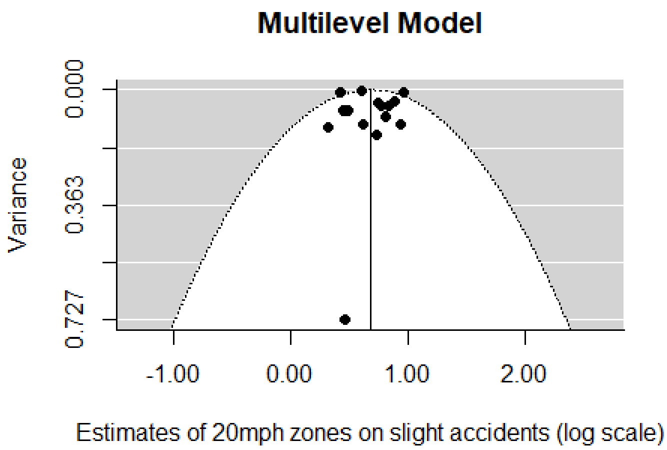


Figure 6. Funnel plot for slight injury collisions (all settings).

4.1.6 Total number of injury collisions (sign only)

A separate meta-analysis was conducted for the studies that introduced the 20mph speed limit without any physical measures or enforcement (i.e. sign only). Similar to the previous analysis regarding the total number of collisions (all severities) (all settings) as presented in section 4.1.1, the fixed effects model has found to be more appropriate and was retained (although it is noted that differences in the final estimate are minor). Results of the fixed effects meta-analysis indicate that the overall estimate for the case of total collisions is 0.7836, while the 95% confidence intervals are 0.7314 and 0.8357 respectively, as shown in Table 7. The p-value (<.0001) indicates a strong effect at the 99% confidence level. Similar to the previous analyses, no clear evidence of possible publication bias exists as the required tests for funnel plot asymmetry were insignificant at the 95% confidence level.

The results can be interpreted as follows: a **reduction of 21.64% in total collisions** (all severities) is expected when **20mph limits (sign only)** are implemented. It can therefore be observed that when **additional countermeasures are implemented there is a further 5% reduction in total collisions**, compared to when no other physical measures and enforcement are implemented.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.7836	0.0266	<.0001	(0.7314, 0.8357)	29

Table 7. Summary results of the meta-analysis for total collisions.

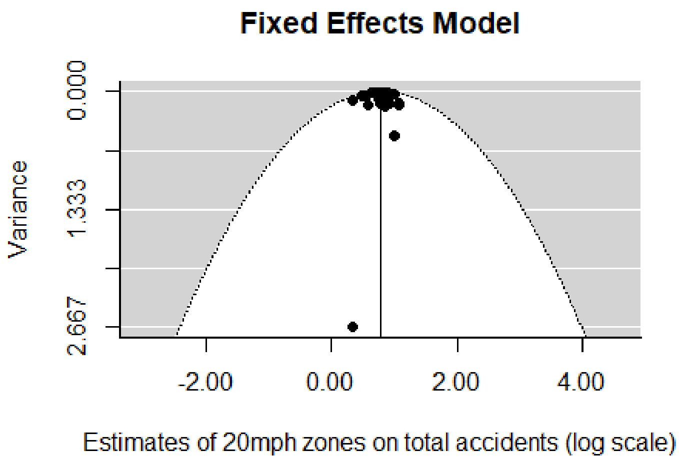


Figure 7. Funnel plot for total collisions.

4.1.7 Fatal collisions (sign only)

Unfortunately, **no estimates for fatal collisions** remained when only studies without physical measures and enforcement were considered.

4.1.8 KSI collisions (sign only)

The fixed effects meta-analysis suggested that the overall **reduction in fatal/serious collisions is only 7.16%**. Once again, no publication bias was detected.

In general, it may seem counterintuitive that only such as small reduction in fatal and seriously injured collisions is observed. However, in some cases, such as a few locations in Portsmouth area and one location in Cheshire, **slight increases in** fatal and seriously injured collisions **were observed** after the implementation of 20mph. As a result, the positive influence of this countermeasure in other areas was counterbalanced and ultimately a small overall reduction was inferred. This can also be observed from the high upper bound limit of the 95% Confidence Intervals which exceeds 1.0 (i.e. a value of 1.0 in the estimate indicated no effect) as well as the funnel plot (Figure 8).

It is remarkable that **physical measures and/or enforcement cause an additional reduction in** fatal and seriously injured collisions by **30%**. Further research is needed towards that direction to provide further insights about this severity category.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.9284	0.1477	<.0001	(0.6388, 1.2180)	10

Table 8. Summary results of the meta-analysis for total collisions.

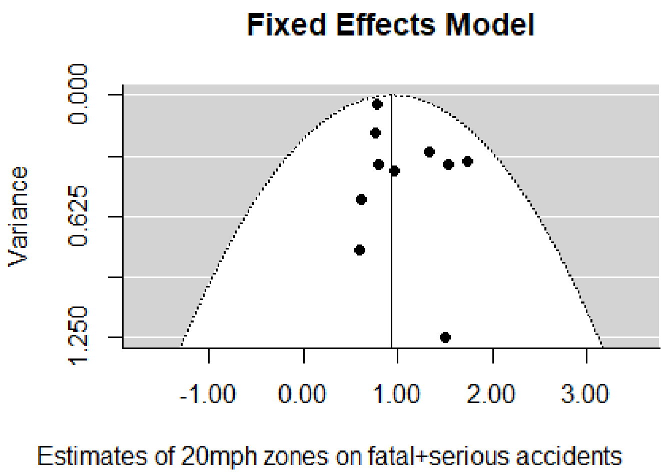


Figure 8. Funnel plot for fatal/serious collisions.

4.1.9 Serious injury collisions (sign only)

Unfortunately, **no estimates for serious injury collisions** remained when only studies without physical measures and enforcement were considered.

4.1.10 Slight injury collisions (sign only)

Interestingly, a big reduction was observed in regard with the slight injury collisions. More specifically, it is revealed that about **a 30% in slight injury collision** is expected. Comparing with the reduction including additional countermeasures, it can be observed that physical measures and enforcement cause **only an additional 2.4% reduction in slight injury collisions**.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.7031	0.0811	<.0001	(0.5441, 0.8622)	9

Table 9. Summary results of the meta-analysis for slight injury collisions.

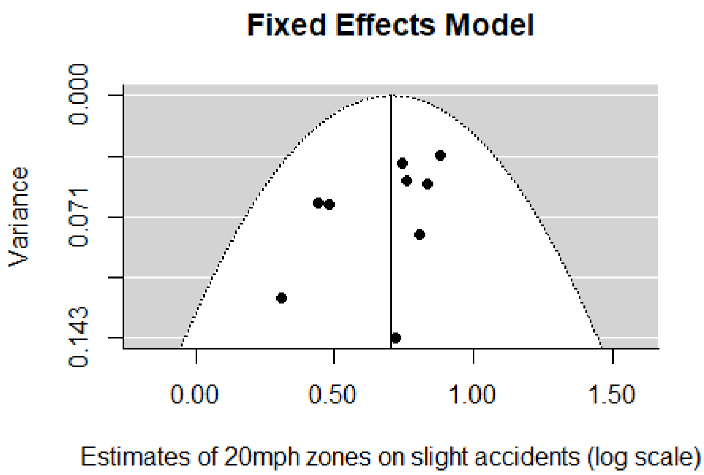


Figure 9. Funnel plot for slight injury collisions.

4.2. Impact of 20mph speed limits on casualties

To estimate the impact of the introduction of 20mph limits on casualty frequencies, the log-odds meta-analysis method was implemented as explained earlier. The following sub-sections provide an illustration of the main findings of our analyses. Initially, all studies and observations were considered, including those studies that introduced physical measures and enforcement alongside the 20mph speed limits implementation. Afterwards, separate meta-analyses were carried out, which considered only studies without physical measures or enforcement (i.e. sign only).

Following the same approach as utilised in estimating the impact of collision frequency, a random effects multi-level meta-analysis was firstly carried out and an additional amount of variance (i.e. an additional variance component) was produced, so as to address potential correlation among multiple observations within the same study. Similarly, when the goodness-of-fit measures (AIC, BIC) of the fixed effect specification were better, and/or when the Q-statistic for heterogeneity was not significant, the fixed effects model was retained.

4.2.1 *Total number of casualties (***all settings***)*

The total number of estimates available for the meta-analysis is 48. A multi-level meta-analysis was performed to calculate the overall estimate of the impact of 20mph on the total number of injuries in all settings. There is significant variance among locations from each study ($\sigma^2 = 0.0244$), while the Q-statistic for heterogeneity was found to be significant at a 95% level (Q[df = 47] = 101.9243, p-value < .0001). Moreover, the rank correlation test suggested no publication bias (Kendall's tau = - 0.0107, p-value = 0.915).

The overall estimate was found to be 0.7708, while the 95% Confidence Intervals are 0.6933 and 0.8483, respectively. It is thus suggested that **the total number of casualties is reduced by 22.92%**.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.7708	0.0396	<.0001	(0.6933, 0.8483)	48

Table 10. Summary results of the meta-analysis for total number of injuries (all settings).

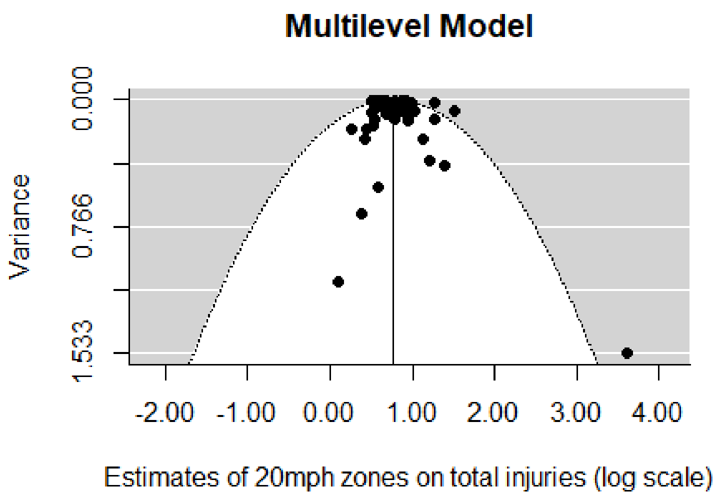


Figure 10. Funnel plot for total number of injuries (all settings).

*4.2.2 Fatalities (*all settings*)*

The fixed effects model was proved to be more appropriate than the multi-level model when dealing with fatalities (Q[df = 16] = 2.9597, p-value = 0.999). The overall estimate was found to be 0.6536, simply meaning that **20mph limits reduce the fatalities by 34.64%**. Table 11 summarizes the main findings of the fixed effect model and Figure 11 depicts the funnel plot. No publication bias was detected (e.g. regression test p-value = 0.9458).

It is noted that although the estimate is significant at the 99% confidence level, results should be carefully interpreted, because the upper bound of the 95% Confidence Intervals is marginally larger than the 1.0 value, meaning that there is a low (but existent) probability that the measure has no effect on fatal injury reductions.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.6536	0.1990	0.001	(0.2636, 1.0436)	17

Table 11. Summary results of the meta-analysis for fatal injuries (all settings).

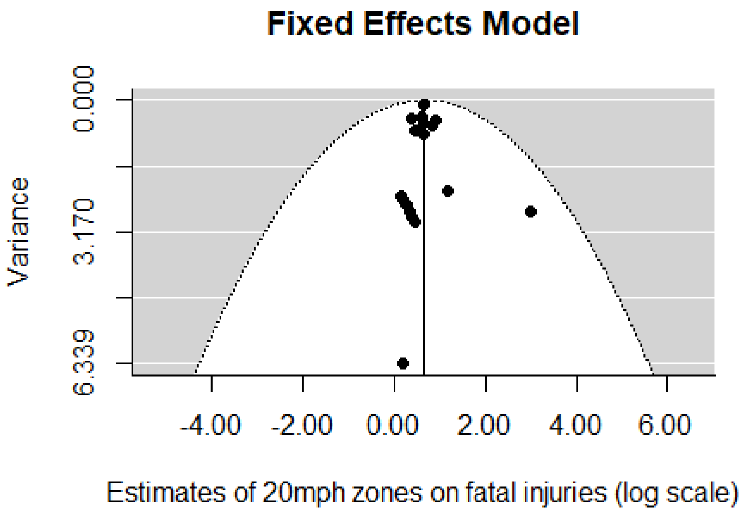


Figure 11. Funnel plot for fatal injuries (all settings).

4.2.3 *Fatal and seriously injured casualties (***all settings***)*

A multi-level meta-analysis was performed to calculate the overall estimate of the impact of 20mph on fatal and seriously injured casualties in all settings. There is an amount of produced variance among locations from each study ($\sigma^2 = 0.0219$), while the Q-statistic for heterogeneity was found to be significant at the 90% confidence level (Q[df = 16] = 25.3427, p-value = 0.064), but was decided to be retained as it performed slightly better than the fixed effects model in terms of AIC and BIC. In addition, the rank correlation test suggested that no publication bias exists (Kendall's tau = 0.214, p-value = 0.2319).

The overall estimate was found to be 0.6973, while the 95% Confidence Intervals are 0.5657 and 0.8289, respectively. It is thus revealed that **the number of fatal and** seriously injured casualties **is reduced by 30.27%** after implementation of 20mph speed limit along with physical measures and/or enforcement.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.6973	0.0671	<.0001	(0.5657, 0.8289)	17

Table 12. Summary results of the meta-analysis for fatal/serious injuries (all settings).

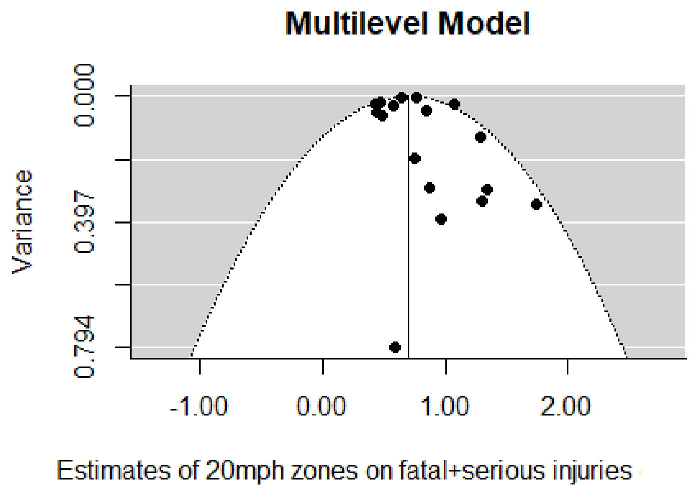


Figure 12. Funnel plot for fatal/serious injuries (all settings).

*4.2.4 Seriously injured casualties (*all settings*)*

As for the serious injuries, it was indicated that the multilevel model was slightly better than the fixed effects model and was retained (σ^2 = 0.0294). The Rank correlation test suggested no publication bias (Kendall's tau = -0.1083, p-value = 0.4016).

The overall estimate was suggested to be 0.7756, while the 95% Confidence Intervals are 0.6348 and 0.9164, respectively. It is thus suggested that **the number of serious injuries is reduced by 22.44%** after implementation of 20mph speed limit along with physical measures and/or enforcement.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.7756	0.0718	<.0001	(0.6348, 0.9164)	30

Table 13. Summary results of the meta-analysis for serious injuries (all settings).

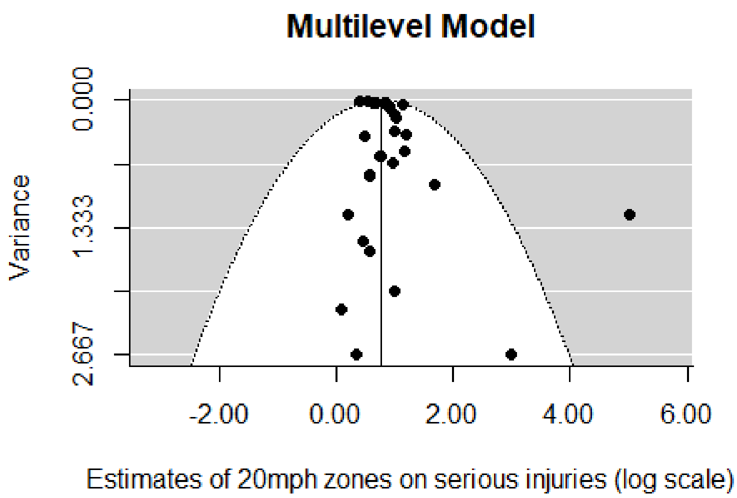


Figure 13. Funnel plot for serious injuries (all settings).

4.2.5 *Slightly injured casualties (*all settings*)*

As for the serious injuries, it was indicated that the multilevel model was slightly better than the fixed effects model and was retained (σ^2 = 0.0294). The Rank correlation test suggested no publication bias (Kendall's tau = -0.1083, p-value = 0.4016).

The overall estimate was suggested to be 0.8263, while the 95% Confidence Intervals are 0.7526 and 0.900, respectively. It is thus suggested that **the number of slight injuries is reduced by 17.37%** after implementation of 20mph speed limit along with physical measures and/or enforcement.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.8263	0.0376	<.0001	(0.7526, 0.900)	38

Table 14. Summary results of the meta-analysis for slight injuries (all settings).

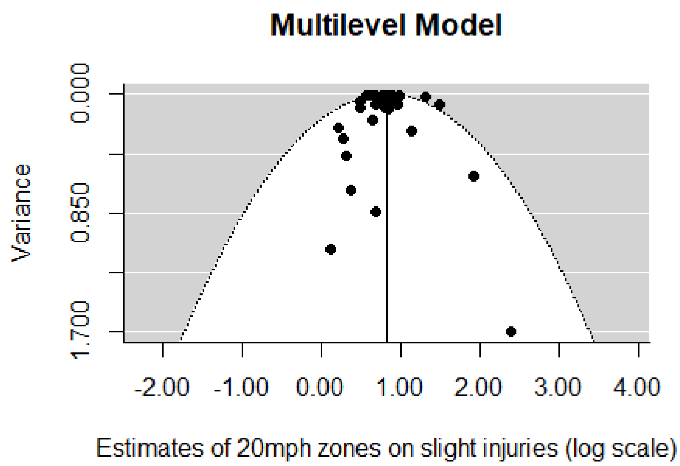


Figure 14. Funnel plot for slight injuries (all settings).

4.2.6 Total number of casualties (sign only)

Contrary to the previous analysis regarding the total number of casualties (all severities) (all settings), in the case of physical measures and enforcement not being considered, the fixed effects model is more appropriate and was finally retained (though it is noted that differences in the final estimate are very minor). The Q-test for heterogeneity was not significant (Q[df = 18] = 20.5092, p-value = 0.3049) confirming the fixed effects model choice. On the other hand, the rank correlation test for funnel plot asymmetry indicated that no publication bias exists (Kendall's tau = 0.0944, p = 0.575).

The overall estimate was suggested to be 0.8909 (p-value <.0001), simply meaning that there is **only an expected 11% reduction in total injuries due to 20mph speed limit implementation.** It is remarkable that **physical measures and/or enforcement lead to an additional 12% reduction of total casualties** (see section 4.2.1).

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.8909	0.0377	<.0001	(0.8170, 0.9647)	19

Table 15. Summary results of the meta-analysis for total injuries.

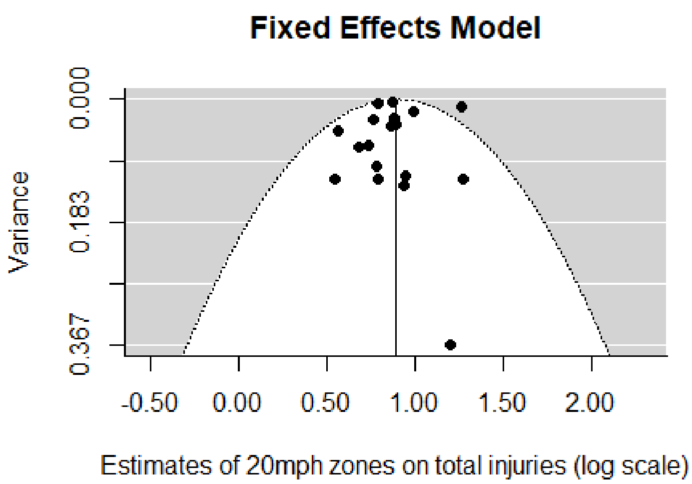


Figure 15. Funnel plot for total injuries.

4.2.7 Fatalities (sign only)

When fatal injuries in schemes without physical measures or enforcement are examined, the fixed effects model is more appropriate and **suggests a 37.73% reduction in fatal injuries**. The required tests for funnel plot asymmetry were found not significant, hence no publication bias exists.

It is noteworthy that this effect **is slightly larger than the reduction with physical measures and/or enforcement**. This may be attributed to the random variation of the estimate as the 95% Confidence intervals exceed the value of 1.0 (0.0009 and 1.2445 respectively), although this estimate is marginally significant at a 95% level. Note that only nine (9) estimates are included here. Therefore, this result is considered unclear and need to be interpreted with care.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.6227	0.3173	0.0497	(0.0009, 1.2445)	9

Table 16. Summary results of the meta-analysis for fatal injuries.

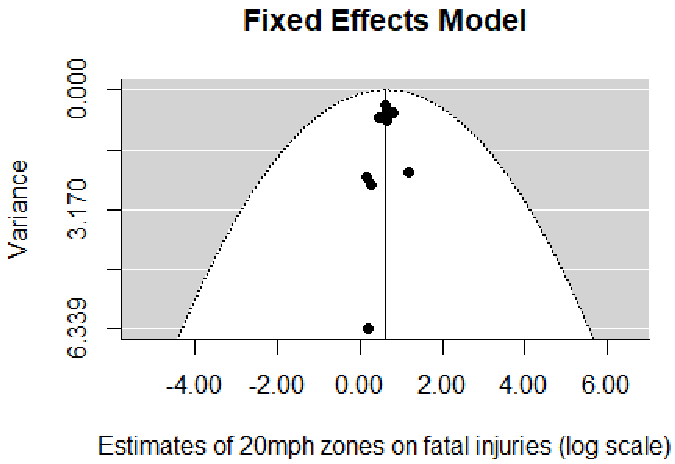


Figure 16. Funnel plot for fatal injuries.

4.2.8 *Fatal seriously injured casualties (sign only)*

A fixed-effect meta-analysis was performed to calculate the overall estimate of the impact of 20mph on fatal/serious injuries without excl. physical measures/enforcement. Overall, no publication bias exists (test for funnel plot asymmetry: p = 0.4016 & Kendall's tau = 0.2381, p-value = 0.5619). The result shows **only a marginal reduction in fatal and serious injury numbers (3%)**. This is **a remarkable difference** when compared to the change in numbers when other countermeasures are included which was more than 30% (see section 4.2.3). The small reduction is shown also by the 95% CI limits which vary around 1.0.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.9701	0.1550	<.0001	(0.6663, 1.2738)	7

Table 17. Summary results of the meta-analysis for fatal/serious injuries.

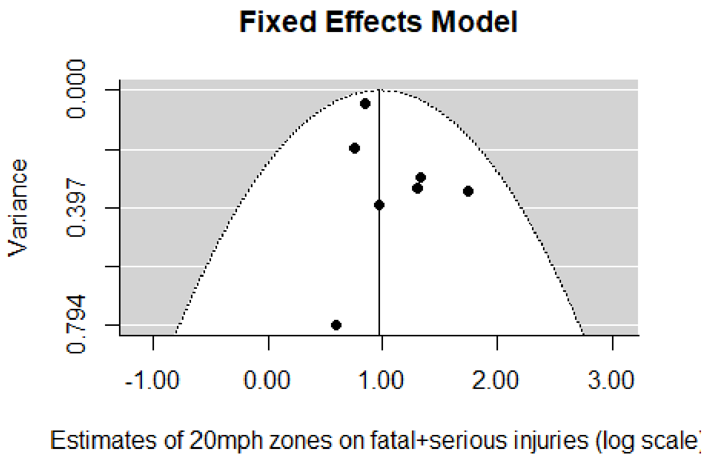


Figure 17. Funnel plot for fatal/serious injuries.

4.2.9 Seriously injured casualties (sign only)

The overall effect of 20mph speed limit on serious injuries was explored through the fixed effects meta-analysis (Q[df = 8] = 4.6670, p-value = 0.7925). The regression test for funnel plot asymmetry shows no publication bias. Results indicated that there is **an estimated 13.87% reduction in serious injuries.** Compared to the estimate including other countermeasures, this estimate **is 8.57% higher**, suggesting that lower serious injuries reduction occur without additional physical measures/enforcement.

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.8613	0.0717	<.0001	(0.7207, 1.0019)	9

Table 18. Summary results of the meta-analysis for serious injuries.

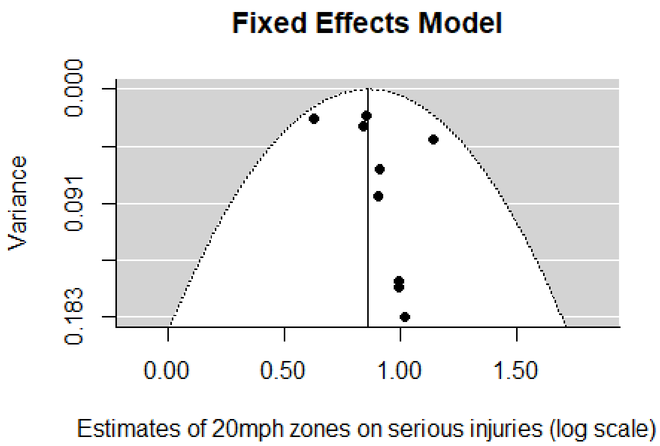


Figure 18. Funnel plot for serious injuries.

4.2.10 *Slightly injured casualties (sign only)*

Lastly, a multi-level meta-analysis was performed to calculate the overall estimate of the impact on slight injuries of 20mph limits without physical measures/enforcement. There is an amount of produced variance among locations from each study ($\sigma 2 = 0.0102$), while the Q-statistic for heterogeneity was found to be significant at a 95% level (Q[df = 14] = 26.457, p-value = 0.0226), but was decided to be retained as it performed better than the fixed effects model in terms of AIC and BIC. In addition, the Rank correlation test suggested that no publication bias exists (Kendall's tau = -0.1933, p-value = 0.3205).

It can be inferred that the 20mph speed limit implementation (sign only) leads to an estimated **12.09% reduction in slight injuries**. We can observe that **about a further 5% reduction is caused by additional physical measures/enforcement** (see section 4.2.5)

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
0.8791	0.0401	<.0001	(0.8005, 0.9577)	15

Table 19. Summary results of the meta-analysis for slight injuries.

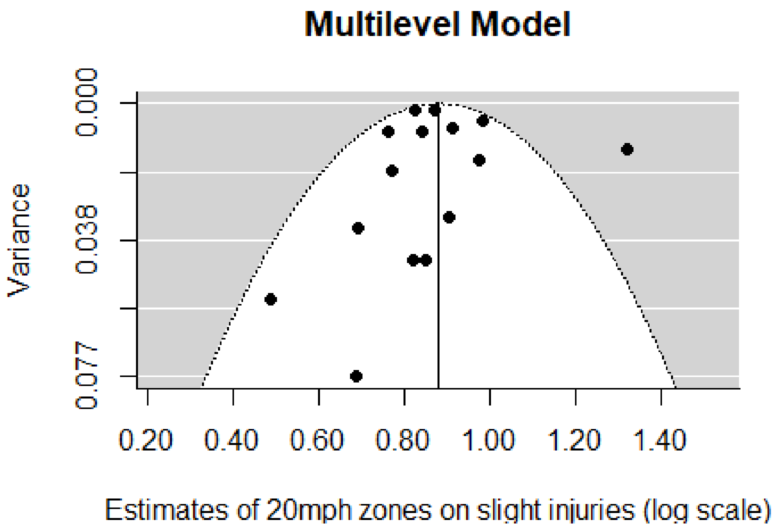


Figure 19. Funnel plot for slight injuries.

4.3. Meta-regression models

This section provides an attempt to i**nvestigate the impact of study design on collision and injury reductions by applying meta-regression models**. More specifically, we explore the relationship between the individual study characteristics (e.g. Year, method, presence of physical measures, presence of enforcement etc.) and the overall estimate of reduction of the total number of collisions as well as the number of total injuries. Each study characteristic is used as input (independent variable). It was selected to carry out meta-regression analyses only for the total numbers, because we need a sufficient number of observations to carry out a meaningful meta-regression. Also note that observations with the unknown countermeasure were not considered.

4.3.1 Meta-regression on the total number of collisions

The best fitting model was the simple fixed effects meta-regression model. It was interesting that the only moderator (independent variable) was found to be the presence of physical measures or not. In other words, the only study design characteristic influencing the overall estimate (i.e. total collision reduction) was the physical measure implementation. More specifically, it is shown that the absence of physical measures, increases the overall estimate at the 99% confidence level (estimates close to zero mean larger reduction of collisions, while estimates close to 1.0 mean no effect). In simple words, when **physical measures or enforcement are present the reduction of total collisions due to 20mph limit is 38.7% and this is 21.6% when there is no physical measure (i.e. sign only).**

Variable	**Beta coefficient**	**Std. Error**	**p-value**	**95% CI**
Constant	0.6130	0.0346	<.0001	(0.5451, 0.6809)
Sign only (Yes=1, 0 otherwise)	0.1705	0.0436	<.0001	(0.0851, 0.2558)

Table 20. Summary results of the meta-regression for total collisions.

Estimate with a physical measure (i.e. *sign only* = 0) = 0.6130 + 0.1705 x 0 = 0.6130
Estimate without any physical measure (*sign only*=1) = 0.6130 +0.1705x1 = 0.7835

4.3.2 Meta-regression on the total casualties

Similar to the previous analysis on the total collisions, the fixed effects meta-regression for total injuries revealed a positive relationship between physical measures and collision reductions (or a positive relationship between absence of physical measures and overall estimate). Thus, the same association was found for total injuries, as the introduction of 20mph speed limit with **physical measures causes a 43.05% reduction in total injuries. This is 12.2% without any physical measures (i.e. sign only).**

Variable	Beta coefficient	Std. Error	p-value	95% CI
Constant	0.5695	0.0294	<.0001	(0.5119, 0.6272)
Sign only (Yes=1, 0 otherwise)	0.3087	0.0450	<.0001	(0.2205, 0.3969)

Table 21. Summary results of the meta-regression for total injuries.

Estimate with a physical measure (i.e. *sign only* = 0) = 0.5695 + 0.3087x 0 = 0.5695
Estimate without any physical measure (*sign only*=1) = 0.5695 +0.3087x1 = 0.8782

4.4. Analysis on the impact of 20mph speed limit on speed changes

As can be seen in Deliverable 3.1, only a few studies have provided the impact of 'speed changes' as a result of implementing a 20mph speed limit. In calculating speed changes, it is worthwhile to note that studies employ 'spot mean speeds' rather than 'space mean speeds (i.e. travel speeds). This section presents **a preliminary analysis** of the impact of 20mph on mean speed changes. Two separate analyses are carried out: (i) speed changes relating to **sign only** schemes and (ii) speed changes relating to the schemes that were accompanied by **physical measures**.

In this analysis, the **raw Mean Difference (MD) meta-analysis was applied**. In other words, the mean speed difference before and after the implementation of 20mph speed limit is compared and the overall estimate of this reduction is calculated. For that reason, the average and the standard deviations of speeds across various locations are extracted for each study.

However, after removing other countermeasures (e.g., physical measures) and studies with only a single estimate, the final number of the estimates and studies was found to be limited. To overcome this limitation, a number of assumptions were made. A rather simplistic but useful approach was followed in order to include as many estimates as possible and shed light on the speed changes due to the introduction of 20km/h speed limit. This has resulted in a total of six estimates relating to speed changes. The following steps were followed to include all **six estimates** (**sign only**):

1. Calculate the mean speed before and the mean speed after 20mph for each study separately.
2. Each study might have one or multiple estimates (locations). If a study provides multiple estimates, the standard deviation of the mean is obtained.

If a study provides only one estimate from a single location, the following process was followed to obtain the standard deviation of speed:

1. Calculate the overall mean speed of all the studies before 20mph implementation.
2. Calculate the overall mean speed of all the studies after 20mph implementation.
3. Estimate a pseudo-standard deviation of speed before 20mph, for each study which provides a 'single estimate', by subtracting the mean speed of that particular study from the overall mean calculated earlier.
4. Apply the same to estimate the pseudo-standard deviation of speed after 20mph
5. At this stage, all the studies have mean values and standard deviations, hence the meta-analysis can be now performed.

It is noted though, that due to the limited number of studies and the assumptions taken in this analysis, the results can be considered only a preliminary analysis of the impact of 20mph schemes on speed reductions. As such the **following findings should be interpreted with care**, as it is imperative need to carry out further research on the topic.

The fixed effects meta-analysis revealed small but statistically significant effects at a 99% level, as an **overall reduction of 1.7604 mph (or 2.816 km/h)** was observed. The regression test for funnel plot asymmetry showed that no publication bias exists (z = - 0.0314, p-value = 0.9749).

Estimate	Std. Error	p-value	95% CI	Number of estimates employed in the meta-analysis
1.7604	0.4969	0.0004	(0.7865, 2.7344)	6

Table 23. Summary results of the meta-analysis for speed reductions in mph (**sign only**).

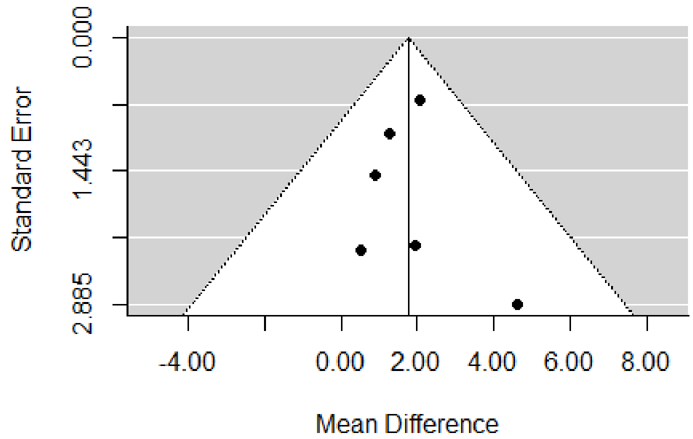


Figure 21. Funnel plot for average speed reductions in mph (sign only).

As the final step, it would be meaningful to compare these findings with the findings of the studies which included **physical measures** to supplement 20mph speed limit. However, only three studies were available for the analysis and the results should, therefore, be considered preliminary and be treated with care. Most importantly, all those **three** studies focused on one location, hence, they provided only one estimate per study. A number of different assumptions and analyses were carried out and they all converged to a statistically significant mean reduction of around 5.6mph while the 95% Confidence Intervals ranged approximately from 5.5mph to 5.78mph. Hence, there is evidence that the implementation of physical measures causes **approximately a further 3.8mph reduction in mean speeds** when compared to sign only measures.

5 Discussion and conclusion

5.1. Discussion and policy implications of 20mph limits

An in-depth examination of academic and grey literature identified 24 studies on the effectiveness of the introduction of 20 mph speed limits in the UK. The studies differ significantly with respect to contexts, scope, data availability, operational environments (e.g. metropolitan, city, town and village), types of scheme (e.g. 20 mph with traffic calming measures, 20 mph with sign only) and types of impact (e.g. speed, collisions, casualties). Therefore, generalising the overall impact of the effectiveness of 20 mph speed limit was challenging. However, a *meta-analysis* was applied for a systematic evaluation of findings and evidence to generate a weighted overall mean effect for two situations: (i) 20mph speed limits with all settings (physical measures & sign only) and (ii) 20mph speed limit without any physical measures (i.e. sign only).

In LUSTRE, three meta-analysis techniques were applied:

(i) a fixed effects model which is a traditional approach and
(ii) a random effects model to accurately control both variability and potential heterogeneity
(iii) multilevel model to control for both within and between correlations of the effects.

One of the key advantages of meta-analyses relates to the fact that they can provide an overall estimate of a measure of interest, rather than a "local" estimate obtained from a typical statistical analysis from a single study. Different specifications of the overall estimate were examined (e.g. proportion, relative risk, odds ratio etc.).

To examine the impact of moderator variables (i.e. where there is any physical measure or enforcement, the design characteristics that influence the study estimate such as year, country, location, awareness campaigns, size of the zone) on the effect size, a meta-regression model was applied (see Equation 12). It should be noted that meta-regression models are linear models that investigate the impact of (one or more) moderator variables on the outcomes. It is noted that continuous as well as categorical moderator variables were included in a meta-regression model.

Findings are summarised in two tables: (i) Table 23 for the overall mean effect in the case of collisions and their different categories and (ii) Table 24 for the overall mean effect in the case of personal injuries and their various categories. In each of the tables, the overall mean effect is distinguished by three situations: (i) a combined effect including all studies (i.e. with physical measures & sign only), (ii) without physical measures (i.e. sign only) and (iii) with physical measures/enforcements. The mean effect relating to physical measures/enforcements (i.e. 3rd condition) has been estimated for comparison purposes only.

Table 23 Summary of meta-analysis results: collisions

Types of collisions	Number of estimates utilised in the meta-analysis	Mean effect – reduction (%)	95% confidence intervals (reduction, %)	
			Lower Value	Upper value
All Settings (Physical Measures, Enforcements and Sign Only)				
Total collisions	38	26.45	30.24	22.66
Fatal collisions	2	**Statistically insignificant**		
KSI collisions	15	36.29	40.8	25.51
Serious injury collisions	4	59.85	81.74	37.96
Slight injury collisions	15	32.4	45.48	19.31
Sign Only				
Total collisions	29	21.64	26.86	16.43
Fatal collisions	-			
KSI collisions	10	7.16	36.12	-21.8
Serious injury collisions	-			
Slight injury collisions	9	29.69	45.59	13.78
Physical Measures/Enforcements				
Total collisions	5	38.27	44.97	31.57
Fatal collisions	2	**Statistically insignificant**		
KSI collisions	2	45.39	57.72	33.06
Serious injury collisions	4	59.85	81.74	37.96
Slight injury collisions	5	45.51	53.81	36.21

(Findings in the highlighted rows should interpret with caution)

Impact on collisions: all settings

As can be seen from Table 23, the frequency of reported collisions involving a casualty has been consistently reduced after the introduction of 20mph speed limits when all studies (with physical measures/enforcements and sign only) are considered together. This is true for all categories of collisions except fatal collisions. However, the finding for fatal collisions is not statistically significant as it is based on only two studies. The overall mean effect is a reduction of 26.5% for all collisions with the 95% confidence intervals of 22.7% and 30.2% reductions. The largest reduction has observed in the case for 'serious collisions' (about a reduction of 60%) but the sample size is low (i.e. n=4) and therefore, this finding should be treated with caution. For KSI collisions (fatal and serious injury collisions combined) the sample size is larger (n=15). These have reduced by 36.3% (with the 95% confidence intervals of -25.5% and -40.8%). The results are visualised in Figure 22.

As can be seen from Table 23, the largest mean effect of the 20mph speed limit across all categories of collisions relates to the schemes with physical measures/enforcements.

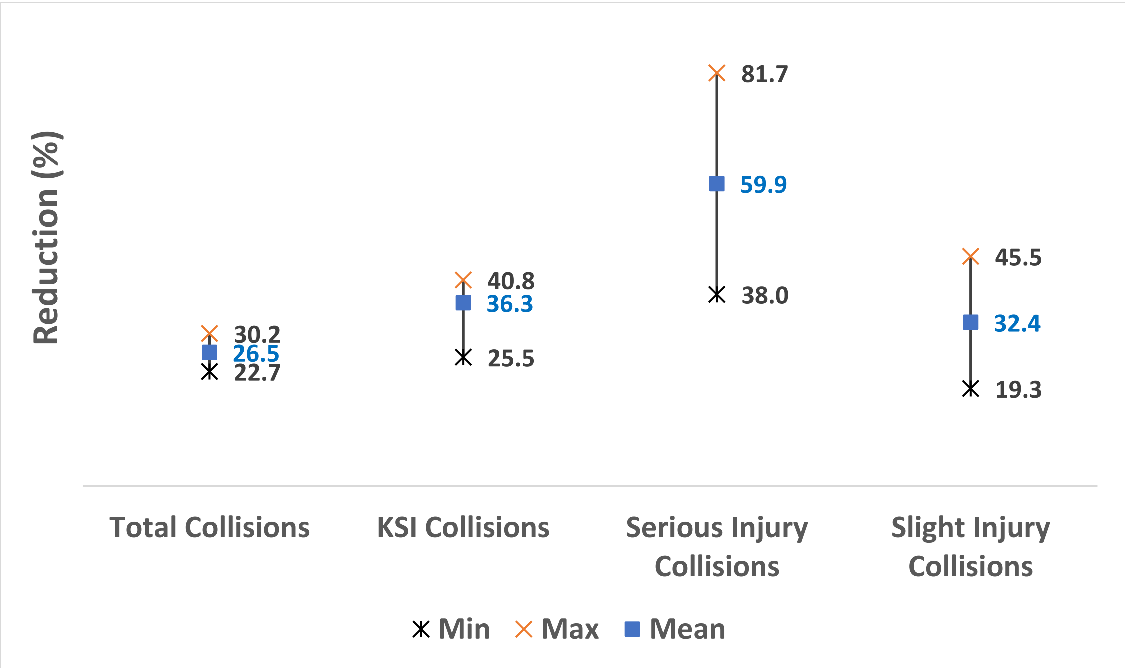


Figure 22: Mean effect of 20mph speed limit on collisions (all settings)

Impact on collisions: sign only schemes

The effect of 20mph speed limits without any physical measures on the frequency of collisions has been found than that of all settings (see Table 23). It should be noted that no studies reported the impact of 20mph on fatal and serious injury collisions (see Table 23 of Deliverable 3.1). Therefore, the meta-analysis could not be conducted for these collisions.

However, the impact of 20mph speed limits (**sign only**) is apparent for other categories of collisions. More specifically, total collisions have reduced by 21.6% (as opposed to 26.5% obtained for 'all settings') with the 95% confidence intervals of 16.4% and 26.9% reductions. This is significant given that sign only schemes do not have any physical measures or enforcements. The mean effect for KSI collisions is a reduction of 7.16%. However, the upper limit of the confidence interval exceeds 1 meaning that the introduction of 20mph speed limits has had a negative impact on safety (see the values within the red box in Figure 23). The schemes with physical measures have outperformed sign only schemes with the analyses of KSI collisions showing a reduction of about 30% over the sign only schemes. However, two of the sign only schemes (i.e. Portsmouth and one location in Cheshire) showed increases in KSI collisions which may well account for some of this difference.

The finding on the slight injury collisions has been consistent with the mean reduction of 29.7% with the 95% confidence intervals of 13.8% and 45.6% reductions. The mean effects are visualised in Figure 23.

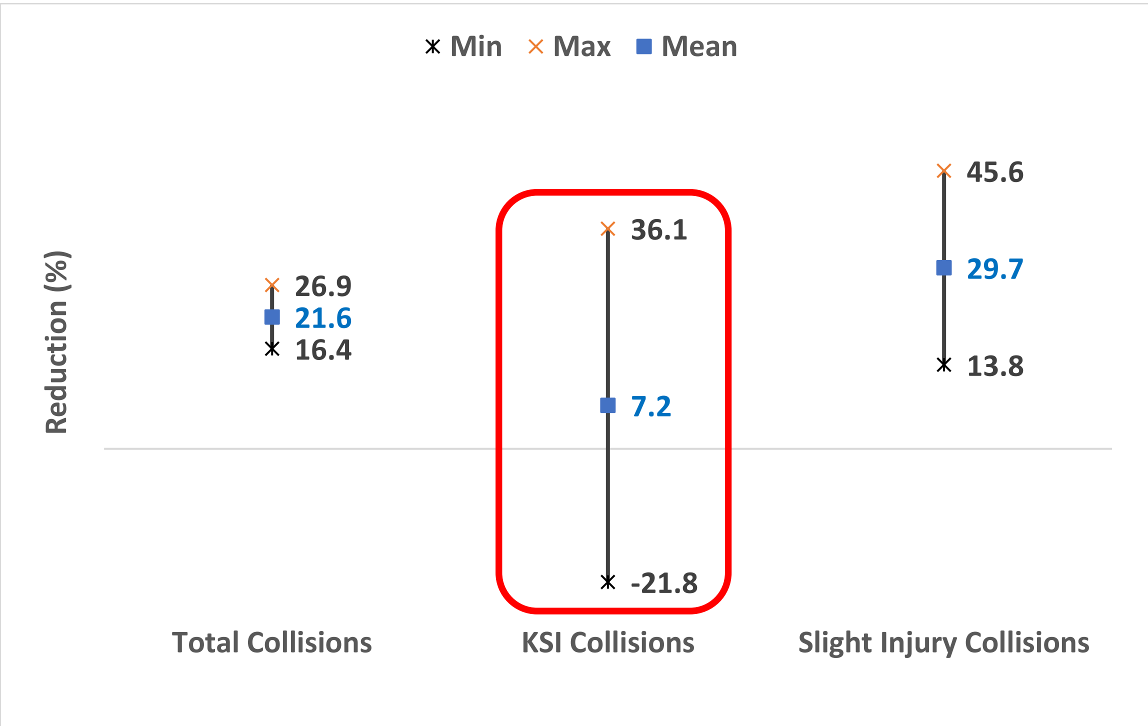


Figure 23: Mean effect of 20mph speed limit on collisions (for the schemes with sign only)

Table 24 Summary of meta-analysis results: Casualties

Types of personal injuries	Number of estimates utilised in the meta-analysis	Mean effect – reduction (%)	95% confidence intervals (reduction, %)	
			Lower Value	Upper value
All Settings (Physical Measures, Enforcements and Sign Only)				
Total injuries	48	22.92	30.67	15.17
Fatalities	17	34.64	73.64	-4.36
Killed and serious injuries	17	30.27	43.43	17.11
Serious injuries	30	22.44	36.52	8.36
Slight injuries	38	17.37	24.74	10
Sign Only				
Total injuries	19	10.91	18.3	3.53
Fatalities	9	37.73	99.91	-24.45
Killed and serious injuries	7	2.99	33.37	-27.38
Serious injuries	9	13.87	27.93	-0.19
Slight injuries	15	12.09	19.95	4.23
Physical Measures/Enforcements				
Total injuries	25	39.99	45.39	34.58
Fatalities	7	27.67	81.75	-26.42
Killed and serious injuries	7	35.55	43.17	27.93
Serious injuries	20	45.26	57.84	32.69
Slight injuries	22	23.38	36.67	10.10

(Findings in the highlighted rows should interpret with caution)

Impact on casualties: all settings

The findings on the personal injuries are similar to those of collisions, as expected. After the introduction of 20mph speed limit under all settings, the average of total injuries has reduced by 22.9% with the 95% confidence intervals of 15.2% and 30.7% reductions. In case of fatalities, the finding shows a mixed effect. Whilst the analysis indicates the mean effect is a reduction of 34.6%, the 95% confidence interval of 73.6% and -4.36% reductions is unusually large. The negative value in the confidence interval indicates that there is an increase in fatal casualties (see the values within the red box in Figure 24). Therefore, the effect on fatalities should be interpreted with caution. The finding on KSI injuries has been consistent with the mean reduction of 30.3% with the 95% confidence intervals of 17.1% and 43.4% reductions. The results are consistent for other injury categories such as the average of serious injuries has decreased by 22.4% whereas this is 17.4% for slight injuries. Figure 24 displays the mean-effect.

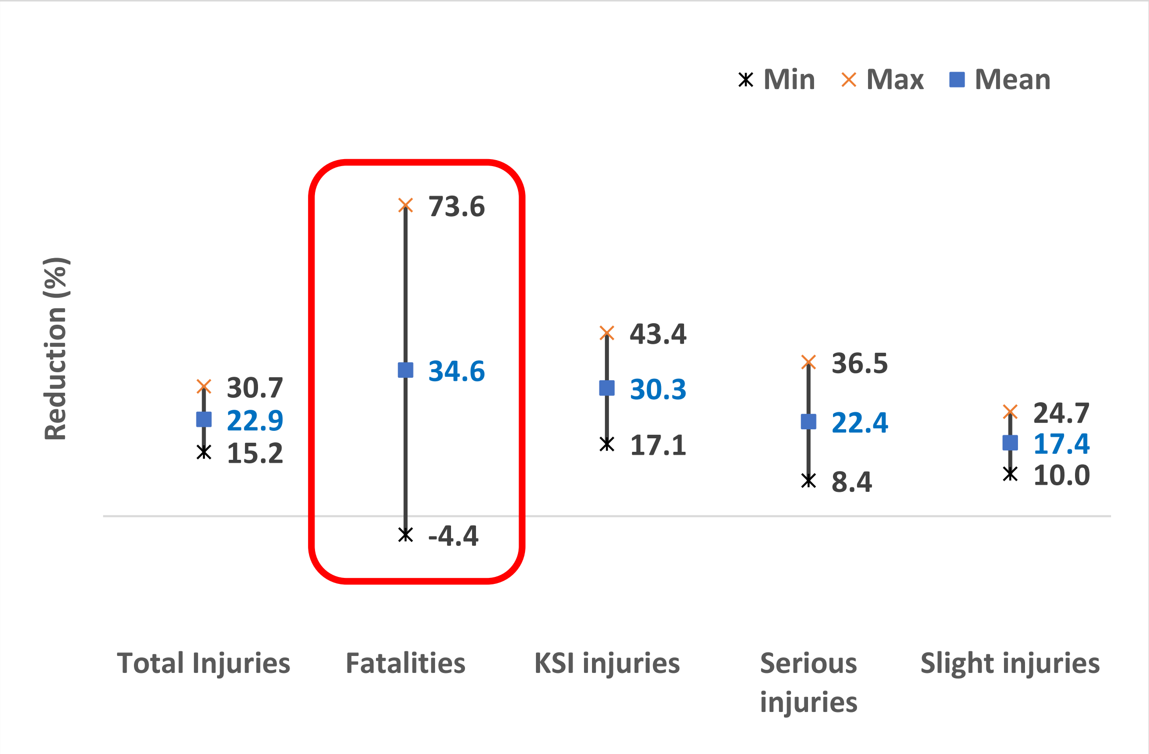


Figure 24: Mean effect of 20mph speed limit on casualties (for all schemes)

Impact on casualties: 'sign only' schemes

As shown in Table 24, the effect of 20mph speed limits without physical measures (i.e. sign only) has found to be consistent and evident for total casualties and slightly injured casualties. For instance, the scheme has brought about a 10.9% reduction in total casualties (all severities) (the 95% confidence intervals are -3.5% and -18.3%). The mean effect on slight injuries has found to be a reduction of 12.1% with the 95% confidence intervals of 4.2% and 20% reductions.

However, the mean effect on fatalities, KSI injuries and serious injuries has found to be *inconsistent* with the effects on slight injuries and total injuries. It should be noted that some local authorities did not report the impact of 20 mph speed limits on casualties by severity category (see Table 34 of Deliverable 3.1). Consequently, the number of studies on fatalities, KSI and serious injuries has reduced to 9, 7, and 9 respectively. While the mean effect of fatalities has found to be ‘large’ (i.e. a reduction of 37.8%), the 95% confidence intervals exhibit a significant variation (i.e. 99.91% to -24.45% reductions). In fact, the upper value of the estimate shows a ‘negative’ sign indicating that fatalities have increased after the introduction of ‘sign only’ scheme. Although the estimates are statistically significant, the findings should be carefully interpreted as the number of studies available in the meta-analysis is relatively ‘small’. “Outlier” results, such as these, are to be expected in studies such as this. This is also true for KSI and serious injuries. Therefore, these results should be carefully interpreted (see the values within the red boxes in Figure 25). Figure 25 shows the mean effects with their confidence intervals.

The conclusion is that the effect of introducing 20mph speed limits without physical measures (i.e. sign only) has a significant effect (a reduction of approximately 12%) on slight casualties but the effect on fatal and serious casualties is uncertain.

As can be seen from Table 24, the largest mean effect of the 20mph speed limit across all categories of injury severity relates to the schemes with physical measures/enforcements.

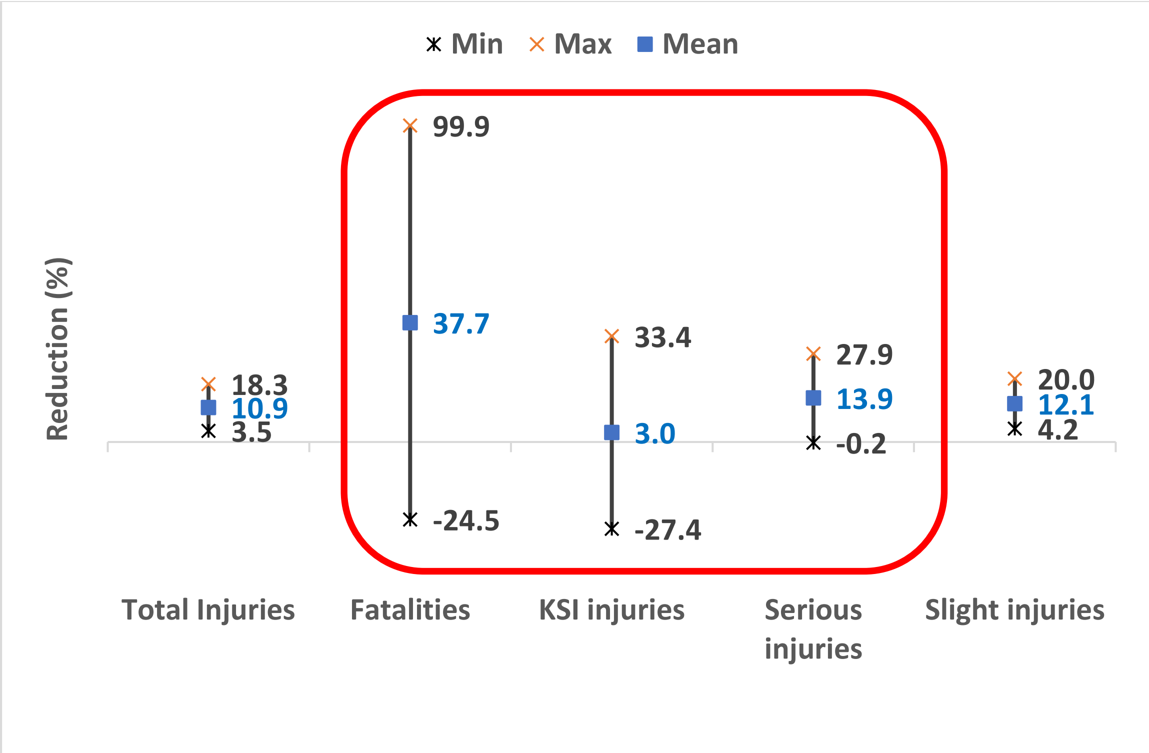


Figure 25: Mean effect of 20mph speed limit on casualties (sign only)

Overall, the results indicate that the introduction of 20mph speed limits without physical measures (sign only) reduced, on average, traffic collisions by 21.6% and total traffic casualties by 10.9%.

Meta-regression:
The finding on meta-regression indicates that total collisions have reduced by 38.7% when 20mph speed limit was introduced with physical measures. This has reduced to **21.6%** when there is no physical measure (**sign only**). Similarly, personal injuries have decreased by 43.1% if there are physical measures. This has reduced to **12.2%** when there is no physical measure (sign only). These findings confirm that meta-analyses and meta-regression provide similar effects of 20 mph speed limits on road safety.

Summary of the findings from the meta-analysis for the overall effects (casualties and speed) of the schemes (sign only):

- The introduction of 20mph speed limits (**sign** only) reduced the traffic collisions by **21.6%** on average (with the 95% confidence intervals: -**16.4% and - 26.7%**).
- The introduction of 20mph speed limits (**sign** only) reduced the total injuries by **10.9%** on average (with the 95% confidence intervals: - **3.5% and -18.3%**). However, the

mean reduction of total injuries was slightly larger (i.e. 12.2%) according to the meta-regression.

- The introduction of 20mph speed limits (**sign** only) reduced average speed by **1.76 mph** (with the 95% confidence intervals: -0.8 mph and -2.73 mph).

Lastly, by referring to the SafetyCube methodology as presented in Table 1 (Martensen and Lassarre, 2017) to qualitatively evaluate this road safety measure, its effectiveness can be categorized as **light green** (effective but with some inconsistencies). Please refer to the following subsection which indicates a number of limitations.

Limitations:
As speculated earlier, the potential limitations of the study are summarised as follows:

Low quality of studies: as stated in Deliverable 3.1, most studies did not control for: (i) regression to the mean, (ii) long-term trends in the number of collisions and (iii) exogeneous changes in traffic volume. Therefore, the studies are deemed to be 'low quality'.

Low number of studies: sample size for some estimates (see Tables 23 and 24) are quite low and therefore, the findings should be carefully interpreted.

Inconsistency in the effect: some studies have reported an increase in fatal collisions where others have indicated a decrease. As a result, some of the 95% confidence intervals provided opposite sign.

5.2. Conclusion

There are, in general, two ways of interpreting the results of research: methodological and substantive.

Methodological

A methodological interpretation would normally argue for rejecting the results of a study or set of studies because the studies used poor methods. It is easy to argue for rejecting the studies of 20 mph zones made by local authorities in Great Britain, as these studies mostly do not control for well-known confounders such as regression-to-the-mean, long-terms trends in the number of collisions or injuries, or changes in traffic volume. However, if these studies are rejected the impacts of a policy of introducing 20 mph speed limit zones without physical measures would remain largely unknown and any estimate would have to be based on a very limited number of studies. The question must therefore be asked, if the available studies, although methodologically weak (mean score 0.49 on a scale of 0 to 1), can still provide some knowledge about the effects of 20 mph speed limit zones.

Substantive

The relationship between changes in the speed of traffic and changes in casualties is closely related to the laws of physics. More specifically, one would expect there to be a systematic pattern in the findings of studies consistent with the following:

1. There should be a greater reduction in the number of collisions or injuries when a 20 mph speed limit zone has physical measures than when it has no physical measures.
2. There should be a greater percentage reduction in the number of casualties than in the number of collisions.
3. There should be a greater (percentage) reduction in the number of killed or seriously injured road users, than in the number of slightly injured road users.
4. The results with respect to the points 1-3 above should be consistent with what other studies have found.

The first point is justified by ample research showing that speed humps or other physical measures reduce speed and collisions, whereas changes in speed limit alone may not have an equally large effect, particularly if the road layout allows for driving faster than 20 mph without much discomfort.

The second point is justified by the fact that, on average, there is more than one injured person in each injury collision. Thus, if a car with two occupants avoids a collision, then two potential injuries are avoided. This has not been confirmed in this study as the number of studies (i.e. estimates) employed in the meta-analysis between collisions and injuries are different.

The third point is derived directly from the law of kinetic energy combined with biomechanical knowledge of human tolerance to physical impacts. The lower the kinetic energy dissipated in a collision, i.e. the lower the speed, the lower the chances that the collision will result in fatal or serious injury.

Finally, the fourth point refers to the fact that, all else equal, studies consistently producing the same, or similar, results give us more reason to trust in the findings than studies producing bewildering or highly inconsistent results that cannot be made sense of.

The results of the meta-analyses presented in this report for ***sign only*** schemes show a systematic pattern which is broadly consistent with the four points above. The introduction of 20mph speed limits (**sign** only) reduced the total casualties (all severities), on average, by **10.9%** (with the 95% confidence intervals: **-18.3%; -3.5%**). This is similar to the mean reduction of total casualties of 12.2% shown by the meta-regression.

The results for casualties show a more systematic pattern than those for collisions. In general, the main tendencies found in the meta-analysis suggest that the changes in the number of collisions or casualties have mainly been produced by changes in speed, and not by some confounding factor not controlled for.

This finding is also consistent with other studies. In a recent summary of studies, Elvik (2020) found that well-controlled studies of speed humps found a mean reduction of the number of injury collisions of 30% (95% confidence interval from 42% to 16% reduction; random-effects meta-analysis, adjusted for publication bias). This is not very different from the 26% collision reduction found in the present report (Table 23).

With respect to total collisions, the introduction of 20 mph speed limit (**sign** only) decreased collisions by **21.6% (-16.4%; -26.7%)**. For schemes without physical measures, Elvik (2020) reported a mean reduction of injury collisions of 14% (-25%; -3%).

The introduction of 20mph speed limits (**sign** only) reduced average speed by **1.76 mph** (with the 95% confidence intervals: -2.73 mph; -0.8 mph). However, the reduction in mean speeds was found to be 5.6mph for the 20mph speed limit with physical measures.

It is concluded that, on the whole, the results display a sufficiently systematic pattern to make it more likely that they reflect mainly the effects of changes in speed than mainly the effects of confounding factors the studies did not control for.

As a last remark, by referring to SafetyCube methodology as presented in Table 1 (Martensen and Lassarre, 2017) to qualitatively evaluate this road safety measure, the effectiveness of 20 mph speed limit (**sign only)** could be categorised as **light green,** that is being **"**probably effective" but with some inconsistencies with respect to collision severity categories due primarily to low number of studies in the meta-analysis.

6 References

Bahar G. (2010). Methodology for the development and inclusion of crash modification factors in the first edition of the highway safety manual. Transp. Res. Board. https://doi.org/10.17226/22959.

Begg C.B., Mazumdar M. (1994). Operating characteristics of a rank correlation test for publication bias Biometrics, 50, 1088–1099.

Berkey C.S., Hoaglin D.C., Mosteller F., Colditz G.A. (1995). A random-effects regression model for meta-analysis. Statistics in Medicine 14(4), 395–411.

Duval S., Tweedie R. (2000a). A non-parametric trim and fill method of assessing publication bias in meta-analysis. Biometrics 56, 455–463.

Duval S., Tweedie R. (2000b). Trim and fill: a simple funnel plot based method of testing and adjusting for publication bias in meta-analysis. Journal of American Statistical Association 95, 89–98.

Egger M., Smith G.D., Schneider M., Minder C. (1997). Bias in meta-analysis detected by a simple, graphical test. British Medical Journal 315(7109), 629–634.

Elvik R. (2003). Effects on Road Safety of Converting Intersections to Roundabouts-Review of Evidence from Non-U.S. Studies. Transportation Research Record 1847, Paper No. 03–2106.

Elvik R. (2003). Corrigendum to: “Publication bias and time-trend bias in meta-analysis of bicycle helmet efficacy: A re-analysis of Attewell, Glase and McFadden, 2001” [Accid. Anal. Prev. 43 (2011) 1245–1251]. Collision Analysis and Prevention 60, 245–253.

Elvik R. (2005). Introductory guide to systematic reviews and meta-analysis. Transportation Research Record 1908, 230-235.

Elvik R. (2011). Effects of mobile phone use on collision risk: Problems of Meta-Analysis When Studies Are Few and Bad. Transportation Research Record 2236, 20-26.

Elvik R. (2020). Assessing the methodological quality of studies evaluating the effects of 20 mph zones. Working paper 51621, Oslo 04.05.2020, 4873 LUSTRE project.

Elvik, R. (2020). Revisjon av Trafikksikkerhetshåndboken: 3.12 Fysisk fartsregulering. Arbeidsdokument SM/51684/2020. Oslo, transportøkonomisk institutt.

Elvik R., Bjørnskau T. (2017). Safety-in-numbers: A systematic review and meta-analysis of evidence. Safety Science 92, 274–282.

Fleiss J. L. (1981). Statistical Methods for Rates and Proportions, 2nd ed. John

Wiley and Sons, New York, 1981.

Hauer E. (1997). Observational Before-After Studies in Road Safety: Estimating the Effect of Highway and Traffic Engineering Measure on Road Safety. Pergamon, Tarrytown, New York.

Hedges L.V., Olkin I. (1985) Fixed-and random effects models in meta-analysis. Academic Press, San Diego, CA.

Konstantopoulos, S. (2011). Fixed effects and variance components estimation in three-level meta-analysis. Research Synthesis Methods, 2(1), 61–76.

Manuel A., de Barros A., Tay R. (2020). Traffic safety meta-analysis of reversible lanes. Collision Analysis and Prevention 148,105751.

Martensen, H., and Lassarre, S., Eds (2017). Methodological framework for the evaluation of road safety risk factors and countermeasures, Deliverable 3.3 of the H2020 project SafetyCube.

Metafor package. A Meta-Analysis Package for R. https://www.metafor-project.org/doku.php/metafor. Accessed October 2020.

Rothstein H.R., Sutton A.J., Borenstein M. (2005). Publication bias in meta-analysis: Prevention, assessment, and adjustments. John Wiley & Sons, Chistester, England, 2005.

Sterne J.A.C., Egger M. (2001). Funnel plots for detecting bias in meta-analysis: Guidelines on choice of axis. Journal of Clinical Epidemiology 54(10), 1046–1055.

Theofilatos A., Ziakopoulos A., Papadimitriou E., Yannis G., Diamandouros, K. (2017). Meta-analysis of the effect of road work zones on crash occurrence. Collision Analysis and Prevention, 108,1–8.

Theofilatos A., Ziakopoulos A., Papadimitriou E., Yannis G. (2018). How many crashes are caused by driver interaction with passengers? A meta-analysis approach. Journal of Safety Research, 65, 11–20.

Van Houwelingen H.C., Arends L.R., Stijnen T. (2002). Advanced methods in meta-analysis: multivariate approach and meta-regression. Statistics in Medicine 21(4), 589–624.

Viechtbauer W. (2010). Conducting Meta-Analyses in R with the metafor Package. Journal of Statistical Software, 36(3), August 2010.

PACTS
Parliamentary
Advisory Council
for Transport Safety

Parliamentary Advisory Council for Transport Safety (PACTS)
Buckingham Court
78 Buckingham Gate
Westminster
London, SW1E 6PE

admin@pacts.org.uk
+(44) 0207 222 7732
www.pacts.org.uk
@PACTS