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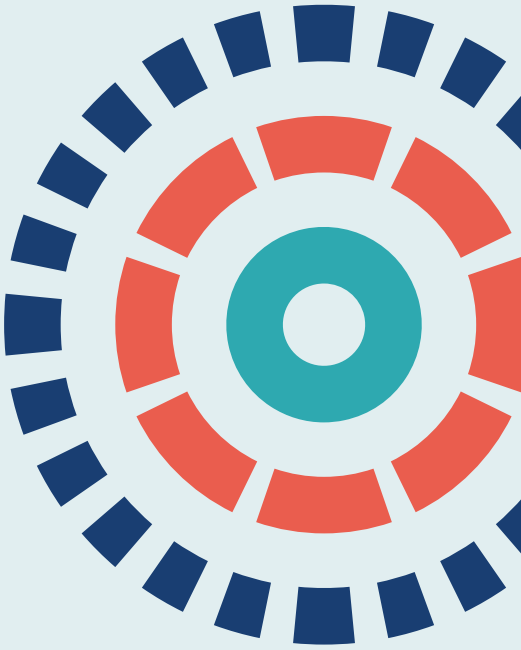

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Developing and implementing 20-mph speed limits in Edinburgh and Belfast: mixed-methods study

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Disclaimer: This report contains transcripts of interviews conducted in the course of the research and contains language that may offend some readers.

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Abstract

Developing and implementing 20-mph speed limits in Edinburgh and Belfast: mixed-methods study

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Background: Transport initiatives such as 20-mph (≈30-km/h) speed limits are anticipated to result in fewer road casualties and improve perceptions of safety, leading to increases in active travel. Lower speeds may also lead to more pleasant environments in which to live, work and play.

Objectives: The main objective was to evaluate and understand the processes and effects of developing and implementing 20-mph speed limits in Edinburgh and Belfast. The focus was on health-related outcomes (casualties and active travel) that may lead to public health improvements. An additional objective was to investigate the political and policy factors (conditions) that led to the decision to introduce the new speed limits.

Design: This was a mixed-methods study that comprised an outcome, process, policy and economic evaluation of two natural experiments.

Setting: The study was set in Edinburgh, Scotland, and Belfast, Northern Ireland, from 2000 to 2018.

Participants: The whole population of each city were participants, as well as stakeholders involved in implementation and decision-making processes.

Intervention: The intervention was the implementation of 20-mph legislation, signage, enforcement, and education and awareness-raising in Edinburgh (citywide) and Belfast (city centre).

Main outcome measures: The main outcomes measured were speed; number, type and severity of road collisions; perceptions; and liveability.

Data sources: The following data sources were used – routinely and locally collected quantitative data for speed, volume of traffic, casualties and collisions, and costs; documents and print media; surveys; interviews and focus groups; and Google Street View (Google Inc., Mountain View, CA, USA).

Results: Collisions and casualties – the overall percentage reduction in casualty rates was 39% (the overall percentage reduction in collision rates was 40%) in Edinburgh. The percentage reduction for each level of severity was 23% for fatal casualties, 33% for serious casualties and 37% for minor casualties. In Belfast there was a 2% reduction in casualties, reflecting differences in the size, reach and implementation of the two schemes. Perceptions – in Edinburgh there was an increase in two factors (support for 20 mph and rule-following after implementation) supported by the qualitative data. Liveability – for both cities, there was a small statistical increase in liveability. Speed – mean and median speeds reduced by 1.34 mph and 0.47 mph, respectively, at 12 months in Edinburgh, with no statistically significant changes in Belfast. History, political context, local policy goals, local priorities and leadership influenced decision-making and implementation in the two cities.

Limitations: There was no analysis of active travel outcomes because the available data were not suitable.

Conclusions: The pre-implementation period is important. It helps frame public and political attitudes. The scale of implementation and additional activities in the two cities had a bearing on the impacts. The citywide approach adopted by Edinburgh was effective in reducing speeds and positively affected a range of public health outcomes. The city-centre approach in Belfast (where speeds were already low) was less effective. However, the main outcome of these schemes was a reduction in road casualties at all levels of severity.

Future work: Future work should develop a statistical approach to public health interventions that incorporates variables from multiple outcomes. In this study, each outcome was analysed independently of each other. Furthermore, population measures of active travel that can be administered simply, inexpensively and at scale should be developed.

Study registration: This study is registered as ISRCTN10200526.

Funding: This project was funded by the National Institute for Health and Care Research (NIHR) Public Health Research programme and will be published in full in *Public Health Research*; Vol. 10, No. 9. See the NIHR Journals Library website for further project information.

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Glossary

20-mph limit A restriction of speed to 20 mph or under, imposed using legislation and signs and lines. It does not include street furniture such as speed humps. This is the intervention being evaluated.

20-mph scheme A set of activities (such as signs, lines, enforcement, street architecture).

20-mph zone A traffic-calmed geographic area that includes road humps, speed cushions and/or chicanes to achieve compliance with the 20-mph limit. It is potentially more effective at reducing road traffic deaths and injuries than speed limits. It is often in specific areas such as around schools, and may or may not include street architecture such as signs and lines. Such zones are not included in the evaluation and are not to be confused with the Edinburgh 20-mph implementation zones.

Active travel (also known as active transportation or mobility) Walking or cycling as an alternative to motorised transport (notably cars, motorbikes/mopeds, etc.) for the purpose of making everyday journeys.

Carriageway The area of the road for moving and parked vehicles. This includes mixed-use (pedestrian and cycle) areas.

City centre Specific to one area of the city: the central area. This was the area of implementation in Belfast.

Citywide Including the whole of a city or council area as part of the implementation; this was the approach used in Edinburgh.

Community severance Transport-related community severance is the 'barrier effect' of transport infrastructure, or vehicles using that infrastructure, on the movement of pedestrians and cyclists, impeding access to the goods, services and social networks necessary for a healthy and fulfilling life.

Cost–benefit analysis A systematic approach to measuring the benefits of a decision or action minus the costs associated with the action.

Cost–consequences analysis An estimation of the costs as well as the health consequences and other consequences associated with one intervention, compared with an alternative intervention, for a health condition; these estimates are then presented in a disaggregated format (i.e. expressed in natural units) rather than combined in a single quantitative measure such as quality-adjusted life-years or monetary value.

Cost–utility analysis A type of economic evaluation that can help to compare the costs and effects of alternative interventions. A cost–utility analysis measures health effects in terms of both quantity (life-years) and quality of life. These are combined into a single measure of health: quality-adjusted life-years.

Data zone Data zone geography covers the whole of Scotland and lies in local authority boundaries (as of 2011). Data zones are groups of census output areas that have populations of approximately 500–1000 residents, and are the core unit for disseminating results from Scottish Neighbourhood Statistics [www.scotlandscensus.gov.uk/variables-classification/sns-data-zone-2011 (accessed 28 March 2022)].

Decision-theoretic approach A method of informing recommendations about whether or not interventions are likely to be effective in the absence of trial evidence and/or where the evidence is unlikely to be strong enough to satisfy conventional levels of statistical significance.

Health-enhancing physical activity Any form of physical activity that benefits health and functional capacity without undue harm or risk.

Implementation phase/period The time that the speed limit order (or traffic limit order) was implemented, as well the other components of the intervention such as 'signs and lines', and education and promotion. In Edinburgh there were three phases; the period of each was 16 weeks.

Implementation zone In Edinburgh, the 20-mph speed limit was rolled out by area; these were called 'implementation zones' by the city council.

Liveability Urban liveability describes communities that are safe, attractive, socially cohesive and inclusive, and environmentally sustainable. Such communities have affordable and diverse housing linked by convenient public transport, walking and cycling infrastructure to employment, education, open public spaces, local shops, health and community services, and leisure and cultural opportunities.

Mode (modal) shift/transfer Voluntary travel behaviour change between modes of transport. There is often a focus of interventions to shift travel behaviour from car and/or single-occupancy vehicles to active travel modes.

Moderate to vigorous physical activity The level of intensity of physical activity at which health benefits are accrued; this is what physical activity guidelines are based on.

National Travel Survey A household survey designed to monitor long-term trends in personal travel. It is the primary source of data on personal travel patterns by residents of England. It has focused on England only since 2013, and so is useful for historical trends [www.gov.uk/government/collections/national-travel-survey-statistics (accessed 28 March 2022)].

Output area An administrative geographic unit in Northern Ireland. There are 5022 output areas in Northern Ireland, each with a population of around 125 households and 350 people.

Problems, policy and politics streams John Kingdon's Multiple Streams Framework is a tool for understanding the policy process, and, more specifically, agenda-setting, through three separate streams: problems, policy and politics.

Programme theory An explicit theory or model of how an intervention, such as a project, a programme, a strategy, an initiative, or a policy, contributes to a chain of intermediate results and, finally, to the intended or observed outcomes.

Risk compensation A theory that suggests that people typically adjust their behaviour in response to the perceived level of risk, becoming more careful when they sense greater risk and less careful if they feel more protected. This is subject to some debate.

Road traffic accident Defined under various Acts of Parliament, including the Road Traffic Act 1988 (Great Britain. *Road Traffic Act 1988*. London: The Stationery Office; 1988), referring to when personal injury is caused to a person other than the driver of the vehicle, damage is caused to another vehicle or damage is caused to property or animals. The term 'accident' is increasingly being replaced by that of 'collision' (i.e. road traffic collision) on the basis that most events called accidents are predictable, and therefore preventable. The BMJ Publishing Group banned the use of the term in 2001. See https://travelwest.info/essential-evidence/75-accident-no-such-thing (accessed 28 March 2022).

Road traffic collision When personal injury is caused to a person other than the driver of the vehicle, damage is caused to another vehicle or damage is caused to property or animals. For the 20-mph speed limit evaluation we have chosen to use road traffic collision rather than road traffic accident.

Road traffic injury As reported through STATS19 (see below) by a police officer attending the location of the road traffic injury.

Roundels (speed roundels) Elongated circles laid in white thermoplastic markings on the road surface with the speed limit in the centre.

Safe systems road safety The systems approach to road safety endorsed by the World Health Organization, the Organisation for Economic Co-operation and Development, and the World Bank, and operated by increasing numbers of high- and middle-income countries. Sometime referred to as 'Vision Zero', which was initiated by the Swedish Parliament in 1996, with the ambition to achieve zero road traffic fatalities in a year.

Scottish Household Survey A continuous survey of the households and people of Scotland, providing a rich source of information covering communities, transport and local government (www.gov.scot/collections/scottish-household-survey/).

Small area An administrative geographic unit in Northern Ireland. There are 4537 small areas in Northern Ireland.

Speed bin A category of traffic speed, such as mph.

Speed limit order Speed limits set in traffic law to denote the maximum speed allowed. Limits do not usually refer to zones or areas, although they can appear within zones/areas. Limits require metal-backed signage on lamp columns or other sign posts by the side of the carriageway.

STATS19 Detailed road safety data about the circumstances of personal injury road collisions in the UK from 1979, the types (including make and model) of vehicles involved and the consequential casualties. The statistics relate only to personal injury events on public roads that are reported to the police, and subsequently recorded using the STATS19 accident reporting form by a police officer at the scene. Importantly, the system only records road traffic collisions where a police officer is present. Many injuries, mostly slight injuries, go unreported but may appear in Hospital Episode Statistics. As yet, attempts to unify STATS19 and Hospital Episode Statistics data have failed.

Traffic limit order The Local Authorities' Traffic Orders (Procedure) (Scotland) Regulations 1999 (Great Britain. *The Local Authorities' Traffic Orders (Procedure) (Scotland) Regulations 1999*. London: The Stationery Office; 1999) defines the process councils must follow when setting or varying speed limits in accordance with the 1984 Act (Great Britain. *Road Traffic Regulation Act 1984*. London: The Stationery Office; 1984), including where they wish to lower the speed limit on a road in a built-up area from 30 mph to 20 mph. Councils must also refer to a range of other regulations, guidance and directions. A principal traffic regulation order was required for the phased introduction of the revised speed limit. See also 'speed limit order'.

Traffic Signs Regulations and General Directions Legal requirements for the placement and format of traffic signs (Great Britain. *The Traffic Signs Regulations and General Directions 2016*. London: The Stationery Office; 2016).

Transport intervention A collective noun used to cover transport policies, programmes, schemes, projects and packages.

Value of a statistical life An economic value used to quantify the benefit of avoiding a fatality. It is also referred to as 'value of preventing a fatality'. Used by the Department for Transport (England) for calculating costs and savings related to casualties and injuries avoided.

Zone Either a 20-mph speed zone or an implementation zone (Edinburgh). In the text we make it clear which one we are referring to.

List of abbreviations

CBA	cost–benefit analysis
CI	confidence interval
DfT	Department for Transport
DTA	decision-theoretic approach
FG	focus group
GSV	Google Street View
MAPS	Microscale Audit of Pedestrian Streetscapes
MRC	Medical Research Council
MSP	Member of Scottish Parliament
NICE	National Institute for Health and Care Excellence
NIHR	National Institute for Health and Care Research
QALY	quality-adjusted life-year
SD	standard deviation
SLiPS	Speed Limits Perceptions Survey
SSC	Study Steering Committee
WHO	World Health Organization
WP	work package

Plain English summary

Background

Speed restrictions of 20 mph aim to decrease traffic speed and lower rates of collisions and casualties. They may also lead to wider benefits such as more pleasant communities and more people choosing to walk or cycle. This study evaluated the implementation of 20-mph speed limits in Edinburgh and Belfast.

Methods

We made use of routinely collected data and collected our own data via surveys and through speaking to people. We were interested in four key issues: (1) the political decision-making that led to the schemes; (2) how the schemes were delivered; (3) the impact of the schemes on perceptions, speed, collisions and casualties; and (4) whether or not the schemes were a sensible financial investment.

Findings

The topic of 20-mph speed limits had been talked about for many years before the schemes were implemented. Small steps were taken, including the introduction of schemes near schools and engaging the general public to try to build support. The large-scale schemes were broadly implemented as intended in terms of signage, education and enforcement. In Edinburgh, the overall percentage reduction in collision rates was 40%, and the reduction in casualty rates was 39%. Average speed was reduced by 1.34 mph at 12 months. At 12 months following implementation, the number of people who were supportive of the speed limits increased, as did their willingness to obey the limits. In Belfast only minor changes were seen for all outcomes. This may be because speeds were already low in the city centre, or could be a result of other factors.

Conclusions

The citywide approach in Edinburgh was effective at reducing speed, leading to reductions in collisions and casualties. Public perceptions and compliance with the speed limits also increased. These findings suggest that 20-mph limits can be implemented at scale, lead to positive public health benefits and are likely to be a sensible financial investment.

Scientific summary

Background

Transport initiatives, such as a reduction of speed limits to 20 mph, are expected to result in lower traffic speeds and fewer casualties, leading to an improvement in the perception of safety and a subsequent increase in cycling and walking.

Objectives

Objective 1

Objective 1 was to explore the decision-making processes that made 20-mph speed limits possible in Edinburgh and Belfast.

Objective 1 research questions:

- What factors led to the rise of 20-mph limits on the local political and policy agendas?
- What processes hindered and enabled agreement to implement the 20-mph policy?
- What are the likely facilitators of and barriers to long-term successful implementation of the 20-mph policy in these cities?

Objective 2

Objective 2 was to describe and understand the 'how' and 'what' of implementation (i.e. the implementation processes) of the two 20-mph speed limit interventions.

Objective 2 research questions:

- How was the 20-mph speed limit intervention implemented in each city?
- To what extent was the intervention delivered as intended in each city, and what adaptations were made to how the interventions were delivered?
- What were the barriers to and enablers of implementation in the two cities?

Objective 3

Objective 3 was to assess the impact of introducing 20-mph speed limits (primarily signage) on a range of health outcomes.

Objective 3 research questions:

- Does introducing 20-mph speed limits result in reductions in the speed of motorised vehicles?
- What is the impact on the number and type of road collisions and casualties?
- What is the impact on population perceptions of the safety and pleasantness of their home and work environments?
- What is the impact on the number of people (journeys) cycling or walking to work or study?

Objective 4

Objective 4 was to investigate people's experiences of, and interactions with, the multiple intervention activities, examining how and why behaviour change occurred or did not occur.

Objective 4 research questions:

- How are the effects (or lack of effects) experienced by various population subgroups?
- Do the qualitative and quantitative data support the hypothesised causal pathways and mechanisms?
- Are there any unintended/unexpected pathways and consequences?

Objective 5

Objective 5 was to carry out an economic evaluation of the 20-mph speed limit policies.

Objective 5 research questions:

- How do the public health benefits compare with the costs (potentially including opportunity costs) of implementation?
- What additional benefits or consequences are there that would make implementing 20-mph speed limits more or less cost-effective?

Objective 6

Objective 6 was to assess the transferability of 20-mph speed limit networks to other cities, towns or districts in the UK.

Objective 6 research question:

- What is the potential for implementing the 20-mph speed limit in other parts of the UK?

Methods

Design

This was a mixed-methods study that comprised an outcome, process, policy and economic evaluation of two natural experiments. The number and variety of individuals, groups and systems likely to be affected by the 20-mph limits, and the importance of their behaviour and the interactions between them, required an evaluation appropriate for the complexity of the intervention. Therefore, guided by a programme theory, we undertook a pragmatic, theory-based, mixed-methods evaluation comprising several studies that, between them, aimed to gather comprehensive data on the 20-mph intervention. The evaluation combined routinely and locally collected quantitative data, and primary quantitative and qualitative data. No single study, or methodological approach, could provide answers to all the research questions related to the overall and differential impacts of the intervention.

The outcome evaluation comprised before-and-after (controlled when possible) studies in Edinburgh and Belfast. Matched (geographic) controls were derived from the routinely collected data. Natural experimental approaches are specifically advocated when '[i]t is possible to obtain the relevant data from an appropriate study population, comprising groups with different levels of exposure to the intervention' (Craig P, Cooper C, Gunnell D, Haw S, Lawson K, Macintyre S, *et al.* Using natural experiments to evaluate population health interventions: new Medical Research Council guidance. *J Epidemiol Community Health* 2012;**66**:1182–6). In Belfast and Edinburgh, a number of stakeholders were already collecting data; it is more efficient to make use of available data, supplementing when necessary, than to replicate costly data collection. We explored and accounted for biases that are known to affect observational methods and, particularly, before-and-after studies. Specifically, the implementation of the interventions and the data that were collected was decided on and controlled by the local jurisdictions; the difficulties (ethical and logistical) of maintaining a robust evaluation design across urban areas meant that observational and natural experimental methods were employed. Outcomes included speed; total number of road collisions and casualties; public perceptions of safety, mode of travel, driver behaviour and attitudes; and liveability.

A substantial part of this study was a process evaluation to provide lessons and recommendations that could be applied to other urban areas wishing to implement new speed limits for motorised vehicles. This included interviews with key stakeholders and focus groups with members of the general population in Edinburgh and Belfast. To understand the context and transferability, we used key informant interviews, documentary analysis and media analysis.

For the economic evaluation, we planned to undertake a cost–utility analysis informed by data on changes in physical activity associated with any changes in active travel, supplemented with a partial cost–benefit analysis based on data on changes in collisions and casualties and cost–consequences analyses based on data on liveability, including perceptions of safety.

Results (research findings)

Pre implementation and process of adopting the 20-mph limits

Speed limits of 20 mph were deliberated in government discussions in both Scotland and Northern Ireland for many years before the schemes became a reality. In both cities the main policy goal was to reduce roads traffic collisions and casualties by slowing down traffic, although it was also intended to use the policy to achieve wider health and environmental objectives.

Strong leadership was key, and in both cities there were politicians who were important in moving the 20-mph speed restrictions forward. In both cities, small-scale restrictions were implemented around schools and these served as pilot schemes for the larger scale-up.

In Edinburgh, an area-wide pilot in the south of the city was also implemented. The main opposition to the 20-mph limits came from bus operators and taxi drivers in Edinburgh, owing to concerns about increased journey times, and the Federation of Small Businesses in Belfast, which was concerned that the public would be deterred from coming into the city, thereby causing a reduction in footfall for local businesses.

Implementation

The intervention activities were viewed as being broadly implemented as intended in both cities, with signage being one example; this is likely, in part, to be because of the rigid parameters afforded by the legislation, with only minor amendments being made. Enforcement activities, specific to the 20-mph limits, were limited by finite resources and competing priorities in both cities, and over time became 'daily business'. Public experiences of these activities varied, but an important finding was the disconnect between agents (e.g. police services) and the public in terms of how the interventions should be enforced. The processes associated with rolling out such a large scheme in Edinburgh were identified as challenging; a dedicated '20-mph team' within the local authority was created to address this. The creation of a dedicated official, and strong partnership and joined-up working, were identified as key facilitators of broad implementation and the delivery of a tailored education and awareness-raising campaign in Edinburgh. In Belfast, the government organisational structure was seen as a potential barrier to formal awareness-raising activities. This latter point may help to explain the different levels of awareness of the 20-mph speed limits that were evident between participants from the two cities.

Impact

Outcomes

In Edinburgh, the overall percentage reduction in casualty rates was 39% (the overall reduction in collision rates was 40%). The percentage reduction for each level of severity was 23% for fatal casualties, 33% for serious casualties and 37% for minor casualties. Mean and median speeds reduced by 1.34 mph and 0.47 mph, respectively, at 12 months. There was an increase in two factors related to perceptions: support for 20 mph and rule-following after implementation, which was supported by the qualitative data.

There were increases in several domains of the Microscale Audit of Pedestrian Streetscapes (MAPS) for Edinburgh (assessing liveability).

In Belfast, there was a reduction of 2% in collisions and a small but statistically significant increase in several domains of the MAPS. There was no statistical change in speed. Active travel outcomes could not be assessed owing to the lack of robust data. The qualitative data supported the findings of the quantitative data. There was evidence that the intervention had increased people's awareness of their own driving behaviour, and also the driving behaviour of others. In relation to perceptions of other drivers' behaviour, there was a consistent, but not conclusive, view from participants that other drivers were adhering to the limits, particularly in certain areas such as residential streets. Again consistently, it was perceived that driving at precisely 20 mph was being done by only a minority, but what the intervention had succeeding in doing was reducing the overall traffic speed within the city by a smaller extent, often from a speed that had been in excess of the previous limit. Insufficient data were available to determine the impact of the schemes on walking and cycling levels.

Economic evaluation

A full economic evaluation was not possible because of the absence of data on active travel and because of changes in the role of one of the economic evaluation leads, as a result of the COVID-19 pandemic. However, interim analyses to inform the progression decision suggested that it was plausible that the benefits of the scheme in Edinburgh, associated with the reduction in collisions and casualties, would exceed the costs. The observed increases in liveability strengthen this conclusion.

Conclusions

Speed limit interventions that use signs and lines (plus education and promotions) instead of traffic-calming infrastructure can reduce casualties, and have significant public support and compliance once implemented. To be most effective, they may need to be implemented at a citywide level, or in areas where speeds are high, and be combined with significant education and awareness-raising. Large-scale implementation may mean that there is a differential effect depending on factors such as time of day and volume of traffic (e.g. a driver would still be restricted to driving at 20 mph at 02.00 on an empty street and the impact on casualties and other health outcomes would be negligible).

The findings of this research suggest that 20-mph limits can lead to similar public health outcomes to 20-mph zones, and have the advantage of being less costly and less intrusive. We have not been able to undertake a full economic evaluation; however, the data suggest that it is likely that the benefits of the 20-mph limits in Edinburgh exceed the costs, and further work has been identified that could make these conclusions more robust and more generalisable to other contexts.

Implications for policy and practice

A speed reduction intervention such as 20-mph limits can be implemented at various scales, from around schools to cities and even countries. Although small-scale changes that have a direct impact on vulnerable road users are generally welcomed, any large-scale change, such as a citywide implementation of 20-mph speed limits, needs careful planning and consultation. Evidence of effectiveness is an important first step to getting the key stakeholders, such as the police, public transport authorities and local councillors, on board. This needs to be followed by addressing local concerns and potentially undertaking pilot studies. Linking with other policy agendas (such as climate considerations, health and tourism) can increase traction. Once implemented, education and promotion are key to getting the public to respond positively. The value of enforcement is complex: although the public in favour of the intervention want more visible enforcement, it may be considered as heavy-handed by others. In addition, police resources are scarce

and need to be considered pre implementation. The impact of these interventions can be primarily demonstrated through the reduction in collisions and in the number and severity of casualties. It was not possible to demonstrate the effectiveness of the 20-mph speed limits on other outcomes such as active travel (walking and cycling). However, although changes in casualties can be achieved through altering the speed limit, changes in active travel depend on changes in perceptions of safety related to speed. This consideration needs to be factored in to any roll-out of this intervention if seeking to increase active travel.

Recommendations for research (numbered in priority order)

1. Develop a statistical approach to public health interventions that incorporates variables from multiple outcomes. In our study we analysed each outcome independently of each other. Further research could incorporate prior knowledge such as estimates from Elvik's models (Elvik R. *The Power Model of the Relationship Between Speed and Road Safety. Update and New Analyses*. Oslo: Norwegian Centre for Transport Research; 2009) and from relevant systematic reviews within a Bayesian framework to allow for a broader modelling approach to the evaluation of the impact of 20-mph speed limits on the rate of road traffic collisions.
2. Develop population measures of active travel that can be administered simply, inexpensively and at scale. The audit of the active travel data sources has raised some important points about the difference between routinely and non-routinely collected data in terms of timing, frequency and location, and the impact that this can have on the evaluation of natural experiments. Of course, such monitoring has to be low burden and low cost for all stakeholders. The required quality of these data combined with the more distal (not directly affecting the outcome of interest) pathway from intervention (compared with, for example, proximal outcomes such as speed or collisions) raises crucial methodological challenges for future evaluation work.
3. Undertake further work on perceptions to establish (1) whether or not there are sustained changes in support for the intervention over time and (2) the relationship between perceptions around safety and support, and change in speed and other outcomes.
4. Further research is needed to assess the differential effectiveness of changes to speed, and effects on different socioeconomic groups and communities. There are many suggestions in the extant literature of differential risk, but it remains an important question as to what happens in different groups following the introduction of speed restrictions.
5. Further research is needed on the effects on noise and air pollution following the introduction of lower speed restrictions. This should be linked to the differential effects in different communities in the previous point.
6. Further research using direct observation of walking and cycling following the introduction of speed restrictions is needed. Direct observation, rather than relying on reported behaviour, will provide much more objective evidence to inform future planning and decision-making.
7. There remain some important broader methodological questions raised by this project. The Medical Research Council guidance on complex interventions was helpful up to a point, but we encountered a situation in which the intervention was not a single thing, but rather multiple things going on in different places at different times, in ways over which the researchers had no control. This was truly a complex intervention in a complex environment, occurring in real time. We learned a great deal, but we think that there is future scope for the complexity guidelines to be revisited to elaborate on some of the problems we encountered.
8. Undertake a full economic evaluation of 20-mph speed limit interventions.

Study registration

This study is registered as ISRCTN10200526.

Funding

This project was funded by the National Institute for Health and Care Research (NIHR) Public Health Research programme and will be published in full in *Public Health Research*; Vol. 10, No. 9. See the NIHR Journals Library website for further project information.

Chapter 1 Introduction

Context to the evaluation

In early 2015, Ruth Jepson and Paul Kelly were at a workshop where Eileen Hewitt from the City of Edinburgh Council was also present. Eileen was the Professional Officer for the 20-mph programme located in Strategic Planning, Services for Communities, City of Edinburgh Council. She talked about the plan for a citywide 20-mph intervention and the evaluation that the Council was planning. She also spoke about outcomes they would be interested in that might be outside the scope of the local evaluation. That short conversation led to the development of this research evaluation. Following the conversation, several further conversations took place between the developing research team and the 20-mph programme team in the City of Edinburgh Council. This led to the creation of an initial programme theory (see *Developing an evaluation programme theory*), the research questions that City of Edinburgh Council was interested in and the identification of the potential data sources that could be used to evidence the programme theory (see *Table 6*). At that time, connections were also being made with researchers in Belfast, another city that was planning to implement a pilot 20-mph scheme in its city centre. In November 2015 we submitted an outline application to the National Institute for Health and Care Research (NIHR), and received final approval for starting in March 2017. This meant that, by the time we started the evaluation, despite some delays in implementation in Edinburgh, we had missed some of the initial implementation stages and were unable to collect baseline data. The implications of this for the evaluation are discussed in *Chapters 4* and *6*.

The 20-mph intervention and implementation

The intervention was the introduction of a 20-mph speed limit. However, within the intervention there were four components, as described in *Table 1*, namely legislation, signage and road markings, promotion and education, and enforcement.

Edinburgh and Belfast took different approaches to the shape and scale of the implementation of the 20-mph speed limits, and so are described separately.

TABLE 1 Components of the intervention in the two cities

Component	Description	Organisations involved in delivery
Legislation	Traffic limit order or speed limit order	Edinburgh: CEC Belfast: Roads Service, DRD NI
Signage and road markings	20-mph road markings and traffic signs installed at the places where the speed limit changes. Smaller '20' repeater signs placed at regular intervals	Edinburgh: CEC Belfast: Roads Service, DRD NI
Promotion and education	In both sites a programme of awareness-raising and education would publicise and support the introduction of the 20-mph network, explain the benefits of lower speeds and ensure a smooth transition process	Edinburgh: CEC, Neighbourhood Partnerships, Police Scotland, schools, Sustrans Belfast: DRD NI, Department of the Environment NI, Police Service of NI, Belfast City Council, Sustrans, schools
Enforcement	Warnings and issuing of speeding tickets. Speeding tickets were not used in the early implementation phases. Instead, warnings (community speed concern letters) were issued	Edinburgh: Police Scotland Belfast: Police Service of NI

CEC, City of Edinburgh Council; DRD, Department for Regional Development (now the Department for Infrastructure); NI, Northern Ireland.

Edinburgh implementation

Edinburgh took a citywide approach to implementing the intervention, that is, streets that fell within the City of Edinburgh Council area. Prior to implementation, 50% of streets already had speed limits of 20 mph. Edinburgh implemented the 20-mph intervention in a further 30% of streets, which equated to an additional 1572 roads being reduced to 20 mph. This implementation resulted in 80% of streets in Edinburgh having speed limits of 20 mph (771 miles/1240.3 km), with a coherent network of 30-mph and 40-mph speed limits in the remaining 20% of streets. The 20-mph network was implemented under one citywide speed limit order. The city was split into seven implementation zones, and the intervention was implemented over three phases (*Figure 1* and *Table 2*). Each implementation phase took approximately 16 weeks over a total period of 24 months (starting in July 2016 and finishing in March 2018).

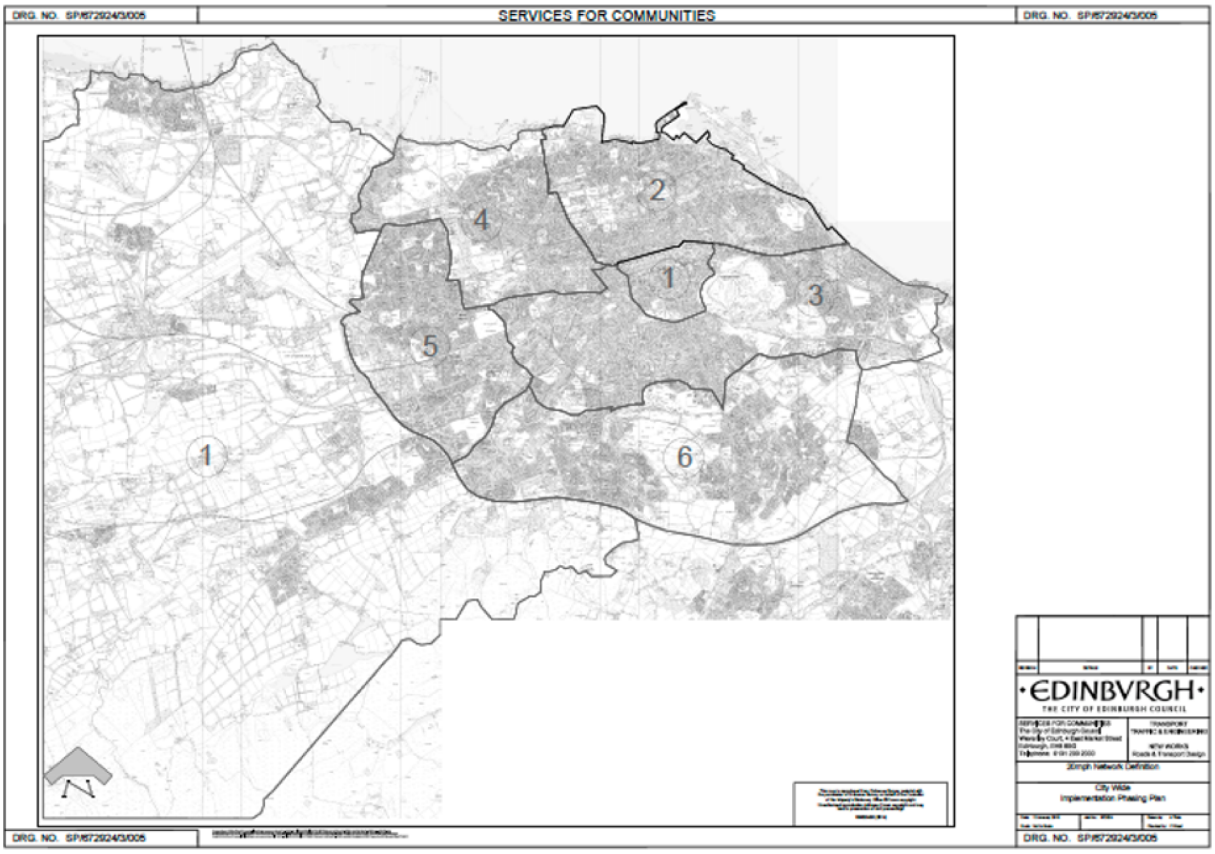

FIGURE 1 Map of the 20-mph implementation zones in Edinburgh. Copyright City of Edinburgh Council, contains Ordnance Survey data. © Crown copyright and database right (2021). All rights reserved. Ordnance Survey Licence Number 100023420.

TABLE 2 Description of implementation zones and phases of the 20-mph speed limits in the City of Edinburgh

Zone	Zone name	Implementation phase	Implementation date
1a	City Centre	1	31 July 2016
1b	Rural West	1	31 July 2016
2	North	2	28 February 2017
3	South Central/East	2	28 February 2017
4	North West	3	16 August 2017
5	West	3	16 August 2017
6	South	4	5 March 2018

Belfast implementation

Belfast implemented the 20-mph speed limit as part of a wider pilot project. Five pilot 20-mph speed limit zones were implemented in Northern Ireland. Four were residential areas only; the fifth and largest site was in the central area of Belfast, encompassing a total of 76 streets. This is the part of the city centre with the highest levels of pedestrian movement, cycle activity and bus facilities. Twenty streets were subject to a Prohibition of Traffic Order (pedestrian zone) and seven were partially subject to a Prohibition of Traffic Order. Comparable with Edinburgh, the 20-mph streets in Belfast are surrounded by a coherent network of 30-mph and 40-mph streets in the city centre. In Belfast the intervention was implemented in a single phase in a similar geographical area (starting in February 2016) (*Figure 2*).

One of the main stages in the initial application to NIHR was to develop a programme theory to understand what change in outcomes were expected to occur as a result of the intervention, and the potential pathways. This programme theory was used to develop our research questions and frame the evaluation.

Developing an evaluation programme theory

This study used a theory-based approach to evaluation. Programme theory is 'an explicit theory or model of how an intervention, such as a project, a program, a strategy, an initiative, or a policy, contributes to a chain of intermediate results and finally to the intended or observed outcomes'.[1] Proponents of this approach argue that evaluation should not be driven by methods, as all have their strengths and weaknesses. Rather, theories should be made explicit, and the evaluation steps (and design) should be built around them by elaborating assumptions, revealing causal chains and engaging all concerned stakeholders. To develop the programme theory, we also had to consider the

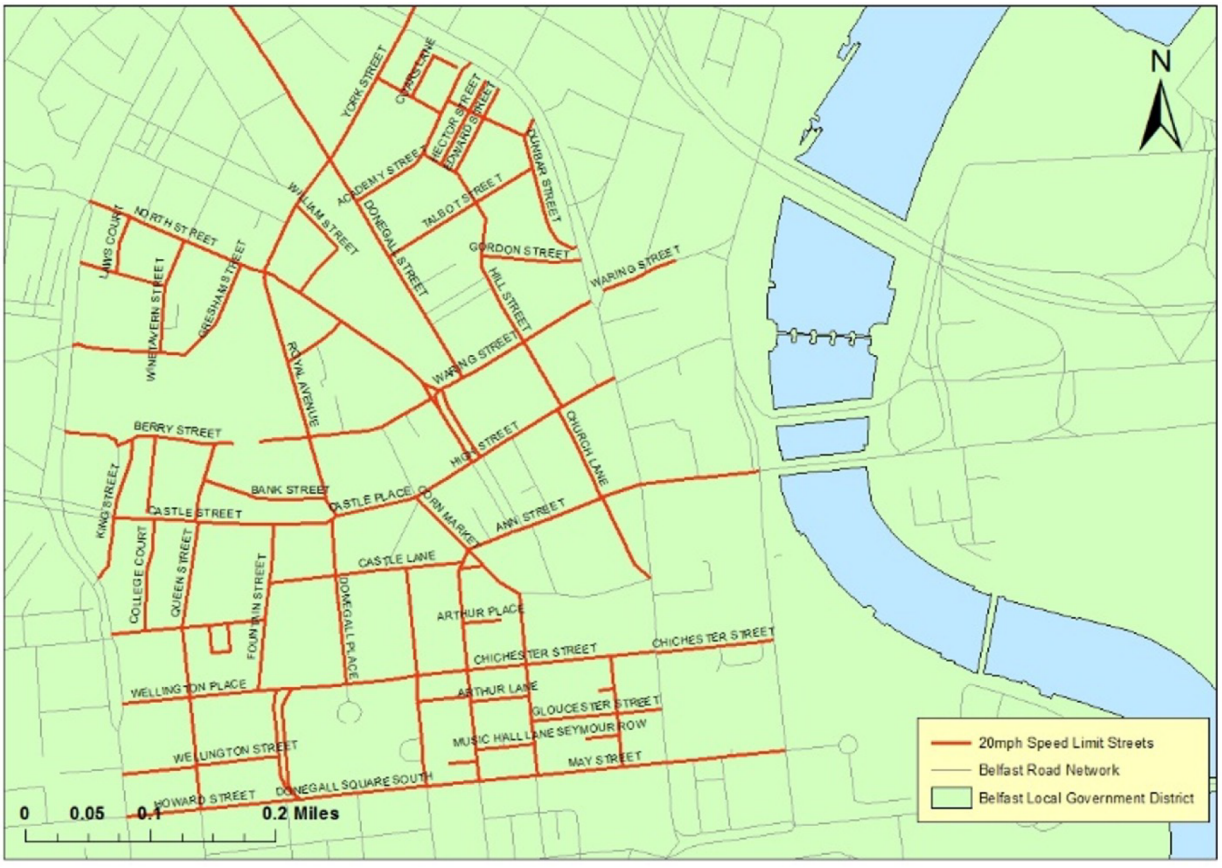

FIGURE 2 Map of the 20-mph implementation zones in Belfast. Provided by the Department for Infrastructure, Northern Ireland. Reproduced from Land and Property Services data with the permission of the Controller of Her Majesty's Stationery Office, © Crown copyright and database rights MOU203.

systems in which the 20-mph intervention was being implemented. Following the Medical Research Council (MRC) guidance,[2] considerable preliminary work was undertaken with stakeholders to develop an initial programme theory to inform, and be tested by, the outcome and process evaluations.[3] We also used a decision-theoretic approach (DTA), which is useful to inform recommendations about whether or not interventions are likely to be effective in the absence of trial evidence and/or when the evidence is unlikely to be strong enough to satisfy conventional levels of statistical significance.[4] It is also a useful way of framing an economic evaluation in which effectiveness is likely to remain uncertain.

The DTA has been described as a transparent way of using 'relevant knowledge, theory and data from observational and experimental studies to [assess whether] an intervention is sufficiently unlikely to cause net harm [and if so, to] assess if the benefit relative to its cost is sufficient for the intervention to be recommended'.[5] The approach is particularly useful when 'inappropriate adherence to underpowered randomised controlled trials'[5] might undermine support for safe and cost-effective interventions with strong theoretical and observational support.

We also considered the role that systems play in modifying the effects of any intervention. Interventions, such as the introduction of 20-mph speed limits, are events in a system and they are best understood by employing systems theory. A system is a 'set of actors, activities and settings that are directly or indirectly perceived to have influence in or be affected by a given problem situation'.[6] Within a system, an intervention exerts its influence by changing relationships, displacing existing activities and redistributing and transforming resources.[7] Systems theories are connected to both ontological and epistemological views. The ontological view implies that the world consists of integrative levels (systems). The epistemological view implies a holistic perspective emphasising the interplay between the systems and their elements in determining their respective functions. It is thus opposed to more atomistic approaches in which objects are investigated as individual phenomena.

Complex interventions take on the characteristics of complex systems: non-standardisation, interaction, multiplicity, emergent properties. Complexity is a scientific theory that asserts that some systems display behavioural phenomena that are completely inexplicable by any conventional analysis of the system's constituent parts.[7] In other words, a complex system is one that is adaptive to changes in its local environment, is composed of other complex systems and behaves in a non-linear fashion (i.e. change in outcome is not proportional to change in input). A complex system approach helps to understand the wider implications of the intervention and the interactions that occur between components of interventions.

First iteration of the 20-mph programme theory

A very initial programme theory was developed (*Figure 3*) in discussion with the City of Edinburgh Council, but needed refinement. We therefore undertook a review of existing literature to refine the theory, and spoke to key stakeholders. This led to the programme theory that was used in the research bid to NIHR.

Second iteration of the 20-mph programme theory (review of evidence)

The second iteration of the programme theory built on the first by drawing on the wider research evidence, complemented by discussions held with, and documents provided by, local authority officers delivering the 20-mph speed limit intervention in Edinburgh. There follows a summary of the evidence that we used to develop the theory.

Transport and health

The links between transport policy/infrastructure and health are well known.[8,9] Transport has the potential to promote health, through enabling greater access to work and social activities and encouraging physical activity, and also to have a negative impact on health through road traffic collisions and influencing exposure to noise and air pollution.[10] Transport interventions that are beneficial for public health include campaigns to prevent childhood injuries, increase bicycle and motorcycle helmet use, promote the wearing of seat belts and apply traffic-calming measures.[10]

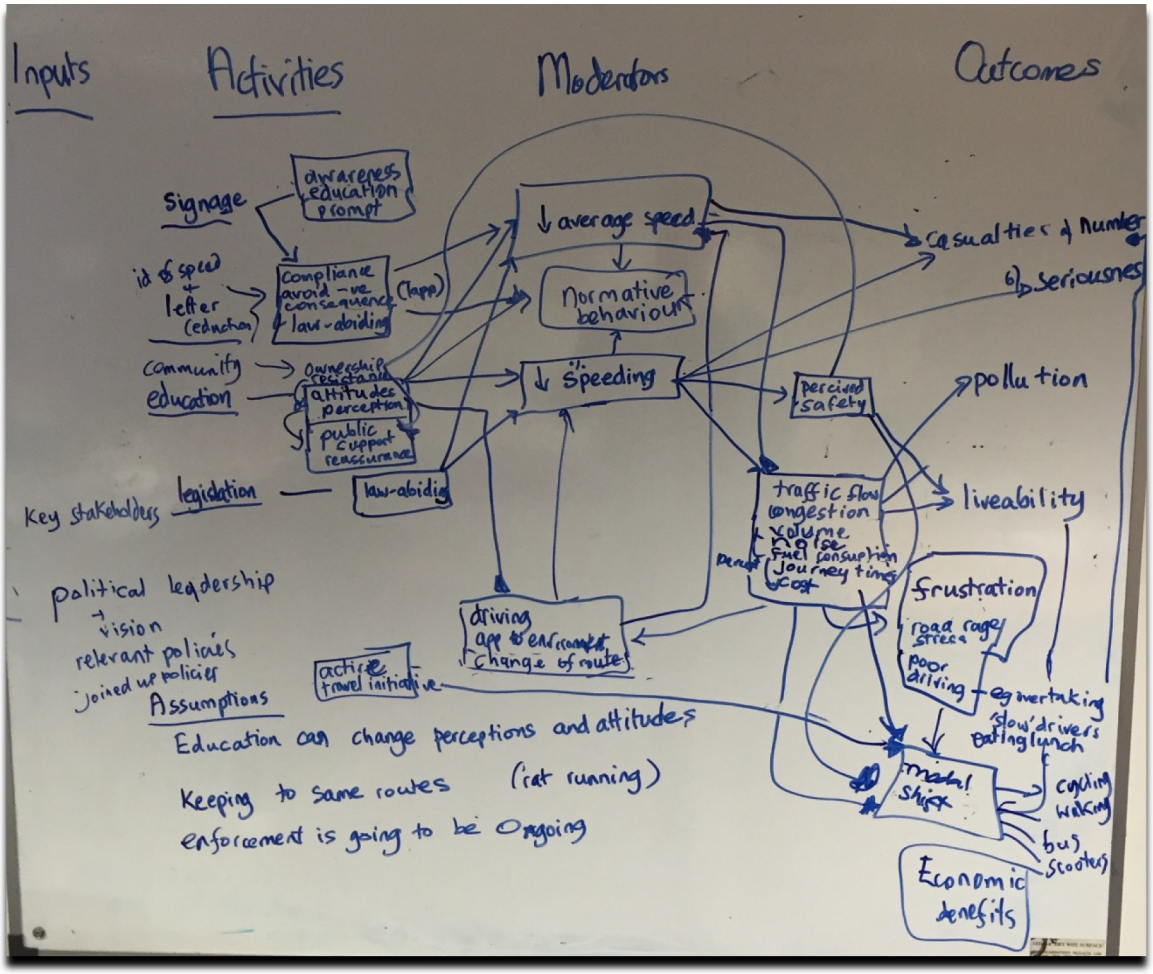

FIGURE 3 First iteration of the programme theory.

The recognition of these links to health has led to more integrated transport and health policies in the UK and internationally. For example, Scotland's Transport Strategy in 2016 set out a vision for transport to play a significant role in enhancing health.[11] Furthermore, the importance of integration between public health and transport and planning policy was stressed by England's public health White Paper, *Healthy Lives, Healthy People*.[12] At international policy level, the Toronto Charter[13] discusses the importance of active travel in having a significant impact on sustainable development.

There are several transport-related issues that can negatively affect health, including a lack of infrastructure to support active travel; motorised vehicles being prioritised with regard to road space;[14] and the direct and indirect health-related impacts of motorised traffic behaviour, for example collisions and perceived lack of safety.[15] Traffic speed, in particular, is a key risk factor in road traffic incidents, with regard to both the risk of a collision and injury severity.[16] For vulnerable road users such as pedestrians and cyclists, the relationship between speed and injury is even more severe.[16] Reductions in traffic speed can, therefore, offer multiple public health benefits. These include reducing the risk of traffic collisions and the resulting severity of injuries, encouraging greater uptake of physical activity (through increased walking and cycling), and improving pleasantness and social cohesion on streets.[17] Implementing 20-mph speed limits in the UK is becoming increasingly common.[18,19] For example, citywide 20-mph speed restrictions were introduced in Portsmouth[20] and Bristol,[21] and other local authorities have introduced 20-mph restrictions on a smaller, more localised scale on a pilot basis (see Cleland *et al.*[22] for a summary).

In both Bristol and Edinburgh, the success of pilot schemes led to the decision to roll out a 20-mph speed limit across the whole city. An umbrella review investigating the health implications of 20-mph

(30-kph) zones and speed limits[8] concluded that these schemes can reduce accidents, injuries, traffic speed and volume; improve perceptions of safety; and be cost-effective. Speed zones of 20 mph typically involve the use of physical traffic-calming measures such as speed humps or chicanes,[23] whereas 20-mph speed limits generally rely on road signage and legislation, and less so on physical traffic-calming measures.[24] Of the 10 studies identified in the umbrella review, only two studies focused on speed limits specifically. Both studies provided evidence to support a reduction in injuries and casualties through a reduction in speed, although the effects on walking and cycling levels were unclear and need further investigation. Our more recent review[22] also reported that 20-mph 'zones' were effective in reducing collisions and casualties. For 20-mph 'limits', the evidence was lacking, which is the primary reason why this evaluation was undertaken.

Road casualties

The term 'casualties' in this context refers to a person killed or injured in a road accident, and can be subdivided into killed, seriously injured and slightly injured.[25] Motorised transport is responsible for about 120,000 deaths and 2.4 million casualties each year in the European region.[26] In Great Britain in 2014, nearly 25,000 people were killed or seriously injured as a result of road accidents, with the proportions of fatalities of pedestrians and cyclists similar to those for the European region, at 25% and 6%, respectively.[25] Casualties were socially patterned, with levels of casualties higher in areas of socioeconomic disadvantage.[27]

Pedestrians and cyclists are at a disproportionately higher risk of death and serious injury than those using motorised vehicles.[26] Data from 1997 for the European region indicated that pedestrians and cyclists accounted for 22% of people involved in serious car crashes for that year, but 33% of those killed,[28] showing their increased risk of death if involved in a collision. Vehicle speed is related to the likelihood of a crash occurring in the first instance; at higher speeds, a driver's time to react is shorter, stopping distance is greater and manoeuvrability is compromised.[29] Vehicle speed is also a significant factor in determining the severity of road traffic casualties. It is suggested that the fatality risk for a pedestrian struck by a vehicle travelling at 31 mph is twice that of being struck by a vehicle travelling at 25 mph, and five times that of being struck by a vehicle travelling at 19 mph.[30] These data align with those from other studies; one study suggested that pedestrian risk of death reaches 10% at 24 mph, 25% at 32 mph, and 50% at 41 mph.[31] One modelled estimation is that a reduction in average speed of 1 mph is associated with a reduction in casualties of 5%, rising to 6% when applied to urban areas.[32]

Previous signage-only 20-mph schemes have provided encouraging results with regard to speed reduction. Results from the pilot scheme in Edinburgh indicated an overall reduction in speed of 1.9 mph on roads where 20-mph limits were implemented.[33] In Portsmouth this figure was 1.3 mph,[20] and the figures for two pilot areas in Bristol were 1.4 mph and 0.9 mph.[34] If these speed reductions were observed in future 20-mph speed limit implementation areas, it would be reasonable to assume a potential decrease in casualties of between 6% and 12%. Furthermore, on roads that were characterised by speeds of > 24 mph before 20-mph speed limits were introduced, an average reduction of 6.3 mph was observed in Portsmouth, and of 3.3 mph in Edinburgh.[20,33] These figures indicate potentially even greater positive implications for casualty rates and severity. In Portsmouth, a reduction of 22% in reported road casualties was observed when comparing the 3 years prior to implementation with the 2 years post implementation.[20] However, there is little evidence to suggest that such schemes will substantially reduce health inequalities in relation to traffic casualties.[8] It is unclear at present whether this is an absence of effect, or an absence of evidence. Some evidence suggests that the greatest beneficial impact in the future will be evident in the least deprived areas,[27] a not uncommon problem with some public health interventions.[35]

Perceived safety

Preliminary findings from our developmental, preparatory, qualitative work with key stakeholders of the 20-mph scheme in Edinburgh identified perceived lack of safety as a substantial factor in deterring greater levels of walking and cycling.[3] Where pedestrians and cyclists are safer, levels of walking and

cycling tend to be higher.[15] A literature review reported that 20-mph limits without traffic calming significantly increased walking and cycling by increasing actual, and perceived, road safety.[36,37] One potential mechanism for this action may be in reducing the speed differential between motorised vehicles and cyclists on the roads, thus increasing cyclists' perceived and actual safety.

Physical (in)activity

Physical inactivity, as characterised by a lack of sufficient physical activity (< 150 minutes/week), is in the top 10 leading behavioural risk factors for global mortality.[38,39] In highly physically active cohorts, reductions as high as 41% in all-cause mortality have been observed.[40] Physical inactivity is responsible for at least 6% of coronary heart disease, 7% of type 2 diabetes and 10% of both breast cancer and colon cancer cases worldwide.[38] The global prevalence of physical inactivity is 31%[41] and the World Health Organization (WHO) has targeted a reduction in physical inactivity of 15% by the year 2030.[42] Research is needed to develop and evaluate large-scale interventions with the potential to increase population levels of physical activity.

Walking and cycling have been shown to reduce the risk of all-cause mortality by 11% and 10%, respectively,[43] and it is estimated that up to 50% of short trips could be easily walked or cycled.[15] Active travel (physical activity primarily through walking and cycling for commuting and utility purposes) has been suggested to be 'the most practical and sustainable way to increase physical activity on a daily basis'.[44,45] There is evidence that active travel can be a major contributor to meeting physical activity guidelines,[44] and is associated with a healthy body weight and composition.[46] Guidance from the National Institute for Health and Care Excellence (NICE) recommends that environmental- and policy-level actions will be required to support walking and cycling, such as reducing the actual and perceived dangers associated with travel on roads.[47] Findings from the 20-mph pilot project in Edinburgh showed an increase of 7% in journeys made on foot, and an increase of 5% in journeys made by bike.[33] Similarly, increases of at least 10% in walking and at least 4% in cycling were found in the Bristol pilot project.[34]

A 20-mph speed limit and social cohesion/connectedness and liveability

There is evidence that walkable streets, as well as encouraging physical activity, also strengthen social support networks, which is of great public health relevance.[45] The impact of traffic behaviour on communities has long been demonstrated. For example, in Bristol,[48] it was found that residents living on streets characterised by heavy traffic volumes had significantly fewer friends and acquaintances on their street in comparison to those residing on streets with light traffic volumes. In discussing the implications for their findings,[48] it was suggested that similar findings of low social connectedness were likely to be found on most UK cities' streets with high traffic flow. In Bristol, on streets with light traffic, occasional speeding was sufficient to create the perception of a dangerous environment; speeding traffic was the most frequently cited cause of stress among residents.[48]

Speeding behaviour by traffic has been identified as the greatest antisocial behaviour problem in local communities, based on data from the British Crime Survey (now the Crime Survey for England and Wales).[49] Traffic behaviour, in particular aggressive and speeding-type driving styles, provide unnecessary noise and can contribute to stress-related illness in residents,[50] indicating that lowering speed limits to 20 mph would result in increased liveability in cities. Dorling[51] proposed that traffic travelling at lower speeds requires less space to move safely, allowing more space and scope to enhance the pleasantness of residential environments, and more space for pedestrians, planting, seating and other street furniture.[10]

Edinburgh pilot implementation

An area-wide 20-mph limit was implemented across south-central Edinburgh, with the scheme launched in March 2012. The speed limit was changed to 20 mph on 28 streets; these streets, along with 20 streets that retained a 30-mph limit, were monitored before (May and June 2011) and after implementation (May and June 2013) for traffic speeds. In the 20-mph streets, average speeds fell by

1.9 mph (from 22.8 to 20.9 mph); in 12 streets where average speeds exceeded 24 mph before implementation, a greater average reduction of 3.3 mph was found. Four streets saw slight increases in average speed after implementation, and four streets had average speeds of > 24 mph. Speeds also reduced on the roads that were maintained at 30 mph, by a smaller magnitude of 0.9 mph (from 26.3 to 25.4 mph). More than 1000 household surveys were carried out before and after implementation. Before implementation, 68% supported 20-mph speed limits; after implementation, this figure rose to 79%. Strong support increased from 14% to 37%. Opposition to the limits reduced from 6% to 4% after implementation. There was a net increase of 7% for journeys on foot, an increase of 5% for journeys by bike and a decrease of 3% for car journeys. This evaluation was small scale and did not utilise the robust methods that were used in the evaluation reported here.

The second iteration of the programme theory was based on the existing evidence base, and hypothesised theories of the effect of the intervention on the outcomes. Although we knew what had happened in other cities, we did not know what would happen in Edinburgh and Belfast.

Figure 4 shows the programme theory we used in the application for funding.

Third iteration of the programme theory

The research team undertook a qualitative study that involved engagement with a range of stakeholders, including the general public.[3] The inclusion of stakeholders in theory development is considered good practice.[52] In the third iteration, the previous (second) iteration was further informed and refined through two streams of activity: semistructured interviews with key stakeholders involved with, or who had a vested interest in, Edinburgh's scheme, and focus groups and interviews with members of the general public covering a range of demographics. Data collected were used to help identify mechanisms of change explaining how intervention activities were proposed to lead to purported changes in health outcomes (*Figure 5*).

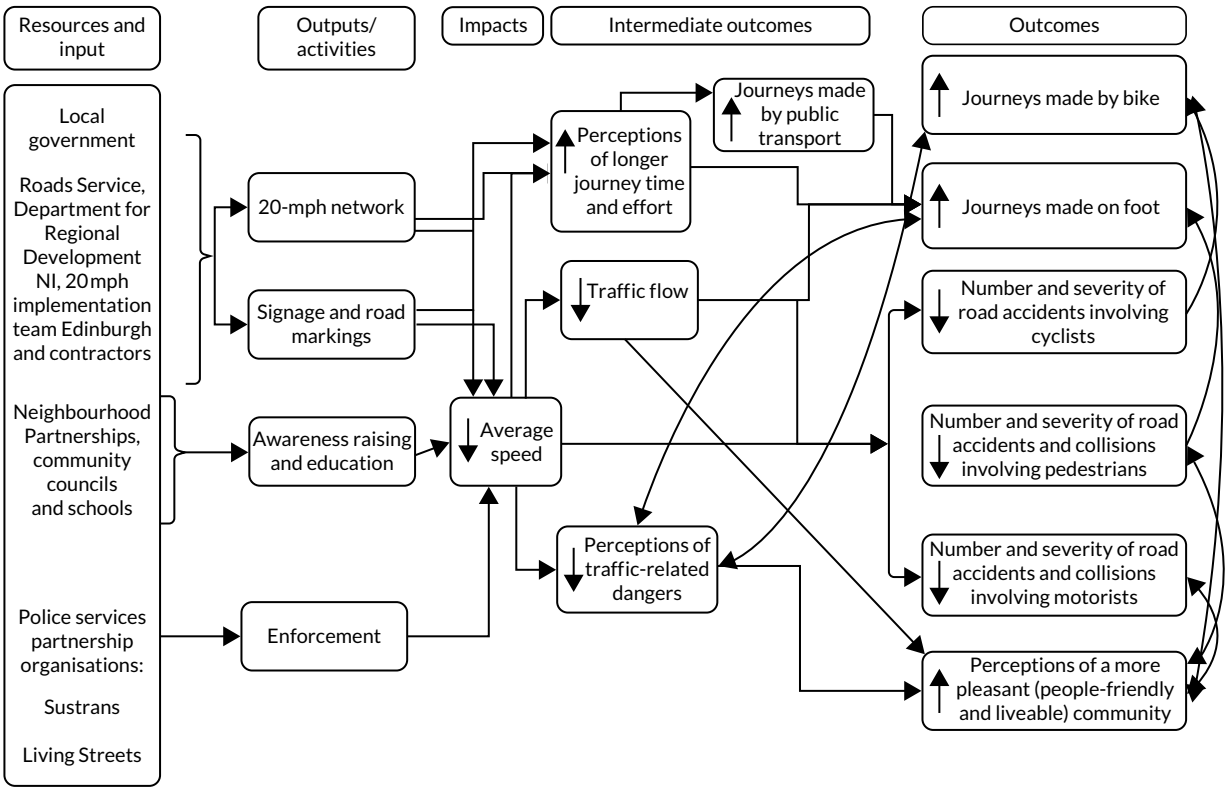

FIGURE 4 Second iteration of the programme theory. Reproduced with permission from Turner *et al.*[4] © 2018 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/BY-NC-ND/4.0/).

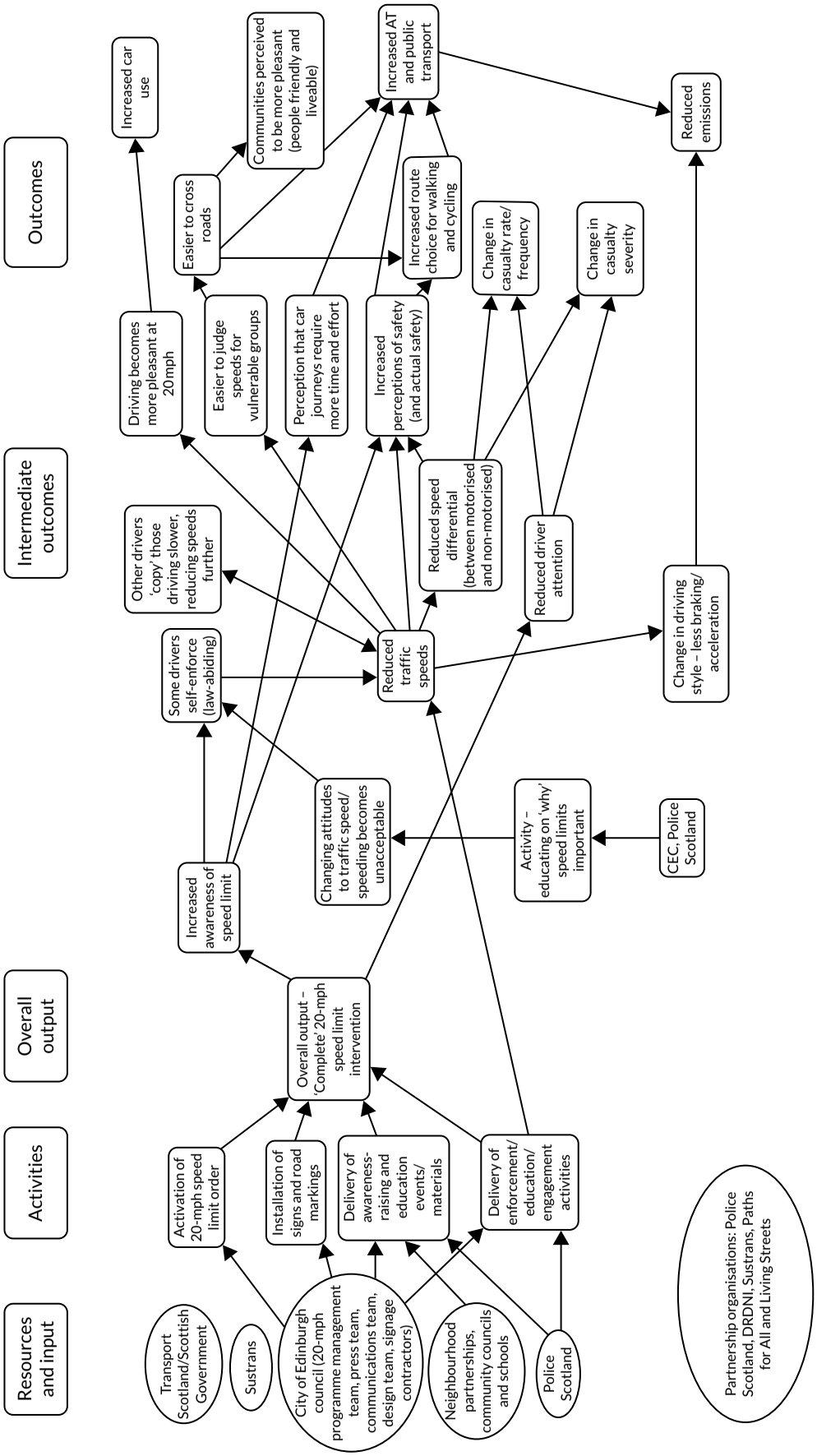

FIGURE 5 Third iteration of the programme theory. AT, active travel; CEC, City of Edinburgh Council; DRDNI, Department for Regional Development Northern Ireland.

The programme theory outlined in this version demonstrates the complexity of the pathways (i.e. perceptions, behaviours) through which the reduced peak and average speed is purported to lead to more objective health-related outcomes such as active travel. Consequently, this study was designed to address not only the question of the effects, impacts and costs of the intervention, but also the question of how and why the intervention and effects/impacts occurred or did not occur.

The fourth iteration (*Figure 6*) provided us with an outcomes framework, which we used to facilitate our appraisal of the various data sources to be used. We organised the outcomes into useful categories by theme and time. Once the data sources were appraised, the outcomes framework further helped us plan and conduct the analysis and reporting of some of the outcomes we observed.

The final project used a range of theoretical frameworks to assist in the interpretation of the results. These theories provide different 'lenses' through which to analyse the policy process, and provide a theoretically grounded underpinning to the analysis. A theory-based evaluation enables the use of a realist perspective to understand what worked, for whom, in what circumstances and why.[53] During the initial period of the grant development, we developed our programme theory further. However, as described in previous sections, this was a hypothesised model. We did not have any evidence to suggest that the intended inputs or activities would be available and/or implemented in the two cities, nor did we have evidence that the input, activities and implementation strategies would result in the desired change in outcomes. The process of developing this model was iterative, and involved important contributions from the Study Steering Committee (SSC) when we presented early drafts of the findings and our explanations. During the evaluation, other smaller side projects were undertaken to contribute to the evidence base, and to help answer some of the questions raised by the SSC; for example, a small-scale master's dissertation looking at the impact on air pollution was undertaken, supervised by a member of the SSC (Dr Stefan Reis) (see *Chapter 4*, *Air pollution*).

At the end of the project, based on the findings from all work packages (WPs), our programme model was further refined to create our final model, as shown in *Figure 7*. A description of each box on the final model is included in *Appendix 1*.

Overall research aim and objectives

Aim

The overall aim of this research was to evaluate and understand the processes and effects of citywide 20-mph legislation in Edinburgh and Belfast. The focus was on health-related outcomes (active travel and casualties) and the pathways and processes that cause this transport policy to have public health benefits. Alongside this was research into the political, historical and policy factors (conditions) that led to the decision to implement the new speed limit, with a view to understanding possible transferability and national impact.

Objectives and research questions

The objectives and research questions were developed to link in broadly with the programme theory.

Objective 1

Objective 1 was to explore the decision-making processes that made 20-mph speed limits possible in Edinburgh and Belfast.

Objective 1 research questions:

- What factors led to the rise of 20-mph limits on the political and policy agenda?
- What processes hindered and enabled agreement to implement the 20-mph policy?
- What are the likely facilitators of and barriers to long-term successful implementation of the 20-mph policy in these cities?

FIGURE 6 Fourth iteration of the programme theory.

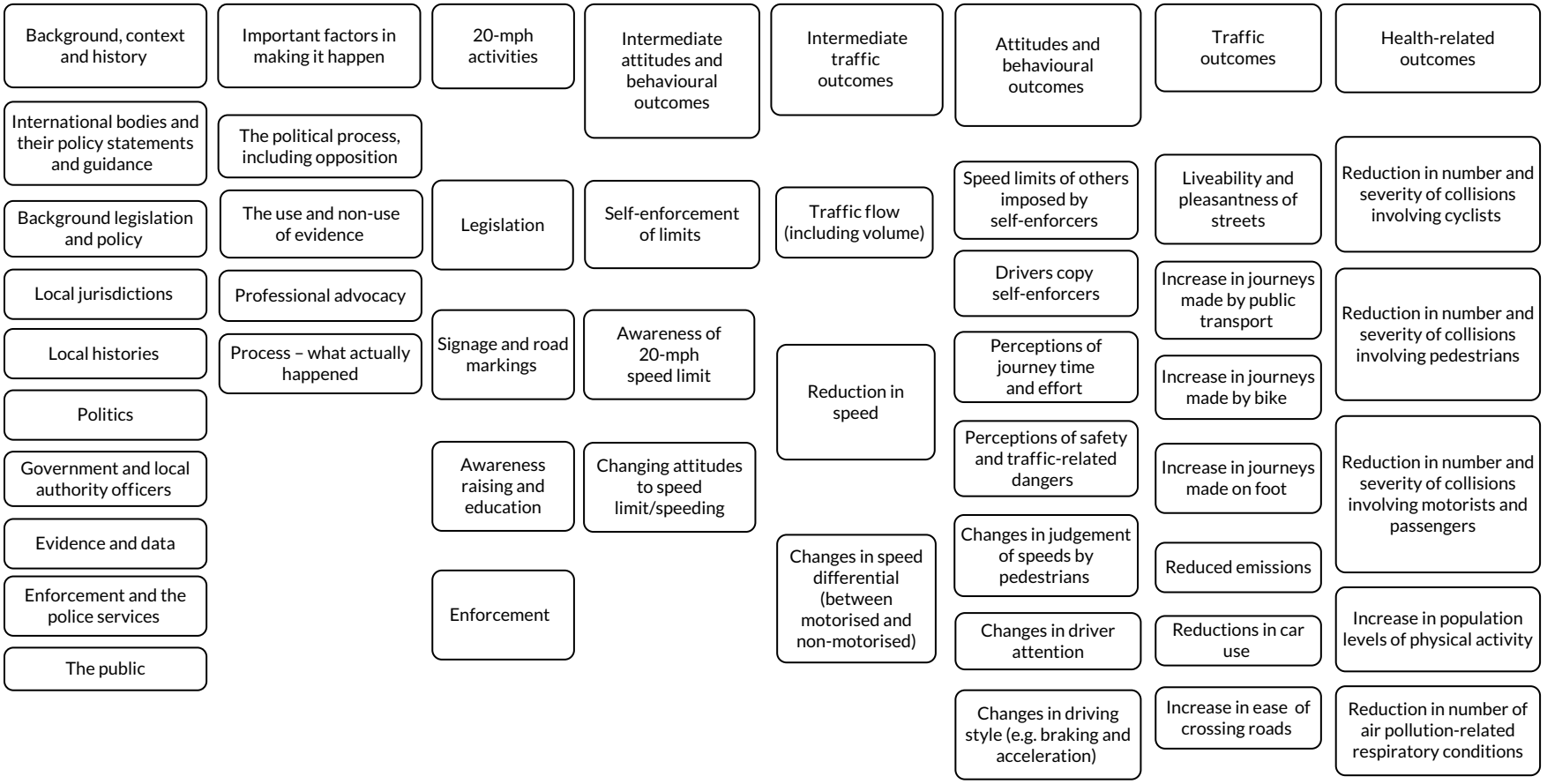

FIGURE 7 Final programme model.

Objective 2

Objective 2 was to describe and understand the what and how of implementation (i.e. the implementation processes) of the two 20-mph speed limit interventions.

Objective 2 research questions:

- How was the 20-mph speed limit intervention implemented in each city?
- To what extent was the intervention delivered as intended in each city, and what adaptations were made to how the interventions were delivered?
- What were the barriers to and enablers of implementation in the two cities?

Objective 3

Objective 3 was to assess the impact of introducing 20-mph speed limits (primarily signage) on a range of health outcomes.

Objective 3 research questions:

- Does introducing 20-mph speed limits result in reductions in the speeds of motorised vehicles?
- What is the impact on the number and type of road collisions?
- What is the impact on participants' perceptions of the safety and pleasantness of their home and work environments?
- What is the impact on the number of people (journeys) cycling or walking to work or study?

Objective 4

Objective 4 was to investigate peoples' experiences of, and interactions with, the multiple intervention activities, examining how and why behaviour change occurred or did not occur.

Objective 4 research questions:

- How are the effects (or lack of effects) experienced by various population subgroups?
- Do the qualitative and quantitative data support the causal pathways and mechanisms outlined in the programme theory?
- Are there any unintended/unexpected pathways and consequences that need to be incorporated in the model?

Objective 5

Objective 5 was to carry out an economic evaluation of the 20-mph speed limit policies.

Objective 5 research questions:

- How do the public health benefits compare with the costs (potentially including opportunity costs) of implementation?
- What additional benefits or consequences are there that would make implementing 20-mph speed limits more or less cost-effective?

Objective 6

Objective 6 was to assess the transferability of 20-mph speed limit networks to other cities, towns or districts in the UK.

Objective 6 research question:

- What is the potential for implementing the 20-mph speed limit in other parts of the UK?

Overall methods and approaches to the evaluation

This was a mixed-methods evaluation, comprising several studies that, between them, aimed to gather comprehensive data on the 20-mph interventions. The number and variety of individuals, groups and systems likely to be affected by the 20-mph limits, and the importance of their behaviour and the interactions between them, required an evaluation appropriate for the complexity of the intervention.[2] Guided by our programme theory, we undertook a pragmatic, theory-based, mixed-methods evaluation. It combined routinely and locally collected quantitative data with primary quantitative and qualitative data. No single study, or methodological approach, can provide answers to all the research questions related to the overall and differential impacts of the intervention. Similar mixed-methods approaches have been used in other transport-related natural experiments.[50,54] This research commenced in September 2017, approximately 14 months after implementation began in Edinburgh and 19 months after implementation in Belfast. The draft project report was submitted in March 2021. In summary, we used the following methods.

The outcome evaluation was a natural experiment, comprising before-and-after (controlled when possible) studies in Edinburgh and Belfast,[55] using matched geographic control zones whenever possible. Natural experimental approaches are specifically advocated when '[i]t is possible to obtain the relevant data from an appropriate study population, comprising groups with different levels of exposure to the intervention'.[55] In Belfast and Edinburgh, a number of stakeholders were already collecting data; it is more efficient to make use of available data, supplementing when necessary, than to replicate costly data collection. We explored and took account of the biases that are known to affect observational methods, particularly before-and-after studies, using appropriate methods.[55] Specifically, the implementation of the interventions and the data that were collected were decided and controlled by the local jurisdictions and the difficulties (ethical and logistical) of maintaining a rigorous experimental study (such as a randomised controlled trial) across urban areas meant that observational and natural experimental methods were employed.[2]

To understand the context and transferability, we used key informant interviews, documentary analysis and media analysis. These are described in more detail in the following sections.

The economic evaluation team used the DTA, using relevant knowledge, theory and data from empirical studies (observational and, if available, experimental) to form a view on:

- whether or not the intervention is likely to cause harm
- if not, whether or not, in the light of the (low) cost of an intervention, it is likely to be effective enough to be cost-effective, even if effect sizes do not reach conventional levels of statistical confidence.

A substantial part of this study was a process evaluation following the MRC guidance on process evaluations of complex interventions[56] to provide lessons and recommendations that could be applied to other urban areas wanting to implement new speed limits for motorised vehicles.

Changes to the original protocol

Over the 3.5 years of the evaluation, we had to make some changes to the study protocol. The main change was the adjustment of our analyses of active travel. We had originally anticipated that the data that we received from the local jurisdictions and Sustrans would be suitable to be able to undertake longitudinal analyses and to measure the effects of the intervention on cycling and walking. However, this proved to be impossible for a number of reasons, linked to how, when and where the data were collected (see *Chapter 4*, *Active travel*). This affected not only the outcome evaluation, but also our ability to do an economic evaluation (see *Chapter 6*). This meant that the cost–utility analysis based on the relationship between changes in active travel and physical activity-related health improvements, with associated changes in length and quality of life, could not be estimated. In addition, emissions data

were not available and the data gathered in the study suggested that perceptions of safety had not changed much following the introduction of 20-mph speed limits. In practice, the final analyses planned were not possible owing to changes in the role of the health economist co-leading the economic evaluation (NC). He is a government economist and was moved full time to COVID-19-related work.

Therefore, in the report, we present the findings from the analyses carried out to inform the progression decision, update these where we can with the data we have, reflect briefly on how these updated findings may affect the overall conclusions from the economic evaluation and give pointers to the further work that would be required to complete the planned analysis.

In our investigation of implementation (see *Chapter 3*), the original aim was to conduct interviews with 20 implementation agents: six in Belfast and 14 in Edinburgh. In Edinburgh, we originally intended to investigate implementation processes at both the citywide level (six interviews) and the local level, following implementation at each geographical phase (totalling eight interviews). Through the early interviews, it became apparent that there was less of a direct implementation role at the local level and the role of individuals/organisations previously identified as potential implementation agents was minimal. Therefore, no interviews took place at the local level; instead, we increased the number of interviews held with agents involved at the citywide level.

We had originally anticipated recruiting members of the general public to focus groups (see *Chapter 5*) via sampling based on responses to routinely collected quantitative surveys (e.g. the Edinburgh People Survey conducted by City of Edinburgh Council). However, only anonymised data sets were provided to the research team, meaning that this was not possible. We instead maximised the recruitment of participants via other means.

We had intended to evaluate the impact on health inequalities, but the data were not suitable. We had wanted to use rates by Index of Multiple Deprivation to investigate casualties by area of deprivation. We examined the multiple deprivation profiles of the implementation areas in Edinburgh and Belfast for the control site selection process. The difficulty was that these areas range in size from 11 to 170 Data zones or small areas, which are the geographic units at which the multiple deprivation measures are allocated. However, the distributions were mostly heavily skewed. Although we sampled the focus groups to reflect low-income areas, and people from different ethnicities, we found no data suggesting that there were differences in impact perceived by the different populations.

Finally, we had expected to conduct workshops to discuss the implementation and transferability of the intervention, but we were not able to because of the COVID-19 pandemic. We have, however, gained additional funding from the Wellcome Trust to undertake other forms of dissemination activities (see *Chapter 7*, *Maximising the impact of the findings: dissemination*).

The idea that complexity is paramount in public health and other policy arenas has gained widespread traction in recent years.[57–59] The MRC has published a series of guidelines over the years[2,60] to help researchers manage the tricky issues that need to be grappled with when doing research on matters defined as complex. Various guidelines have been developed and the problems with doing evidence synthesis when complexity is involved are widely discussed (e.g. Noyes *et al.*[61]). The current project sits firmly within the complexity arena: the actual intervention was multiplex, and variable things were done at different times, in different places, in different ways, in environments with varying histories, politics, organisations and personnel. The initial programme theory was the first opportunity to describe the complexities involved. Through subsequent iterations, we elaborated the theory to take account of local political and organisational dynamics and to identify some of the uncertainties involved. The interventions were not under the control of the researchers, and the fidelity of the individual components was pretty well impossible to assure. Although we framed our work in terms of being theory based, we have not overtheorised our work; instead, we have tried to disentangle the component parts of the activities in both cities and empirically get as much purchase as possible on

what was going on. Our report reflects this approach, and, we hope, provides insights into the effectiveness of this type of intervention, as well as the difficulties in doing research in real-world settings and with the constraints described here.

Ethics arrangements and data management

This was a complex evaluation comprising several studies. Different types of data were being utilised, which required different levels of ethics approval. The study was conducted in line with MRC guidelines[62] and the Economic and Social Research Council ethics framework.[63] Ethics approval was sought from the Moray House School of Education Ethics Committee, University of Edinburgh (see *Chapters 3* and *4* for details). The committee has three levels of approval:

- level one – study that includes only anonymised data (e.g. large data sets)
- level two – study that includes primary data collection (qualitative and quantitative)
- level three – study that includes primary data collection from vulnerable groups (e.g. children, those who do not have capacity to consent).

The evaluation required level one and level two, but not level three, approval. When there were minor changes in research instruments, further ethics committee advice was sought.

The evaluation utilised a mixture of routinely collected and primary data:

- Routinely collected data – many of the data were collected by other parties (e.g. local councils and Sustrans) as part of routine monitoring and evaluation. We received data from these sources only after they had been fully anonymised.
- Primary data – the main primary data collected by the evaluation team were qualitative and survey data. For these types of data, we sought informed consent to participate. All data will be held for 5 years on university password-protected computers. Paper documents such as consent forms were stored in locked filing cabinets.

Patient and public involvement

For a project such as this (evaluating a natural experiment/an intervention that we were not delivering), our approach to patient and public involvement was about engaging the public and various public bodies. Considerable impetus for getting the 20-mph limit to the stage of implementation in Edinburgh and Belfast originally came from public opinion and public interest groups such as Sustrans and Living Streets. Both organisations worked closely with the team as the original research proposal was developed. They were particularly helpful concerning the collection of process and outcomes data. Sustrans also partly funded the intervention in Edinburgh and a senior member of Sustrans was a co-applicant on the grant. Sustrans has significant experience in collecting data on active travel and collected many of the data in Edinburgh and Belfast. Living Streets also advised on data collection methods for the liveability assessments. Both organisations were represented on the SSC and were involved in dissemination.

We conducted qualitative work (focus groups and interviews) with members of the public, which informed the development of the original research proposal and objectives. The data collected from this work allowed us to produce the original programme theory that framed what (and how) we evaluated in the project, an example being the development of questions for the perceptions survey. This qualitative work involved 37 members of the public from various professions and public groups: teachers, NHS workers, young professionals, older adults, school parent councils, students and residents. Stakeholders were also involved with the evaluation strategy and the planning and design of the research. We conducted 17 stakeholder interviews from a broad range of public service organisations: the council, charitable organisations (Sustrans, Living Streets), public transport companies (bus and taxi), driver groups (Institute for Advanced Motorists, Motorcycle Action Group), the local health board, Transport Scotland and the Scottish Fire and Rescue Service.

The SSC had representatives from public transport (Lothian Buses); driver groups (Institute for Advanced Motorists); charitable organisations (Living Streets, Sustrans, Belfast Healthy Cities); the local health board; Transport Scotland; the Department for Infrastructure, Northern Ireland; Police Scotland; and the City of Edinburgh Council.

During the project we engaged with 29 stakeholders from a broad range of public service organisations [the council, charitable organisations (Sustrans), the local health board, government agencies (Transport Scotland; Department for Infrastructure, Northern Ireland), police], 159 members of the public (across 24 focus groups in the two cities), the parents of young/school-aged children, older adults, pedestrians, cyclists, motorised transport users, young drivers, residents/community councillors, public transport companies (bus and taxi) and driver groups (Institute for Advanced Motorists, advanced motorcyclists).

Other groups, such as Belfast Healthy Cities; the Department for Infrastructure, Northern Ireland; the Police Service of Northern Ireland; Belfast City Council; and the City of Edinburgh Council 20-mph implementation team, also sat on the SSC and assisted with providing access to data and with dissemination.

Structure of the report

Rather than have a single methods section followed by results, each of the consequent chapters focuses on a different research objective (*Table 3*) that relates to our initial programme theory. We undertook the work in different WPs.

Each of these chapters focuses on explaining and/or evidencing the programme theory, which continued to evolve during the evaluation period. The final programme theory is described step by step in the next chapters. Each chapter focuses on specific objectives and sections of the programme theory, highlighting where effects were found or not found (*Figure 8*).

TABLE 3 Research objectives, summary of methods and approaches, and chapter in report

Research objectives and related WPs	Summary of methods and approach	Chapter in report
To study the factors that led to the eventual implementation of the schemes (pre implementation), including the historical and political contexts in both cities. WPs 2 and 3	• Key informant interviews • Documentary analysis • Print media analysis	*Chapter 2*
To understand barriers to and facilitators of successful implementation in Edinburgh and Belfast. WPs 2 and 3	Stakeholder interviews	*Chapter 2*, *Chapter 3*
To assess the impact of introducing 20-mph speed limits (primarily signage) on a range of health outcomes. WP1	Before-and-after (controlled when possible) studies in Edinburgh and Belfast	*Chapter 4*
To explore and refine the causal pathways and mechanisms in the conceptual model. WP2	• Focus groups with a range of population groups in Belfast and Edinburgh • Triangulation with results from WP1	*Chapter 2*, *Chapter 5*
To carry out an economic evaluation of the 20-mph speed limit policies. WP4	Cost–utility analysis supplemented with partial cost–benefit and cost–consequences analyses	*Chapter 6*
To assess the transferability of 20-mph speed limit networks to other cities, towns or districts in the UK	Key informant interviews	*Chapter 1*, *Chapter 7*

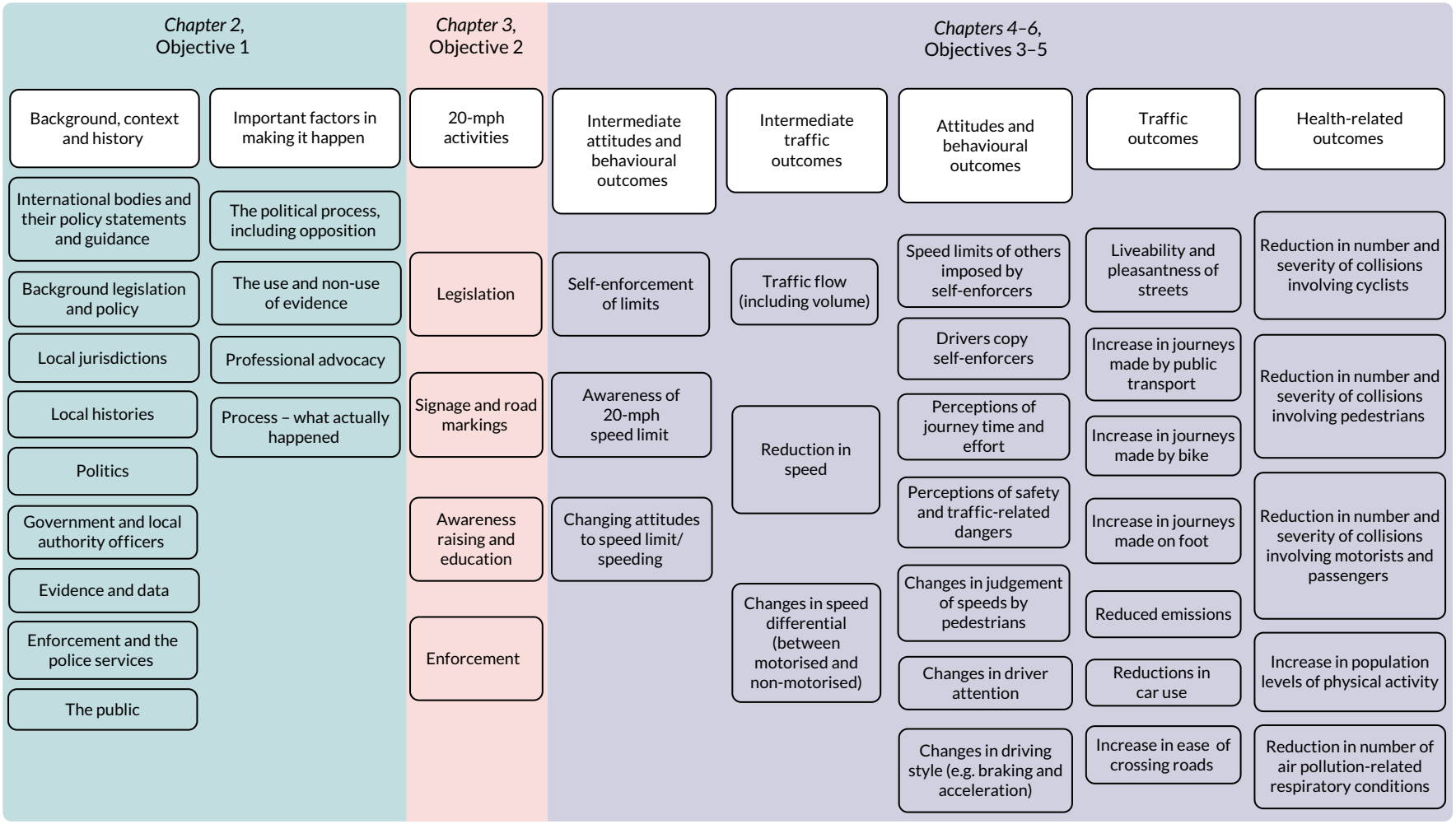

FIGURE 8 Programme theory and relationship to chapters and objectives.

Chapter 2 How did 20 mph become a reality in Edinburgh and Belfast?

Introduction

Given that most public health interventions are implemented in complex systems, we explored and explained the political, historical, policy and cultural factors involved in implementation in both sites. As both Northern Ireland and Scotland have legislative powers for transport, this part of the evaluation provides useful learning across jurisdictions and may help inform transferability UK wide and development of implementation guidance.

Objective and research questions

The objective was to explore the processes that led to the development and implementation of 20-mph speed limit policies in Edinburgh and Belfast.

The research questions were as follows:

- What factors led to the recent rise of 20-mph limits on the political/policy agenda in the UK?
- What processes hindered and enabled agreement and implementation of the 20-mph policy in different cities?
- What are likely to be the facilitators of and barriers to long-term successful implementation of the 20-mph policy in the two cities?

This chapter focuses on the first two columns ('background, context and history', and 'important factors in making it happen') of the explanatory model outlined in *Figure 7*. We explored the processes involved in 20 mph becoming a political reality in the two cities using three data collection methods: (1) document analysis, (2) stakeholder interviews and (3) print media analysis. The methods and analysis and results of the documentary analysis and stakeholder interviews are reported in *Documentary analysis and stakeholder interviews*, with *Print media methods and analysis* focusing on the methods and analysis of the print media.

Documentary analysis and stakeholder interviews

Documentary analysis

We conducted searches of key websites to identify documents relevant to 20-mph speed limits, including UK-wide developments, as well as national and local activity. We were interested in identifying any legislation, policy documents, research reports and official statistics, as well as other written records of events including political speeches, official announcements, committee reports and debates. The websites searched included those of the national governments (Scotland and Northern Ireland) and the City of Edinburgh Council. We did not look for local council documents in Belfast as the scheme was led and managed by the government of Northern Ireland (through the Department for Regional Development, which is now the Department for Infrastructure).

We compiled a timeline of the publication of relevant documents for each of the two cities. These were shared with a range of stakeholders in each city to confirm their comprehensiveness. Any additional documents that were identified by the stakeholders were added to the list. Each interviewee (see *Stakeholder interviews* for details) was also asked to verify the completeness of the list. In total we

identified 19 documents for Edinburgh, published between 2000 and 2016, and 20 documents for Belfast, published between 2001 and 2016. These documents consisted of policy statements, reports of council decisions and reports of responses to public consultations. We obtained a copy of all documents and conducted thematic content analysis using NVivo 12 software (QSR International, Warrington, UK). An inductive approach was used, whereby no themes were proposed a priori. Documents relevant to Edinburgh and Belfast were analysed separately. Data were extracted independently by two members of the research team (KM and MPK), and the final coding framework for each city was agreed through discussion.

Stakeholder interviews

Interviews were conducted with 16 stakeholders: eight in Edinburgh and eight in Belfast. These were the same stakeholders as discussed in *Chapter 3*, *Stakeholder interviews* (more details of the methods can be found there). The Edinburgh-based participants consisted of council officers ($n = 2$), elected members of the council ($n = 3$), Sustrans officers ($n = 2$) and a civil servant. In Belfast, seven interviews took place with eight interviewees including representatives from government departments ($n = 6$), the Police Service of Northern Ireland ($n = 2$), a public transport organisation ($n = 1$) and a third-sector organisation ($n = 1$). Interviewees could represent more than one department. Interviews took place in November 2017: 25 months after the legislation went live, and 22 months after the signage was implemented. An additional interview (interview 8) took place with two representatives from the Department for Infrastructure (responsible for implementing the intervention) in March 2019 (38 months post implementation of signage) following completion of the initial '3-year pilot' phase.

Briefly, a semistructured interview guide was used to discuss topics such as involvement in the scheme, the main drivers for getting it onto the policy agenda, barriers to and facilitators of moving it forward and key individuals or groups. The audio files were transcribed verbatim and uploaded to NVivo 12 for analysis. As with the document analysis, the analysis of the interviews was approached inductively using thematic content analysis and conducted separately for each city. Data were independently coded by two members of the research team (KM and MPK), and the final coding framework for each city was agreed through discussion. The findings from the documents and interviews for each city were triangulated to provide a more complete picture of the political processes and events in each city.

Results from the document analysis and interviews

The findings from the documents and interviews from the two cities are presented together under 11 key themes that emerged from the analysis (*Table 4*).

TABLE 4 Description of key themes identified from documentary analysis and interviews

Theme	Brief description
The political context of the two cities	Local and national government responsibilities for 20-mph speed limits
Agenda-setting and key policy drivers	How 20 mph reached the policy agenda
Leadership for 20 mph	Importance of leadership
The gradualist political–bureaucratic process	How 20 mph moved up the policy agenda
The role of evidence	How scientific evidence affected decision-making
Facilitators of and influences on momentum	How momentum was maintained
Support for 20 mph	Levels of support for 20-mph speed limits
Opposition to 20-mph speed limits	The main opposition groups
The role of 'pilot' schemes	How pilot schemes influence decision-making
Implementation	Factors involved in implementation decisions
Sustainability	Factors influencing sustainability

The political context of the two cities

Although the Scottish Government sets policies and targets for the design of streets, road safety and other related issues, responsibility for implementation of these policies lies with local authorities. In 2014 the Scottish Government published its *Good Practice Guide for 20 mph Speed Restrictions*;[64] however it was left to local authorities to set appropriate speed limits on local roads to meet local circumstances. According to interviewees from Edinburgh, the Scottish Government officials in transport were passively supportive of Edinburgh taking 20-mph speed limits forward, but they remained distant from implementation of the scheme.

In contrast, Northern Ireland operates differently to the rest of the UK, in that decision-making about traffic regulation takes place centrally by the devolved government. The Department for Infrastructure is responsible for all aspects of the road network, including speed limits, bus lanes and changes to infrastructure. The local authority plays no role in decision-making nor implementation of speed limits or other traffic regulation measures.

Agenda-setting

In relation to the 20-mph initiatives, there was a long process in both cities, with many years of thinking, planning and discussion. In Edinburgh this began in 2000 when the council adopted its first Local Transport Strategy, which included the installation of 20-mph 'zones' in residential areas, outside schools, and in shopping areas, as one measure to 'eliminate deaths on the City's roads'.[65] In Belfast, discussions began about the same time, with the publication of *New Directions in Speed Management*,[66] which set out the evidence from speed-related research in the UK and concluded that a framework was needed in Northern Ireland for determining speeds on all roads with limits that were rational, consistent, readily understood and appropriate for the circumstances.

A key driver for 20-mph speed limits in both cities was road safety, particularly near schools, and both cities initially introduced full-time or part-time 20-mph schemes close to schools. Road safety seems to have been a key driver for scaled-up action beyond schools, although this was not explicit in Belfast and there was no apparent problem with safety or collisions in the city centre. There was, however, significant regeneration taking place across the city to create a more welcoming environment, particularly for tourists, and it was intended that 20-mph speed limits would contribute to this through reductions in traffic in the city centre. Increasing walking and cycling levels was also a driver in both cities, although it was noted, particularly among stakeholders in Belfast, that there was limited empirical evidence to support the notion that reducing speed limits would increase the number of people walking and cycling.

Leadership for 20 mph

There was political leadership for 20 mph in Edinburgh from the Scottish Labour Party councillor, and then convener of Edinburgh's Transport, Infrastructure and Environment Committee, Lesley Hinds, and broad political buy-in across the Scottish National Party and Scottish Labour administrations. There was not a clear political divide in terms of support and opposition, but key individuals across parties and other stakeholder groups were in support of the initiative:

> *There wasn't widespread party-political support. It was much more about individuals in different political parties, council officers in the active travel and activists within the local community not necessarily aligned with any party, just community council activists and other community groups, schools, parents, boards and stuff like that that were pushing for this.*
>
> *Elected member*

The Scottish Conservatives did not see it as one of their priority areas but did not express strong opposition. Community councils showed active support and were considered to have been critical in giving the politicians sufficient 'weight' to drive the initiative forward:

> *I don't think politically there was the strength of feeling to drive this forward without the active participation, the active support of the community councils . . . I don't think it would have been possible to*

> *get it through. In fact, I'm sure it wouldn't have been possible to get it through the committee if there hadn't been active support from the community councils that were affected . . . It was the community support for this that made it possible.*
>
> *Elected member*

In Belfast there were key politicians who were important in moving the idea forward. One Social Democratic and Labour Party member introduced a private member's bill:

> *Conall McDevitt's private member's bill, which was 2012 when he first introduced that to the Northern Ireland assembly, and that was the Road Traffic (Speed Limits) Bill and that was to make the 20 mph the default speed limit on residential roads across Northern Ireland.*
>
> *Translink*

The bill took some time to go through the legislative process and eventually fell owing to the cost of signage to implement it. As a way to reduce costs it was suggested that 20mph should be made the default limit, meaning only a few remaining 30mph would need to have signs, but it seems there was insufficient support for 20mph and cost continued to be cited as a barrier to their implementation.

As with Edinburgh there was not a clear party-political divide between those who supported 20-mph speed limits and those who did not; rather, across all parties, there were individuals who were for and individuals against. In Belfast, all parties were supportive of the intended outcomes – safer streets and more walking and cycling – but there were mixed views on whether 20-mph speed limits was the best intervention for achieving those outcomes.

The gradualist political–bureaucratic process

In both cities the approach was gradualist, with a range of reasons to implement 20-mph speed limits building over time, creating a progressive move towards gaining support and, ultimately, the scheme being implemented. In both cities, discussions about 20-mph speed limits started to emerge around the year 2000; however, clear decisions to implement, subject to public and stakeholder consultations, did not happen till 14 or 15 years later. Neither city had major landmark events that caused a radical shift in policy. Rather 'baby steps' were taken to nudge closer and closer to the idea and the eventual reality over a sustained period of time, such that what eventually unfolded was seemingly inevitable.

Over the long lead-in time, the narrative shifted from a specific intent to reduce collisions and casualties to 20-mph speed limits contributing to a wider range of aspirations. This was particularly the case for Edinburgh. For example, in the 2011 report on the consultation on the 20-mph South Edinburgh pilot proposal, the council argued that its approach would contribute to living longer, healthier lives, free from crime and disorder, in well-designed, sustainable places with access to amenities and services, where it is possible to value and enjoy the built and natural environments, protect and enhance them for future generations and reduce the local and global impact of consumption and production.[67] The subsequent Local Transport Strategy, published in 2014, emphasised the contribution of speed restrictions to enhancing 'the Council's reputation for excellence, inclusivity and responsiveness to Edinburgh's communities'.[68] In Belfast, the narrative was less aspirational, although the proclaimed benefits of 20-mph speed limits also broadened over time. For example, 20 mph was linked to overcoming social exclusion and strengthening rural communities, as well as aiding wider economic and environmental objectives.

The role of evidence

In Edinburgh there were references to evidence throughout the various documents. In 2010, the City of Edinburgh Council explored the relationship between speed and risk. The evidence was interpreted to mean that risk increases slowly until impact speeds of around 30 mph. They noted

that even though the risk of pedestrians being killed at 30 mph is relatively low, approximately half of pedestrian fatalities occur at or below this impact speed. The council argued that vehicle speed was the single most important factor in the severity of road collisions, with the risk of fatal injury to pedestrians being more than eight times higher at 30 mph than at 20 mph. They noted that the chance of survival halves again between speeds of 30 mph and 40 mph. They also observed that streets with slower traffic are more attractive to residents, pedestrians, cyclists and children, and can improve the environment for business and social interaction. They argued that cars travelling at 20 mph generate less noise. An emphasis was put on the fact that a high proportion of pedestrian and cyclist casualties occur on the busiest streets in the inner areas of the city. In many of these streets, average speeds were already fairly low, but a 20-mph limit had potential to help rebalance them in favour of pedestrians and cyclists. Although evidence on speed and risk was referenced in Edinburgh, there was little mention of any evidence on the effectiveness of 20-mph speed limits. There seemed to be an assumption that 20 mph 'works' despite very little reference to any empirical evidence.

In Belfast, a range of evidence was presented to support the 20-mph initiative from 2010. A 1996 document on setting local speed limits presented a range of data.[69] It argued that 20-mph zones are very effective at reducing collisions and injuries. It noted that 20-mph speed limits may reduce overall average annual collision frequency by around 60%, and the number of collisions involving injury to children may be reduced by up to two-thirds. Twenty-miles-per-hour zones, it observed, help reduce traffic flow, where research has shown a reduction in injuries by over one-quarter as well as a modal shift towards more walking and cycling.[69] The authors pointed out that signed-only 20-mph speed limits generally led to only small reductions in traffic speeds, and that therefore 20-mph speed limits are most appropriate for areas where vehicle speeds are already low.[69]

The same document pointed out that there was clear evidence of the impact of reducing traffic speeds on reducing collisions and casualties, as collision frequency is lower at lower speeds, and when crashes do occur, there is a lower risk of fatal injury at lower speeds. It noted that, on urban roads with low average traffic speeds, any 1-mph reduction in average speed can reduce the collision frequency by around 6%.[69] It suggested that there may also be environmental benefits, as, generally, driving more slowly at a steady pace will save fuel and carbon dioxide emissions, unless an unnecessarily low gear is used. Later documents made reference to the economic benefit of preventing collisions and casualties. For example, a document published in 2014 stated that the average value of preventing a collision is approximately £72,700.[70]

Facilitators of and influences on momentum

Lower speed limits were seemingly consistently viewed as a good idea by City of Edinburgh Council. Scottish Government guidance at the time of the South Edinburgh pilot was that 20-mph interventions had to involve physical traffic-calming infrastructure, but the Scottish Government allowed the South Edinburgh pilot to go ahead as a trial of a 'signs-only' approach. Following the pilot, the Scottish Government relaxed its guidance on 20 mph such that 20-mph 'zones' with physical infrastructure were no longer necessary and 'limits' using only signs was an option. This meant that citywide implementation would be more feasible and would cost substantially less. This seems to have been the most significant factor in the council increasing momentum for large-scale roll-out.

Subsequently, NICE recommended the introduction of 20-mph speed limits without physical measures to avoid unnecessary accelerations and decelerations in a bid to promote smooth driving and speed reduction and to improve air quality.[71] Then *Northern Ireland's Road Safety Strategy to 2020*[72] outlined a commitment for Transport Northern Ireland to pilot a number of 20-mph speed limits without additional self-enforcing engineering measures, the most substantial of which became the Belfast city-centre intervention.

Support for 20-mph speed limits

The public were supportive of 20-mph speed limits in Edinburgh, and this support was thought to stem from accident statistics and concerns about road safety:

> *But also because there was demand from the local residential groups who wanted to bring 20 miles an hour in. So, we would continually be getting letters and deputations, etc. to bring it in.*
>
> *Elected member*

Other lobbying groups were equally important, including Sustrans, Living Streets and cycling organisations:

> *I think the most coherent lobby in favour, I would say, was the cycling lobby. Yeah, there was, I mean, Living Streets were also in there in favour, but the strongest and most coherent component was the cycle lobby.*
>
> *Council officer*

Views among the public were mixed in Belfast. Although there was relatively wide support for limits in residential areas and near schools, the city-centre scheme elicited mixed reactions. Those who expressed objections had concerns over traffic flow and the potential economic impact. There were also concerns that 20 mph may conflict with other government commitments to reduce greenhouse gas emissions and improve air quality. If speed restriction measures were to be put in place, drivers favoured the signs-only approach over the physical traffic-calming measures owing to the 'wear and tear' on cars caused by physical infrastructure. Some people felt, however, that the physical infrastructure was necessary to change behaviour. Physical infrastructure was felt to be inappropriate in rural areas because it presents challenges for modern agricultural and heavy goods vehicles. Lobby groups were also perceived to play a significant role in Belfast:

> *. . . it was probably pressure from the Twenty's Plenty lobby groups and the people who thought this is the answer to our . . . be it antisocial driving or be it . . . this is something that would help our quality of life, and there was the 20 mph, that lobby group are powerful, they know how to get their message out there and so on . . . it's hard to resist if you haven't got empirical evidence that demonstrates your argument is flawed. So you've got to try it and you've got to give it a go.*
>
> *Police Service of Northern Ireland*

Opposition to 20-mph speed limits

In Edinburgh, the main opposition to 20-mph speed limits came from bus operators and taxi drivers, although opposition was also expressed in the local evening newspaper and by the Institute of Advanced Motorists. Bus operators were worried about the impact of 20-mph speed limits on their operations. The council responded to these concerns with assurances that research in other cities had shown that journey times would not significantly increase, and that by easing traffic flow during busy periods, 20 mph may actually reduce some journey times. The council agreed to work with the bus operators to ensure that remaining uncertainties regarding impact on the bus network could be satisfied, or that solutions could be developed to mitigate any impact.[68]

According to one of the interviewees:

> *The thing that changed for Lothian Buses was they installed Wi-Fi on the buses after they were consulted on the pilot in South Edinburgh. That gave them the opportunity to monitor in real time how fast the buses were going and where they were on the route. When they modelled that based on real information, they found that the cumulative effect of all buses going through the total area of the pilot area, was 30 seconds, that was the impact on their selves.*
>
> *Elected member*

Taxi drivers proved the hardest group to convince and were described as the 'last man standing in terms of opponents' (elected member). Even after implementation of the intervention, taxi drivers felt that the speed limit should not apply to them as they drive according to 'common sense'.

In terms of stakeholder groups in Belfast, the main opposition was from the Federation of Small Businesses in the Belfast Chamber of Trade and Commerce, which was concerned that the scheme would slow down business. This included pizza deliveries being delayed because the city would be 'grinding to a halt', but also people being deterred from coming into the city, thereby causing a reduction in footfall for local businesses.

In both cities the police expressed concerns. Because the intervention would consist of signs only, without traffic-calming measures, extra police enforcement would be needed and the police in both cities expressed concern over the additional burden this would place on their workload. Civil servants were of the opinion that enforcing 20-mph speed limits should not be a police priority:

> *There's a bigger question, really. If police resources are stretched, is that really the best use of police resources? If people aren't being killed or seriously injured because somebody goes 5 miles over a 20-mph speed limit . . . I think you have to put it into context, and to have police sitting around Belfast city centre just trying to catch people breaking the speed limit doesn't seem to be great use of their time.*
>
> *Civil servant*

The role of 'pilot' schemes

As part of the gradualist approach in Edinburgh, and to 'test the water', the council decided to implement a pilot 20-mph scheme in South Edinburgh. The south of Edinburgh was purposefully selected as the pilot site owing to the demographic mix in the area (students, young families, cyclists) and local activism for safer streets. The pilot scheme was launched on 23 March 2012. The evaluation report[33] drew on information from elsewhere in the UK (Portsmouth, Oxford, Bristol, Warrington, Islington, Hackney, Norwich and Birmingham). The way this information (not evidence) was presented in the report was that, in some of the towns, such a scheme had been introduced successfully; it was not stated that it worked, although the assumption clearly is that it had.

Evidence on the impact of the pilot on a range of outcomes was equivocal. Four locations across the pilot saw slight increases in average vehicle speeds from the 'before' to the 'after' survey; four locations continued to have average speeds of $\geq$ 24 mph; and there was an overall increase in the number of vehicles on most (34 from the 48 locations measured) 20-mph and 30-mph streets from the 'before' to the 'after' period, although in no location was this deemed 'notable'.[33] However, the pilot was reported to have had a significant positive impact on attitudes towards 20 mph:

> *The figures were startling, because the pilot was in Edinburgh south, when we asked people initially, 'do you support it?', two-thirds said no. The numbers for cycling, walking, playing outside for kids and all that kind of stuff was quite low. When we asked people after the pilot, 'do you support it?', the figures completely inversed. So, when people were living with it, support just skyrocketed and opposition just crumbled. So, it was then about two-thirds support and one-third opposition. The stats on 'would you let your kid cycle to school? Would you let your kid play outside unattended?', were much higher . . .*
>
> *Elected member*

In reporting the attitudes of residents, the main benefits of the pilot, as viewed by residents, were (in priority order): safety for children walking about the area, safety for children to play in the street, better conditions for walking, fewer traffic incidents and better cycling conditions.[67] The report concluded that there had been a net increase in levels of walking and cycling during the pilot, levels of car use during the pilot reduced overall and there had been a general fall in overall speed.[33]

Belfast had not conducted a pilot, but the city-centre scheme was itself viewed as a pilot. There was an intention to implement the scheme on a 'trial basis' and determine the impact. This would inform decisions on whether or not to implement similar initiatives in other cities and towns. Although the Belfast scheme was termed a 'pilot' that would run on a 'trial basis', there was no explicit intent to restore the streets to their former 30-mph limits if the impact of the intervention was found to be non-significant.

Implementation

At the time that the decision was made to roll out 20-mph speed limits citywide, parts of Edinburgh had already had 20-mph limits for a number of years; this was thought to have helped, in that 20 mph was already starting to feel like 'the norm'. The scheme in Edinburgh was rolled out in stages. Phasing it in area by area had many advantages in terms of staff capacity for putting up signage and ensuring that only sections of the transport network were disrupted at one time. Interviewees reported that some council officers felt under pressure to ensure that gridlock was not caused in the city, as this would have had a negative impact on support for the initiative. Implementation was done in six phases over 2 years, allowing 16 weeks for each phase. The localities that had the greatest number of road collisions and the highest levels of pedestrian and cycling activity would be phased in earliest. This plan was itself subject to consultation in individual areas.

At the time of implementation in Belfast, there were no permanent 20-mph limits in Northern Ireland. The area to be covered by the 20-mph scheme in Belfast was the city centre, and thus was a much smaller geographical area than the Edinburgh scheme. A decision was made to introduce the change across the whole city centre on a specific date; therefore, implementation happened 'overnight' across the whole area.

Sustainability

Once the 20-mph scheme was in place in Edinburgh, there was a sense that the political landscape changed, and that it would now be politically contentious to take the scheme away and restore the streets to their former limit of mostly 30 mph:

> *Yes, opposition has reduced. So, I mean I said at the time if we get to a point of implementation it will be really difficult for anyone to go to someone on a street and say 'we're taking away your 20 miles an hour and make it 30 miles'. It's quite easy to oppose something that's unknown, so if it's quite easy for a street to say 'we don't want to be 20 miles an hour, we want to be 30 miles an hour', and it would have been easy politically to respond to that or it was also easy politically to say, well actually for other reasons we're going to impose it. To take it away you only need one, realistically, mother with a child saying 'wee Johnny now cycles to school because of this policy, do not take this away'. It takes one now to make it almost politically impossible to change, which is great.*
>
> *Elected member*

Belfast was always presented as a 'pilot' scheme; there does not seem to have ever been an intention to withdraw the scheme if it had no or minor impact. It seems likely that the intervention will be sustained in both cities.

Finally, it was suggested that Edinburgh's geography and history were important:

> *I think that the fact that Edinburgh has a very intact sort of eighteenth-, nineteenth-century street pattern, with a lot of high-density development with no sort of like, almost nothing in the way of great big modern roads, kind of like anywhere near the city centre, means that it is . . . that's helped in terms of sort of having quite a large coherent area near the city centre which is all 20.*
>
> *Council officer*

Some important contextual factors were also noted for Belfast and, in particular, the low proportion of people with access to a private car:

> *The other thing about it is in Northern Ireland, there's something like 40% of people in Belfast don't have access to a private car, it's quite a high number, but it's the other ones that dominate the debate. I've been involved in whether or not areas should be pedestrianised or whether we should be giving more infrastructure over to bus priority, or accessibility issues, that silent 40% that aren't vocal, either because they don't feel they're capable of being vocal, but the people who are most vocal are the middle-class car driver who 'do you know how important I am? I should be allowed to drive my car at 40 mph through Belfast because I've worked hard and paid for my BMW and you're just a whatever, for stopping me'.*
>
> *Civil servant*

Although there were similarities in the processes involved in the decision-making and implementation of the 20-mph speed limit interventions in Edinburgh and Belfast, there were also major differences between the two cities (*Table 5*). The contrast between the two cities demonstrates that it is possible to implement 20-mph speed limits in varying ways, and that local context is critical for informing how 20 mph might best be operationalised in a given location. Given that the intervention can be operationalised in diverse ways to suit the local context, we believe it is likely to be transferable to other towns and cities.

TABLE 5 Summary of themes and comparison between the two cities

Theme	Edinburgh	Belfast
Political context and locus of decision-making	Scottish and UK government supportive CEC local government	UK government supportive Central government of Northern Ireland
Agenda and key drivers	Long lead-in time (16 years) • Improving attractiveness of city for residents and visitors • Road safety • Then other agendas with wider aspirations, such as cycling and walking	Long lead-in time (16 years) • Improve amenities in the city centre • Road safety • Then reducing social exclusion and strengthening rural communities
Leadership	• Strong leadership from individuals • Cross-party support	• Strong leadership from individuals • Cross-party support
Gradualist political–bureaucratic process	Gradualist, building support over time	Gradualist, building support over time
Role of evidence	• Use of background data and evidence from sources such as the DfT • Politicians hone the evidence into a deliverable narrative	• Use of background data and evidence from sources such as the DfT • Politicians and officials hone the evidence into a deliverable narrative
Facilitators of and influences on momentum	The move from a focus on physical infrastructure (zones) to limits, which were cheaper	The move from a focus on zones to limits make it more feasible
Support for 20-mph speed limits	Broad coalitions of special interest groups	Broad coalitions of special interest groups
Opposition	Opposition from special interest groups and some journalists	Opposition from special interest groups and some journalists
The role of 'pilot' schemes	South Edinburgh pilot was a dress rehearsal for full roll-out	Not applicable
Implementation	Carefully planned and staged	Big bang, with a pause for Christmas
Sustainability	Aspiration to maintain the intervention	Aspiration to maintain the intervention

CEC, City of Edinburgh Council; DfT, Department for Transport.

The factors identified in *Figure 7*, such as policy statements, extant legislation, local organisations in local jurisdictions, local histories and politics, are parts of a rich interweaving of actions and activities that come together in particular configurations to eventually facilitate the decision to go ahead with the schemes. This constitutes an explicit recognition of environmental and other elements that influence, as predisposing determinants, the decision-making processes for these interventions. In other words, it is not a simple linear process driven by any one thing. This, we believe, is important learning for many public health and other policy initiatives.

Print media methods and analysis

Print media methods

One of the ideas that we encountered when we were planning the project was the view that local print media had been hostile, especially in Edinburgh, to the whole idea of 20-mph restrictions. To explore the ways that the reporting was done, we conducted a thematic and narrative analysis of print media. This would allow us to understand the process of construction of the 20-mph policies, as portrayed by the print media.

Free-text searches were conducted on the LexisNexis® (New York, NY, USA) database for the main print media relevant to Edinburgh and Belfast, including a mixture of local and national publications, and including articles from 1990 to October 2019. Search terms included '20mph', 'speed controls' and 'traffic calming'. Searches were also made on print media outlet websites, when not available on LexisNexis. Hits were downloaded and deduplicated. Two reviewers (CF and KM) screened articles for inclusion. Articles were excluded if they did not mention 20-mph schemes and were not related to the study areas and the environs. Excluded studies mainly related to criminal acts involving speed or collisions, or used the term '20 mph' but not in relation to a speed reduction intervention, for example in car reviews. Full-text articles were assessed against three eligibility criteria: (1) published in a print outlet relevant to Belfast or Edinburgh; (2) mentioned 20 mph relating to road traffic, speed, congestion, collisions or safety; and (3) published before October 2019.

Eligible media articles were categorised into one of two types of coverage, defined as 'news reports' and 'editorials or opinion pieces', with details on key actors recorded within themes. Data were extracted from each article to determine key themes, and these themes were categorised according to the three 'streams' of Kingdon's Multiple Streams Framework (problems, policies and politics).[73] The themes were also mapped in publication order to examine the shifts in media focus on news and opinions across the three streams over time. Articles could be classified across more than one stream.

Results from print media sources

The electronic searches of databases and media websites identified 242 hits (post deduplication). Post title screening, 154 full-text media articles were assessed for eligibility, leaving 84 articles meeting the inclusion criteria. Articles were excluded for not being relevant to 20 mph or for being related to criminal acts (*Figure 9*).

The majority of hits for Edinburgh were derived from six Scottish media sources, whereas there were only three key media sources for Belfast. This is probably because of the greater number of local and national newspapers in Scotland. The types of stories were more frequently classified as news rather than opinion based. Owing to the very low number of media stories related to 20 mph from Belfast (12 articles), thematic results are presented only for Edinburgh and the environs.

Each stream existed contemporaneously, rather than independently, as articles were coded across streams and codes appeared in each, especially pro- and anti-20-mph views and evidence. Examples of article texts for each of the streams can be found in *Appendix 2*.

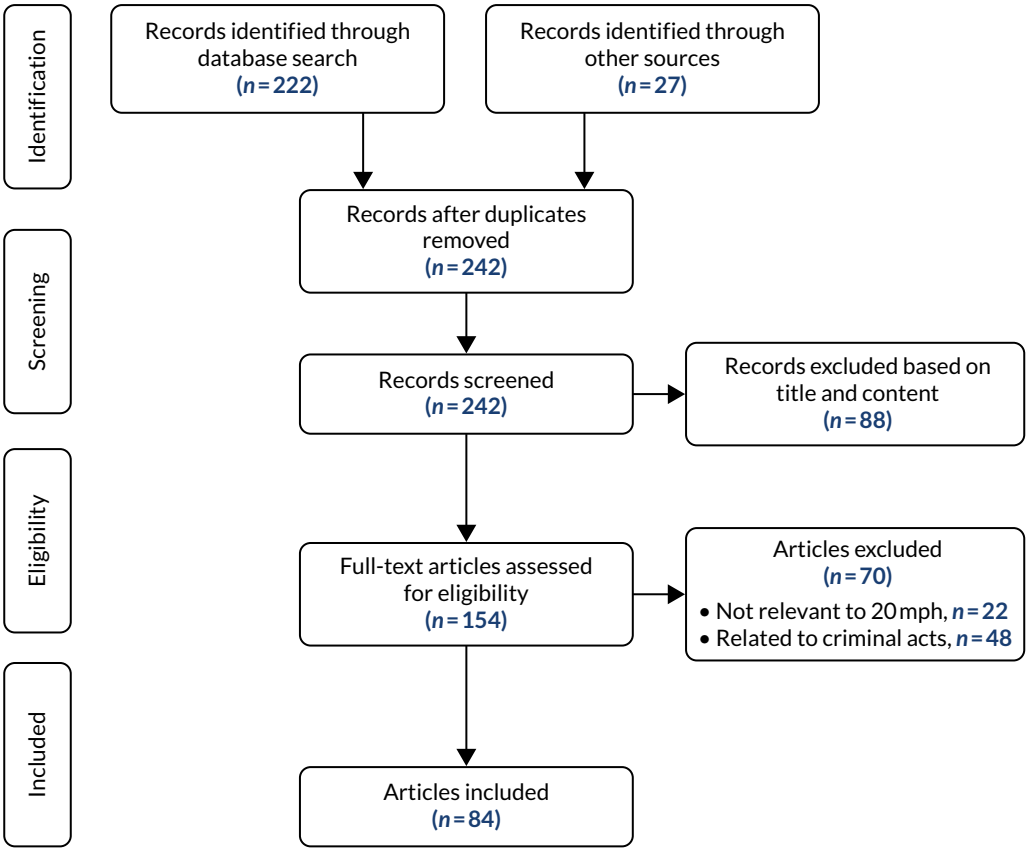

FIGURE 9 Flow chart for identification of records (articles).

Problem stream

In the problem stream, the impacts of traffic speeds, collisions and pedestrian fatalities were reported long before the adoption of the Edinburgh 20-mph scheme in the earlier articles published since 1993. The key themes identified placed traffic-related problems across three types of advocacy (professional, public and universal) against anti-20-mph reporting (*Figure 10*).

The personal impact and consequences of traffic-related problems were most profoundly expressed in the personal stories of child fatalities. The professional and public advocacy responses were universal in calling for a solution to the problem of speeding and accidents, and placed 20-mph schemes as an immediate solution for safer streets, especially in places where deaths had occurred. Evidence sources were also reported from outside Scotland to support the call for safer streets from professional advocacy groups. These combinations of both professional advocacy and public advocacy merged into a universal advocacy call for improvements to this problem:

> *Demonstrators lay in the street yesterday bearing 103 crosses to symbolise the projected death toll on Britain's roads before the Government launches its safety review in 11 days' time.*
>
> *Protest over road deaths, The Herald (Glasgow), 21 February 2000. Reproduced with permission from Newsquest Media Group*

As 20-mph schemes were being more widely reported, opposition to such ideas were also reported. Nearly all of these anti-20-mph views were expressed as editorial or opinion articles stressing a political positioning of anti-speed and depersonalised positions or non-enforcement:

> *The Green Party have been advocating this, but do any of these people actually drive a car? Or could they be cyclists? And have they tried to drive at 20 mph?*
>
> *Efforts to get drivers on go-slow must have been dreamed up by cyclists, Evening Express, 12 May 2018. Reproduced with permission from Aberdeen Journals Archive*

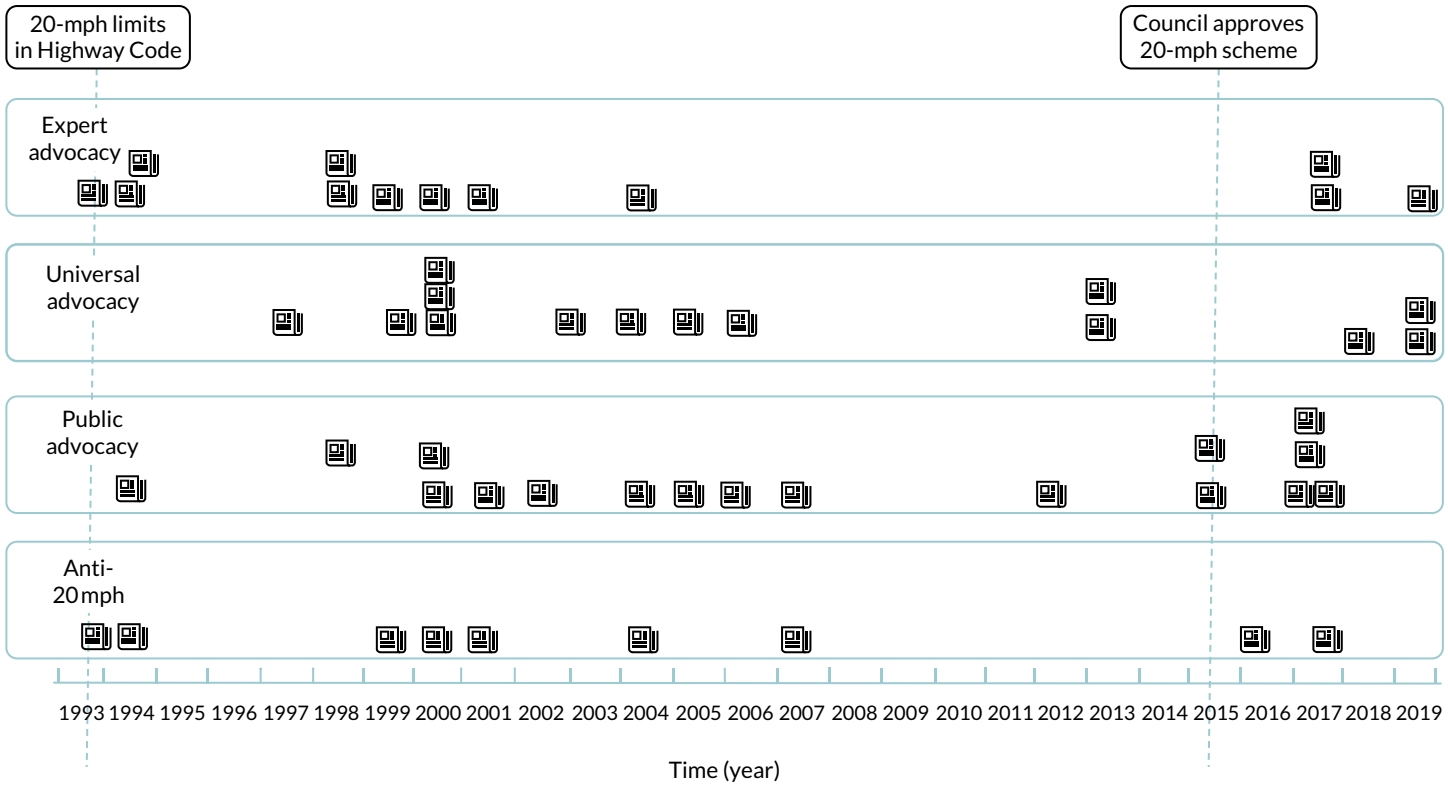

FIGURE 10 Timeline (1993–2019) of Scottish media coverage by themes in the problem stream.

Policy stream

The policy stream saw a continued use of evidence presented in the problem stream for 20-mph schemes, the start of calls for using 20-mph speed limits as a solution to these problems and the 20-mph policy adoption by the Green Party. Anti-20-mph views were found in articles on issues of enforcement and cost. Key themes identified were the remessaging of evidence (i.e. developing positive statements about the evidence to support the views of the advocates of the speed limits) and the idea that policy solutions to these issues already exist. These were supported by political advocacy, but also received anti-20-mph pushback as policy options were reported (*Figure 11*).

The problem stream's pro-20-mph speed limit evidence of impacts had focused on speed and child fatalities, pre 2000. Now new types of evidence appeared in the policy stream that had more breadth in terms of the range of issues reported, across health, economic, environmental and social benefits for individuals and communities. The problem of traffic was now expressed in policy language in terms of economic cost. This broadening of benefits was coded as a theme of remessaging of evidence as it was reported and as it was being trumpeted by advocates and, for the first time, political individuals and parties. Despite 20-mph schemes being sought as a solution to the problem, there were few calls for a political and policy solution pre 2000; however, articles post 2000 introduced examples of 'successful' implementation of 20-mph schemes in Scotland, reporting additional and potential benefits, proposing 20 mph as a solution, and calling for political support. The impact of 20-mph schemes in other parts of the UK and within Scotland were more frequently reported post 2000 and connected with solving similar problems elsewhere. This powerful connection was expressed in terms that indicated that a solution already exists and is being used by others like us. For example, redevelopment plans in Aviemore included 20 mph as part of their traffic safety measures:

> *Two roundabouts at either end of Grampian Road will take traffic at 20 mph up to a new system of streets organised around the green, designed as the heart of the village, its commercial as well as its community life.*
>
> *Blueprint unveiled for new face of Aviemore, The Herald (Glasgow), 9 September 1997. Reproduced with permission from Newsquest Media Group*

The impact of the pilot of the 20-mph Edinburgh scheme on road safety was reported as successful and as the principal reason for expansion of the scheme across the whole city in 2014, with the endorsement of a local pressure group.

Editorial and opinion articles reported the problem of traffic and its impacts on Scottish communities, with the potential solution of 20-mph schemes, as early as 1994. Twenty-miles-per-hour schemes were presented as the local street solution to the local speeding and accident problem. The concept of universal justice (higher accident rates in poorer communities), environmental impacts and pollution were problems also connected to the potential policy solution of 20-mph schemes:

> *Creating 20 mph zones around schools, which the innocent among us might think could be enacted almost overnight and which has been proven to save lives, is apparently hindered by a classic Catch 22 . . .*
>
> *Pollution and danger on the walk to school, Scotland on Sunday, 30 October 1994. Reproduced with permission from Scotland on Sunday*

Pushback against this proposal and anti-20-mph speed limit reporting included a broader range of reasons to oppose the scheme, including problems with cost, maintenance, enforcement and even 20-mph zones causing more speeding as a result of driver frustration.

Politics stream

The politics stream was identified across the majority of articles post 2000. Themes included the political adoption and remessaging of evidence, supporting political activation and the agreement that 20-mph speed limits have worked (and worked elsewhere), riposted by anti-20 mph public arguments. Although these themes appeared similar to those found in the problems and policy streams, what made them also political was the reporting of these issues with a local or national political figure (*Figure 12*).

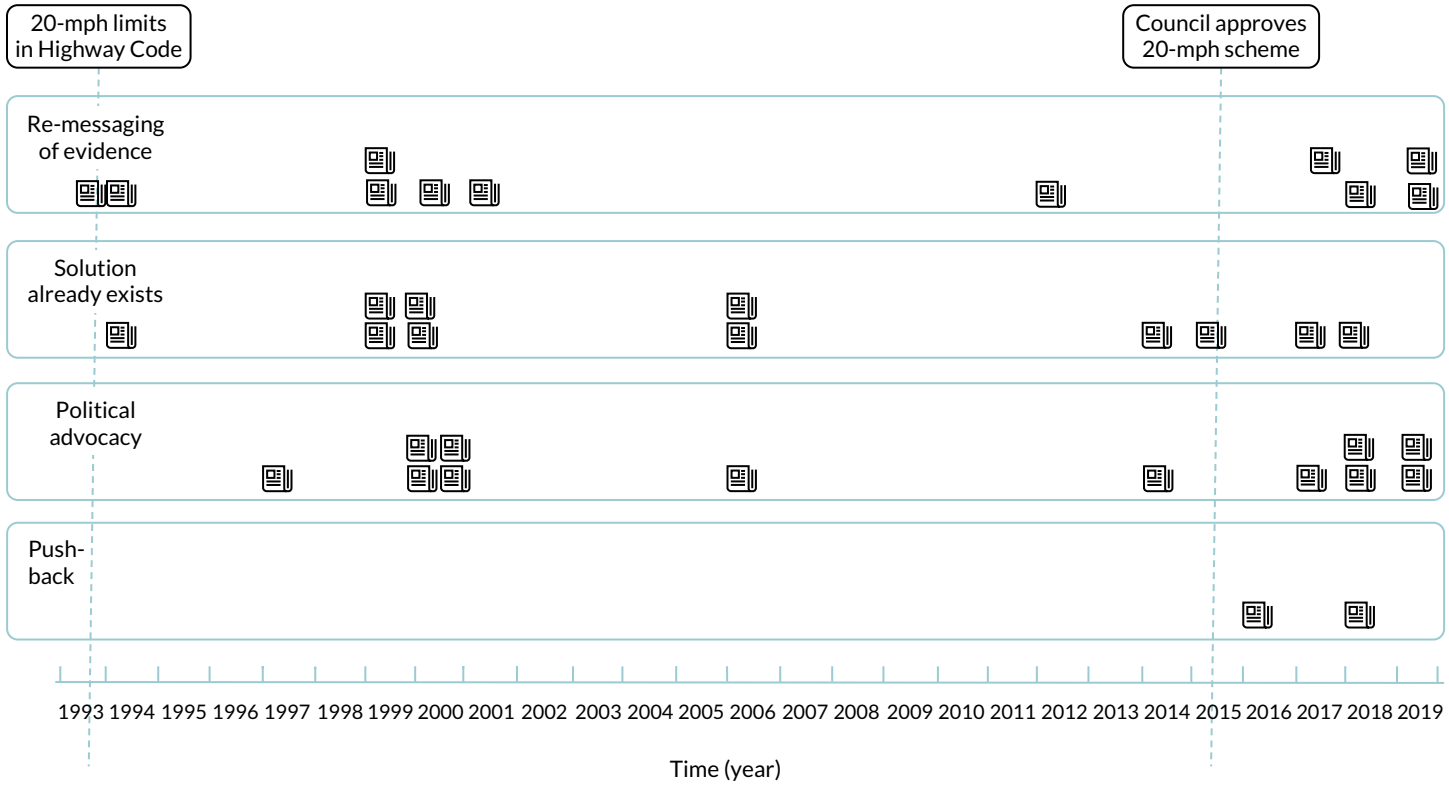

FIGURE 11 Timeline (1993–2019) of Scottish media coverage by themes in the policy stream.

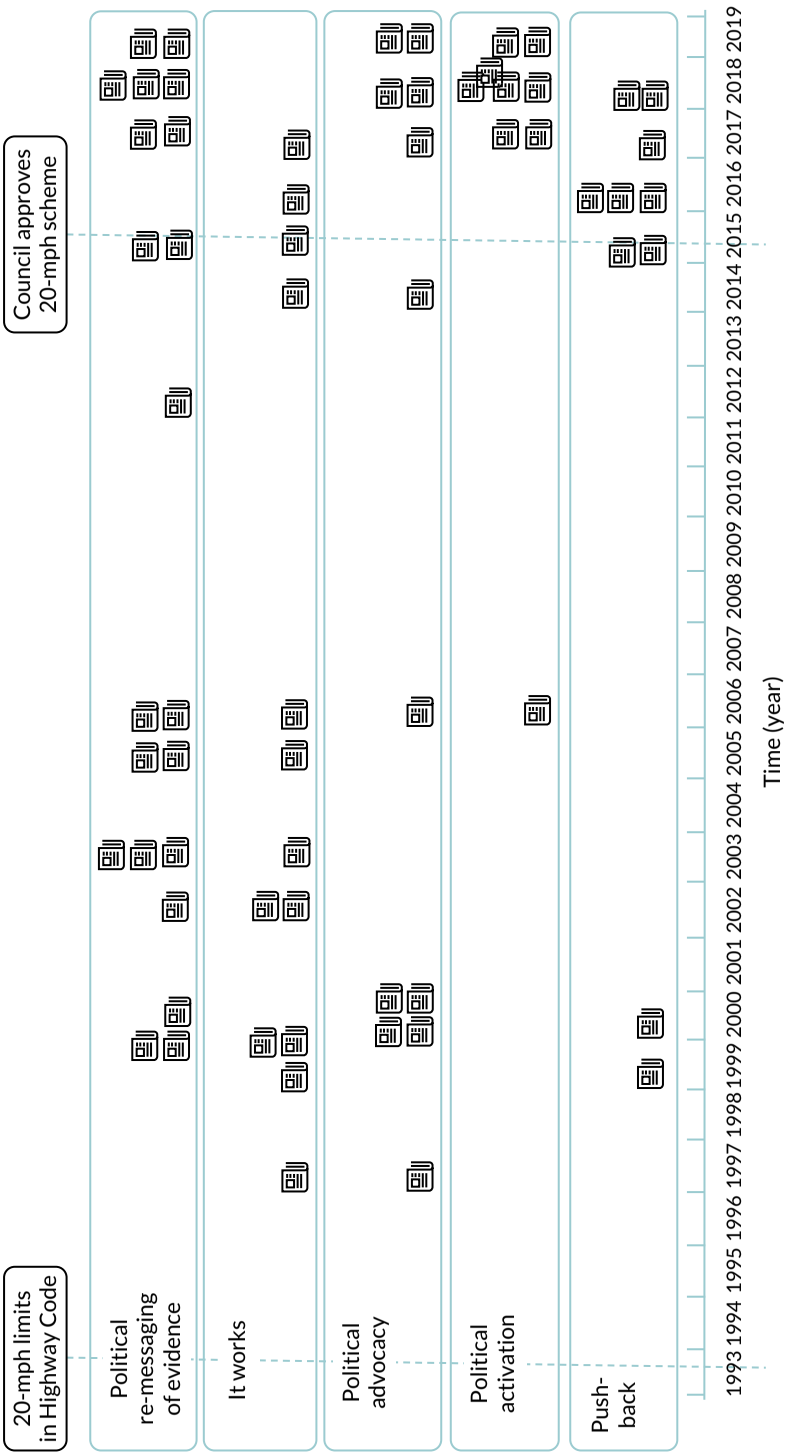

FIGURE 12 Timeline (1993–2019) of Scottish media coverage by themes in the politics stream.

Political parties began to connect the problems of traffic and 20-mph schemes as a policy option to champion:

> *Robin Harper, Green Party, Lothian, expressed sympathy with the petition, but added: 'I hope that every council in Scotland will introduce home-zones and 20 mph areas.'*
>
> *Speed freeze, The Scotsman, 24 May 2000*

The effect of political support for 20-mph schemes was reported within the policy stream, and the critical efforts of one Green Member of Scottish Parliament (MSP) to champion 20-mph schemes. The reporting quoted 'the postcode lottery' and inequality that some areas had these schemes already whereas others did not. This political advocacy and offering of a policy solution shows the interaction of both the problem and policy streams preceding the political stream in which legislation was agreed.

The benefits of 20-mph schemes were similar, but tended to be reported in clear groups: children and vulnerable users, protecting schools and saving money by stopping speeding and 'rat runs'. The evidence quoted in articles from politicians tended to be in sound bites or short summaries, whereas those opposed to 20-mph schemes used emotive short anti-20-mph slogans.

Convergence of the three streams: the policy window

The theme of political activation reflected news and editorial articles that brought together evidence, the 20-mph bill and political support, leading to the convergence point of the problem, policy and politics streams (*Figure 13*).

The underlying principle of this theme was the clear assumption and undisputed fact that 20-mph schemes work. This editorial shows this convergence and undeniable need for a 20-mph scheme in Edinburgh and beyond, published in 2018:

> *Several cities have launched or experimented with 20 mph limits or zones in built-up areas, and pressure is growing for Scotland as a whole to follow suit . . . The case for 20 mph limits cannot be overstated, but the same surely applies to the importance of such provisions.*
>
> *Safer-roads bill deserves much wider support, The Herald (Glasgow), 2 October 2018. Reproduced with permission from Newsquest Media Group*

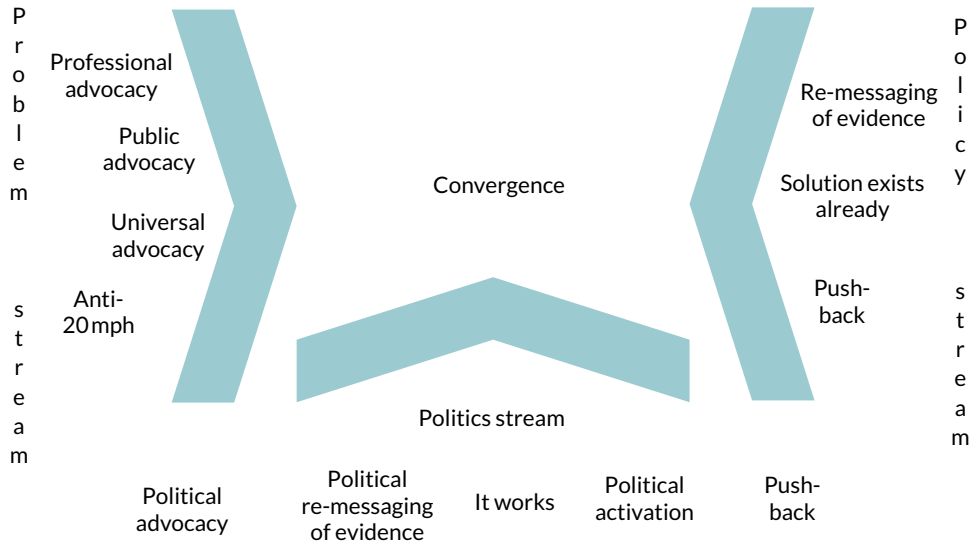

FIGURE 13 Themes within the problem, policy and politics streams from Scottish news articles, 1993–2019.

Strengths and limitations of the media study

There are some limitations to our study. We were unable to search the *Edinburgh Evening News* as it was not online. Despite extensive searching, we located very few articles from Belfast, compared with Edinburgh. We used the same search methods for both locations, but identified fewer publications related to Belfast and the environs. We are aware that the media is in itself biased and we cannot be sure if the media presented the real story of what happened. The media may present a simplified public view of what happened, or perhaps from only one perspective, with other local voices being excluded; however, we were able to find examples of different views (e.g. anti-20 mph) being reported. We acknowledge the limitation that we did not examine social media (although we have done this since the main project concluded, see Semwal, *et al.*[74]), which may have given us greater insight into new issues or broader views. However, some articles were views from the paper's social media activity. We feel that these missing media may not be so critical to Edinburgh; our analysis predates the decision to approve the Edinburgh scheme in 2015, whereas the largest expansion of social media use for adults aged > 30 years was post 2016.[75] Finally, we are aware that we bring our own biases and reflexivity to this analysis at all stages, but, by checking key decisions at each stage, this may be reduced.[76] The strength of our study is the combination of systematic searching, screening and coding frames, and use of a theoretical and practical framework to understand processes through the lens of a key social mechanism that shapes opinion and reflects views. Our study also sits as part of broader analysis of local documents to understand the political processes to create the 20-mph policies in both cities.

Chapter 3 Understanding barriers to and facilitators of successful implementation in Edinburgh and Belfast

Introduction

Evaluations of 20-mph speed reduction interventions have tended to be impact and outcome focused, primarily examining the impact on vehicle speed,[21] with additional analyses investigating any resulting impact on road traffic collisions and casualties.[77] Much less is known about the pathways and processes that cause this transport policy to have public health benefits, particularly for 20-mph speed limit interventions. Without an understanding of whether or not the components of the intervention were implemented as intended, it is not possible to determine whether any lack of effects are due to poor programme theory or less than optimal implementation. In addition, identifying the barriers to and facilitators of implementation can provide important learning for the transferability of such schemes to other settings.[78]

Objective 2

Objective 2 aimed to describe and understand the what and how of implementation (i.e. the implementation processes) of two 20-mph speed limit interventions: Edinburgh (citywide) and Belfast (city centre). We aimed to explore the role of the agents responsible for implementing the multiple intervention activities and to identify emerging changes in implementation.

The objective 2 research questions were as follows:

- How is the 20-mph speed limit intervention being implemented in each city?
- To what extent is the intervention being delivered as intended in each city, and what adaptations were made to how the interventions were delivered?
- What are the barriers to and facilitators of successful implementation in the two cities?

This chapter focuses on reporting the findings on the implementation of the different components [(see *Table 1* and 'Chapter 3, objective 2' section of the programme theory (see *Figure 8*)] from both stakeholders and those living in the two cities. Based on our programme theory and informed by guidance on conducting process evaluations,[56] we aimed to examine key processes related to 20-mph speed limit interventions. This is an area with a limited evidence base, but it is important to elucidate it to provide insight into how such interventions may work. These processes included the 'what' and 'how' of implementation of 20-mph speed limit interventions. Context was considered throughout the process evaluation,[79] acknowledging that there were likely to be multiple contextual factors influencing the following: implementation; how the interventions were experienced and perceived; the impact on the outcomes assessed; and the mechanisms through which change may, or may not, have occurred.[78]

Methods

We undertook two qualitative studies: one with stakeholders (implementors of the interventions) to describe and understand the 'what' and 'how' of implementation (i.e. the implementation processes) in Edinburgh and Belfast, and another with people living in the two cities. The methods for each are described in the following sections.

Stakeholder interviews

We aimed to explore the role of agents responsible for implementing the multiple intervention activities and to identify emerging changes in implementation. We sought to answer the following additional research questions:

- How was the 20-mph speed limit intervention implemented in each city?
- To what extent was the intervention being delivered as intended in each city, and what adaptations were made to how the interventions were delivered?
- What were the barriers to and enablers of implementation in the two cities?

The stakeholders were the same as those who provided data in the stakeholder interviews discussed in *Chapter 2*.

Sampling and recruitment

We developed a sampling framework to identify all implementation agents likely to have been involved with the interventions, considered to be after the final passing of the traffic regulation order (or citywide speed limit order) legislation in each city (for Belfast: October 2015; for Edinburgh: January 2016). We initially used purposive sampling, aiming for representation from organisations involved in implementing the main intervention activities: legislation (e.g. city council transport convenors), road signage (e.g. council design teams, roads services and outsourced contractors), education and awareness-raising (e.g. council programme delivery teams) and enforcement (e.g. police services), accounting for the contextual differences in terms of stakeholders involved in the two cities. We also utilised snowball sampling, asking each interviewed stakeholder to identify any other relevant individuals or organisations.

In Belfast

Initially, six interviews took place with eight interviewees (two interviews were conducted with pairs of respondents). These were with representatives from government departments ($n = 4$), the Police Service of Northern Ireland ($n = 2$), a public transport organisation ($n = 1$) and a third-sector organisation ($n = 1$). Interviews took place in November 2017, 25 months after the legislation went live and 22 months after the signage was implemented. A further interview took place with two representatives from the Department for Infrastructure (responsible for implementing the intervention) in March 2019 (38 months post implementation of signage) following completion of the initial '3-year pilot' phase.

In Edinburgh

Sixteen interviews were conducted with representatives from the local council ($n = 10$), Police Scotland ($n = 3$), a public transport organisation ($n = 1$), a private sector organisation ($n = 1$) and a third-sector organisation ($n = 1$). Interviews took place between July 2017 and April 2018. In addition, given the phased roll-out over a 20-month period in Edinburgh, we conducted six 'repeat' interviews between April and May 2018 with agents likely to have a continued role, to assess any changes in implementation over time (local council, $n = 3$; Police Scotland, $n = 3$).

Focus groups with the general population

We aimed to investigate people's experiences of, and interactions with, the multiple intervention activities, examining how and why behaviour change occurred or did not occur, and exploring and refining the causal pathways and mechanisms of the programme theory.[3] We sought to answer the following research questions:

- How are the effects (or lack of effects) experienced by various population subgroups?
- Do the qualitative data support the proposed causal pathways and mechanisms outlined in the programme theory?

- How and why does the programme theory operate, or not operate, across different subgroups or in different contexts?
- Are there any unintended/unexpected pathways and consequences that need to be incorporated in the model?

Data from these focus groups are also reported in subsequent chapters.

Sampling and recruitment for focus groups

We developed a pragmatic sampling framework based on the concept of maximum variation[80] and accounting for what was possible within the time frame and resources of the study. An important concept that underpinned this sampling was the potential for the exposure of the public to the 20-mph speed limit interventions (through residing in, working in or travelling through the cities), given the scale of implementation across Belfast (city centre) and Edinburgh (citywide). Thus, we endeavoured to sample by several variables and sociodemographic groups where the existing literature provided an indication that there may be a differential impact of the interventions, or to include different travel behaviour/modes. Key groups included different pavement and road users (e.g. pedestrians, cyclists and motor vehicle drivers such as professional bus and taxi drivers); those of different age groups (e.g. parents of children, older adults); and those from lower socioeconomic status areas. We also sampled by the geographical phased implementation within Edinburgh. Within each site, a range of recruitment methods was used to invite the potential participants from the target groups to a focus group discussion. These involved the following:

- contacting key individuals (i.e. previously identified key contacts and gatekeepers) known of within the research team
- contacting individuals who took part in the perceptions survey (see *Chapter 4*, *Analysis of public perceptions*) and who had provided consent to be contacted (Edinburgh only)
- community councils (as residents, not community council members)
- online databases of certain groups (e.g. school parent groups)
- snowballing to new groups' key contacts from groups already conducted.

Recruitment continued until data saturation occurred. The final sample size was 159: 99 participants took part in 15 focus groups in Edinburgh and 60 participants took part in nine focus groups in Belfast (see *Appendix 3* for full details of focus group participants).

In Edinburgh, 99 participants took part in 15 focus groups {mean age 56.2 years [standard deviation (SD) 16.8 years]}. Fifty-nine participants were male (59%), and the majority of participants were white ($n = 92$, 92%). Nearly all participants identified as having no disability or medical conditions affecting their mobility ($n = 97$, 98%). Participants included advanced motorcyclists ($n = 11$), public transport users ($n = 6$), car/private motorised vehicle users ($n = 7$), people using active travel modes ($n = 3$) and cyclists of mixed experience ($n = 13$). One group consisted of taxi drivers ($n = 4$), and another of bus drivers and a bus company management representative ($n = 3$). Participants also included older adults ($n = 19$), parents of toddlers ($n = 7$) and parents of school-aged children ($n = 6$). Finally, participants also included those from a semirural location within the intervention area ($n = 9$), and community councillors and residents from South-Central Edinburgh ($n = 6$), and the west of Edinburgh ($n = 5$). It was ensured that participants covered a wide geographic spread of the intervention area, to ensure an understanding of any geographical differences in intervention experience among participants.

Procedures for both studies

All study procedures were reviewed and approved by Moray House School of Education and Sport, University of Edinburgh, in 2017. Stakeholder interviews in both cities were conducted by Kieran Turner. Focus groups were conducted by one lead researcher in each site (CC in Belfast and KT in Edinburgh).

Interviews and focus groups took place at locations convenient for participants. Following an overview of the study, participants read the participant information sheet and were given the opportunity to ask questions before providing written informed consent. Participants in the focus groups also completed a short demographic questionnaire (e.g. gender, age and ethnicity). When possible, a second researcher was present to facilitate and take written field notes. All discussions were audio-recorded with participants' consent.

Following the completion of the interviews/focus groups, audio-recordings were securely stored, transcribed by a professional service and anonymised. All data were held securely on password-protected University of Edinburgh computers and paper transcriptions were stored in locked filing cabinets in both the University of Edinburgh and Queen's University, Belfast.

Areas of investigation and development of topic guides for the two studies

Stakeholder interviews

The interview schedule (see *Appendices 4* and *5* for the Edinburgh and Belfast interview guides, respectively) was guided by the researchers' understanding of the implementation of 20-mph speed limit interventions achieved through the development of the programme theory[3] literature and policy documents, and informal contact with implementation agents in both sites. The intervention activities (signage, education and awareness-raising, enforcement) were explored in relation to what each consisted of, how each had been implemented, changes over time, and whether or not these activities had been delivered as intended (fidelity). We investigated barriers to and enablers of implementation and considered setting and contextual differences between Belfast and Edinburgh.

Focus groups

The focus group schedule (see *Appendix 6*) was guided primarily by the overall project programme theory.[3] In general, the focus groups sought to understand the public's attitudes to, and perceptions of, 20-mph speed limits, and their experiences of, and behavioural responses to, the implemented 20-mph speed limit intervention activities, exploring the mechanisms through which any behaviour change occurred. The key health-related outcomes of interest included traffic speed, active transport (walking and/or cycling), and liveability. Specifically, the topics included in the guide were as follows:

- awareness of the 20-mph speed limit intervention and perceived rationale
- attitudes towards the 20-mph speed limit intervention
- views on, and experiences of, the 20-mph signage
- views on, and experiences of, enforcement of the 20-mph speed limit intervention
- behaviour change across a range of outcomes (see *Chapter 4*)
- views on the impact on liveability (see *Chapter 5*).

The topic guide was amended iteratively, initially after the first focus group following discussions with the research team, and then tailored for different groups focusing on specific behaviours of interest (e.g. driver behaviour among professional drivers, liveability among young parents' groups). Questions from several iterations of the perceptions survey (see *Chapter 4*) were also incorporated into the topic guide.

Analysis of interview and focus group data

Interviews and focus group transcripts were checked for accuracy and managed in the NVivo qualitative analysis software package. Preliminary inductive coding of one transcript was undertaken by at least two team members. Following discussion around agreement and inconsistencies, initial coding frameworks were developed, which were then applied to at least another three transcripts for

double-coding, with further discussions taking place. Revised coding frameworks were then applied to the remaining transcripts by the lead researcher for that specific project/setting and final revisions were made regarding overarching themes and levels of categories under each theme.

Data were analysed thematically by implementing Braun and Clarke's[81] six-step approach. This useful approach enables patterns to be determined as they transpire throughout the data. For example, this allowed us to generate themes of barriers and enablers that might be common across participants, regardless of their professional role. Our analysis was predominantly inductive in nature, allowing us to generate additional themes, identify new proposed mechanisms and explore unintended consequences/outcomes but, because of the specifically designed interview schedule and topic guides, we could also answer our research questions and examine prespecified putative mechanisms as per the programme theory.

The research team looked to consider differences that may, or may not, be present between the two cities (Edinburgh and Belfast). The samples were purposive, and not randomly drawn, and the interview schedules and topic guides were tailored to the individual. We therefore do not report on the specific frequency of codes/categories, but instead comment on where accounts were consistent throughout the sample or where views were mixed, inconsistent or infrequent.

Results

To provide context, we have tagged the interview extracts quoted in this report. To preserve the anonymity of participants, we have not provided the specific job description of each participant. Individuals would have potentially been identifiable given the small number of participants recruited from each organisation, and the specific role of each participant. Therefore, we have tagged interview extracts with the city (i.e. Edinburgh or Belfast) and organisation (e.g. council, police, government department).

The predominant perspective emerging from both cities was that the interventions were generally implemented as intended. Once the legislation had been passed, and delivery plans approved, there were few practical issues noted, and only minor amendments to the implementation of some intervention activities were made (e.g. additional signage).

Both cities had to issue legislative traffic regulation orders to allow enactment of the 'minimum' activities. Both cities also had to implement the associated signage and road markings required for a 20-mph speed limit to be legally implemented and enforced, and had to ensure full-time hours of operation (24 hours per day, 7 days per week). However, there existed substantial differences in (1) the geographical scale of the implementation between Edinburgh (citywide across seven zones, 5711 streets covering 687 km of road networks) and Belfast (city centre, 76 streets covering 10.7 km of road networks) (see *Table 1* for a full description of the interventions) and (2) the specific intervention activities constituting the 'complete' intervention in each city, as discussed in *Signage and road-marking activities*, *Education and awareness-raising activities* and *Enforcement activities*.

Signage and road-marking activities

Stakeholders

Agents in both cities indicated that signage had broadly been implemented as intended, in part because of the requirement to adhere to the relatively rigid The Traffic Signs Regulations and General Directions 2016[82] in terms of size, shape and fonts used:

> *The signage is all prescribed by the regulations. I mean, it's national legislation, there's no, there's no leeway upon that . . .*
>
> *Edinburgh, council*

Signage implementation consisted of post-mounting advanced warning signs (i.e. new limit in force), terminal signs (on entering the 20-mph area) and repeater signs (throughout the area). Carriageway '20' roundels (i.e. road markings) were implemented in Edinburgh, but not in Belfast:

> *It was just felt that we didn't really need them to start off with, and it was something that we could introduce if there were any problems associated with it . . . Belfast city centre is very congested, so probably for, well, a large portion of the day, traffic's going to be almost stationary . . . maybe road markings might not be that evident as well.*
>
> *Belfast, government department*

Agents noted some, albeit minor, flexibility within the Traffic Signs Regulations and General Directions[82] that allowed for local-level decision-making. This was often utilised to provide additional signage to reinforce messages, for example on wide roads, pedestrian areas, streets where drivers would not naturally drive at 20 mph or streets connected to those with a higher speed limit:

> *We have certain flexibility within the regulations on the placing, the frequency of placing the repeater signs; they must be between 50 and 70 m apart, or something like that, for 20 mph.*
>
> *Belfast, government department*

> *. . . it states the minimum, so there's no maximum, so you really can have a sign every 10 m apart, so, in case of doubt, we just put an extra sign up.*
>
> *Edinburgh, council*

Only minor changes to implementation over time were noted in both cities. For example, in Belfast some signage was amended approximately 8 months after being introduced, based on monitoring and feedback from the public and police, to make the signs more visible:

> *. . . we had a minimal scheme and then after about 6 months we actually changed most of the signs to have yellow backing boards because we felt that some of the things weren't working as well or there wasn't the same conspicuity . . .*
>
> *Belfast, government department*

In Belfast, some agents suggested that road markings could be, and potentially should have been, introduced to reinforce the message:

> *. . . I think it was too cheap and cheerful . . . and I would go for more carriageway markings at the key points.*
>
> *Belfast, government department*

However, others stated that the intervention had been operating well at the time of interview (November 2017), and, at the time of follow-up data collection (March 2019), no road markings had been introduced and no other changes related to signage (type, design or scale) had been made.

In Edinburgh, minor amendments had been made owing to errors in street names or in response to public feedback. There were also relatively small extensions to the intervention, with additional traffic regulation orders written to incorporate streets that had originally been missed and roads within new housing developments or around schools. Completing new traffic regulation orders was described as being complex, time-consuming and labour intensive, particularly with limited resources, which may have implications on longer-term sustainability when ring-fenced funding for the programme has been spent:

> *[J]ust, you know, it's a complex process to get through and there's lots of statutory operations to undertake, . . . particularly with limited resources on the table. And the council has fairly cumbersome mechanisms of dealing with people.*
>
> *Edinburgh, council*

The consensus from Edinburgh agents was that signage and road markings were implemented consistently across the phased roll-out of 20 mph across the city, affected to only a minor extent by natural weather conditions (e.g. snow) and existing in situ underground utilities (e.g. gas pipes). The phased roll-out allowed for learning from early phases, meaning that initial teething problems were rectified in later phases.

In Belfast, barriers included the challenge of installing signage in a cluttered city centre and a related concern over signage visibility. This issue has potential implications for the impact of the intervention through a lack of awareness of the 20-mph speed limits:

> *A lot of people said they didn't even know where the 20-mph limit was, despite us having it signed completely in accordance with chapter 3 of the Traffic Signs Manual. It just gets lost in the sign clutter in the city centre, so we tried yellow backing boards to reinforce it . . .*
>
> *Belfast, government department*

In contrast, implementers in Edinburgh discussed providing additional signage where it was not legally required to do so. Prior to the new legislation in 2016, 50% of streets in Edinburgh were already 20 mph; one agent described the process of implementing additional signage to ensure a consistent network of 20 mph signage throughout the city:

> *We did want to make sure there was some consistency, so I think when the job was originally considered, we would just be signing the additional 30%. But that meant there was, there'd be two types of zone, so we have put signs in the existing areas, even though they're not actually legally required, we've put them in so there's a consistency for drivers.*
>
> *Edinburgh, council*

It is plausible that this consistency may aid in enhancing signage visibility, increasing awareness of the 20-mph speed limits and helping to influence attitudes and perceptions of the intervention through avoiding confusion and frustration.

Public experiences and perceptions

Participants from both Edinburgh and Belfast were relatively consistent in their views on signage. Although participants did note observing some signage, the level of implementation of this aspect of the intervention was described as 'insufficient' and 'inadequate'. Such descriptors relate to the size and frequency of signs, which were perceived to be too small and placed too far apart, and thus easy to miss when concentrating on other things on the road:

> *But it's a very valid criticism that a lot of people made, that the signs were too small. And that, I mean, I think, to be fair, quite a lot of the implementation of it by the council, left a bit to be desired . . . Yeah, I think that the signage was inconsistent, and I think that it's targeted towards people who are familiar with the system, uh-huh.*
>
> *Edinburgh, focus group (FG) 12*

The signs were viewed as not being obvious, which was identified as a particular concern when travelling between areas of the cities where different speed limits came into effect:

> *It's hard to see where it starts, because the signs aren't very obvious, it's impossible to see where it ends because there's no signs telling you that you're back in the 30 mph again. It's confusing for people, when they don't know where it starts and ends.*
>
> *Belfast, city-centre workers*

There was also a fairly consistent view that carriageway markings were more effective at highlighting the speed limit when travelling through the city:

> *. . . and I think it's especially more useful on the quiet roads because a quiet road . . . quiet empty road is one where motorists will . . . their speed will increase. And . . . because they're driving [according] to [the] conditions. And seeing it repeated on the road in front of them is much more noticeable than just a small mini repeater on a lamp post.*
>
> *Edinburgh, FG11*

One tool that was identified by several drivers as an alternative to the implemented signage, and perceived as being useful in affecting their behaviour, was vehicle-activated signs:

> *I think, for me, everybody's different, but for me, those flashing signs are the worst. See when it flashes up 'you're doing . . .' that really works for me.*
>
> *Belfast, city-centre workers*

On a similar note, one potentially negative consequence of the citywide approach in Edinburgh (implemented consistently according to legal regulations) was the resulting impact on local signage. One example of this was interactive traffic signs outside schools, perceived to be more appropriate for the setting, being replaced:

> *We'd previously had big, huge flashing signs saying, 'School', and 'Slow down', and '20', temporarily, when the schools were opening and closing. And they just removed every sign, and replaced it with a grapefruit-sized 20 mph, you know [. . .] we're not going to complain about a safety initiative for the children, it's not a bad thing. But we didn't understand, there wasn't enough pre information, and we didn't understand [. . .] they were going to make such a major change.*
>
> *Edinburgh, FG12*

Education and awareness-raising activities

Stakeholders

In Edinburgh, an education and awareness-raising campaign was viewed by agents as an integral intervention activity, and was delivered as intended. A council official was dedicated to this activity during the implementation of the 20-mph intervention, with additional involvement from officials in the council responsible for media and communication, and for other agents (i.e. intervention funders).

The Edinburgh education and awareness-raising campaign consisted of a co-ordinated set of activities, including physical advertisements (e.g. on buses, bus shelters, billboards), and press, media and social media releases being delivered prior to signage being put in place, at the 'go-live' stage and throughout implementation of each phase. These activities were often tailored to a specific geographical implementation phase and informed by public feedback about preferences:

> *. . . phase 1 . . . we did something with the castle and the backdrop, we did it with the police . . . phase 2 was covering a really big area that included Hearts [Heart of Midlothian football club] and Hibs [Hibernian football club] grounds . . . that was a key decision behind that as well, was to target the young male driver, being one of our main audiences.*
>
> *Edinburgh, council*

> *And phase 2, we used a lot of – because people said that they weren't aware of 20 mile per hour, we used a lot more information, putting out information on bus shelters and using the billboards and, you know, adverts and things like that, we did a lot more advertising . . . but for this phase, phase 3, it's more of a community approach.*
>
> *Edinburgh, council*

Primary implementers highlighted the involvement from multiple stakeholders as an important enabler of delivering a co-ordinated campaign, maximising the potential reach and ensuring that locally relevant materials were incorporated. These included other implementation agents such as the police service, Sustrans and local stakeholders (e.g. libraries, schools, community councils and professional sports clubs).

Implementers also discussed various things that informed their approach to message creation, such as the preparatory work conducted for campaigns in other cities (e.g. Bristol). In addition, the creation of an internal communications group enabled the generation of messages based on formative research with the target population, identifying key aspects of message content:

> *We wanted to get the slogan right, you know the, the 'Life is better at 20' . . . So that took some time, and when we did the campaign development, a lot of people came back and said that they, people wouldn't get the 'it's better for walking and cycling, and it's better . . . it's in a better place to live.' They felt that the road safety was the hook.*
>
> *Edinburgh, council*

In contrast, implementers in Belfast described there being no official education and awareness-raising materials, other than an initial small-scale press release and media interviews. It was thought, in retrospect, that a dedicated campaign may have been beneficial:

> *. . . engineers are engineers, 2 + 2 = 4, 4 + 4 = 8 . . . I think some of the publicity and education of a more esoteric nature would have been useful around the cuddly ends of it 'and this is better for communities, and this is better for families' . . . We probably could have done with more of that, yeah.*
>
> *Belfast, government department*

Belfast implementers cited the government organisational structure as a key factor in the final implementation of intervention activities, specifically in helping to explain the lack of an education and awareness-raising campaign:

> *They've amalgamated a couple of departments and this work could have commenced in the old department, and that might be an explanation as to why my team weren't involved in it, because you would have thought, somewhere on the edges, because we were road safety, that there might have been some involvement.*
>
> *Belfast, government department*

There may be alternative factors (e.g. resources) that influenced why education and awareness-raising were lacking from the intervention in Belfast, but these were not explicitly discussed by stakeholders.

Public experiences and perceptions

There were stark differences between cities in the levels of public awareness of the 20-mph interventions. In Edinburgh, participants consistently reported high levels of awareness. This was generated through various means: predominantly the city council's official education and awareness-raising activities, but also conventional (local press) and social media, knowledge of the prior pilot scheme, and political and activist groups.

By contrast, in Belfast, there was consistent reporting of a lack of awareness of the 20-mph speed limit being introduced, and also of any specific intervention activities such as education or awareness-raising campaigns:

> *Really? The 20-mph zone? We should have been doing 20 mph for the last 2 years? [Laughter.]*
>
> *Belfast, city-centre worker*

> *[N]o flyers, no posters. I used to be in advertising as well, so I do know a little bit about it, and as far as I'm concerned, as a punter, as a consumer, I've seen nothing. I would imagine, as a resident of Belfast, I would be a prime target market – it hasn't got to me. I don't think I'm particularly stupid, I would have seen it; I haven't, you know.*
>
> *Belfast, older adult*

This lack of awareness of the 20-mph speed limit has implications for the data generated from all other areas of the topic guide among Belfast participants. Whereas Edinburgh participants typically expressed views informed by their actual experiences of the intervention (which they were aware of), in many instances, Belfast focus group discussions generated data that were reflective of perceptions and opinions about 20-mph speed limits more generally, and on the potential impact the Belfast city-centre intervention may have.

Enforcement activities

Stakeholders

The Police Service of Northern Ireland and Police Scotland were the agencies in Belfast and Edinburgh, respectively, responsible for enforcing the 20-mph speed limits and implementing the framework set out in the new legislation. Enforcement involves administering a fixed-penalty fine (or attendance at a speed awareness course) to individuals caught breaking the speed limit.[83] Discussions around enforcement provided mixed views from a range of agents. First, the general approach to enforcement in both cities was described by the police services as being fairly light touch, delivered as intended and principally reactive to complaints from councillors and residents in 'problem' areas:

> *. . . and it was very much about this, saying it has to be proportionate and it has to be very measured and we've other things that are . . . and here's what ACPO [Association of Chief Police Officers] are saying, the best policing minds across Great Britain are saying about them, they've come up with this approach and we're adhering to that, we embrace that.*
>
> *Belfast, police*

This discussion by police services about enforcement is in keeping with the perspective that 20-mph speed limits should be self-enforcing (e.g. through existing road layout):

> *[W]e said right from the outset that it would be, you know, self-enforcing, really, as a sort of principle, given the range of that right across the city, you know, over cities.*
>
> *Edinburgh, police*

In Belfast the general perspective and approach seemed fairly stable throughout implementation. By contrast, in Edinburgh, there was evidence of increased resources and efforts allocated to enforcing the speed limits, particularly in the early stages, using existing roads policing teams and newly appointed council-funded community officers with a specific remit of enforcing the 20-mph limits:

> *We trained up extra officers at the time in Unipar [Unipar Services, Tunbridge Wells, UK], which is the device that, you know, your speed gun, for want of a better phrase.*
>
> *Edinburgh, police*

> *. . . probably disproportionately we've looked at 20 mile per hour limits over the last year to ensure that visibility and engagement wi' the public, to try and educate them, which I think's quite positive, you know, within it.*
>
> *Edinburgh, police*

This additional police presence, without necessarily accompanying enforcement, was described by officers as potentially influencing drivers' behaviour:

> *You know, it doesnae matter if it's speeding, if it's drug-taking, if it's assaults – if the police are there, it'll get reduced naturally just wi' our presence.*
>
> *Edinburgh, police*

Representatives from the Edinburgh police service also discussed working within current guidelines for the issuing of fines, and the role of individual officers using their discretion to deal with the range of situations where enforcement may be possible:

> *There is guidelines provided by the procurator fiscal in relation to when warnings can be issued, when a ticket should be issued, when a summons should be issued and these sorta things. So we go on the guidelines of the procurator fiscal because they're not wanting inundated with people having this sorta 20 mile an hour zone, they're travelling 21 mile an hour . . . They're only guidelines, so it doesn't say that you can't. It a' depends on every circumstances and every situation's different. So it's giving the officers a wee bit sorta tolerance within themselves, how they deal with a situation . . . So you've got tae take a lot o' things intae consideration.*
>
> *Edinburgh, police*

However, strict enforcement through fines was considered by the police services as just one component of their activities and role in the 20-mph intervention. Educating the public was viewed as being just as important, particularly in the early stages of the limits:

> *. . . and it's not about just enforcement, it was really about education, so that the public could see that, actually there are limits and at times we will look at those limits and enforce those limits, and also educate people around those limits. So a lot of the work initially was around that education, to see 'There's a 20 mile-per-hour speed limit sign. There are police officers in the morning on these key roads, looking at that and enforcing that' to get that psychology in play.*
>
> *Edinburgh, police*

However, one agent described the emphasis on education and light-touch ticketing as having the potential to change over time, with an increased focus on issuing fines once the 20-mph limits were more established:

> *[A]t times people weren't aware of the signage. They weren't aware of the change, that sort of thing. It is about awareness-raising and education, probably hand in hand. I think now there's a period where you would look at it just in a sort of quite a black-and-white way, if the threshold's met and there's no other circumstance which leads you to that discretionary look at it then that you would charge the person, but we never dictate that to officers . . . So I think the numbers [of speeding tickets] you would see going up naturally though.*
>
> *Edinburgh, police*

These data also highlighted what appears to be differing views about enforcement between the police service and other agents involved in implementation of the interventions (see also *Chapter 5* for public perceptions on enforcement):

> *I think there is not enough of monitoring [meaning enforcement] the speed . . . So, I think enforcement is probably the one where, that is most difficult, 'cause we [the local authority] don't control it, it's the police that control it.*
>
> *Edinburgh, council*

In both cities, the two most common barriers cited were a lack of resources and competing priorities, with enforcement of 20-mph limits viewed now as 'daily business', just one of multiple policing duties required to be undertaken:

> *Definitely, resource was one issue. The Police Service [of] Northern Ireland are going through, and have been going through, a tremendous amount of change and a tremendous shrinking of our police service over the last 10 years, so resource was certainly one of the issues, and priority, policing priorities was the other issue . . . with dwindling resources, you've got to go where you're going to get the biggest bang for your buck.*
>
> *Belfast, police*

> *For us, it's thefts, it's assault, it's [20 mph] really not right up there, to be honest, and there's a general feeling in the business community that it would be another thing to stop people coming into Belfast . . .*
>
> *Belfast, police*

> *. . . it's one of the many activities that we carry out, from a policing perspective in general in the city, but actually even if you think of a roads policing and road safety perspective, it's just one of numerous things, like targeting disqualified drivers, people wi' no insurance, dangerous driving, you know, parking issues that are becoming dangerous, collisions – a whole host o' things – and then all the different limits – the 40, the 30, the 20 . . .*
>
> *Edinburgh, police*

The sociocultural and political context of Belfast also acted as a barrier to enforcement activities, with restrictions in relation to geographical areas and times of day:

> *The thing is, as well, for us, I'm sure you know that we're slightly restricted on the hour and we couldn't send a motorcyclist out in the dark on their own, because of the security risk over here; we would have to have crews to back them up. We couldn't send certain crews, for instance, up the [road X], we have to [be] very mindful where we send people at times, where they're going. So that is a wee restrictive element for us, that the night-time stuff isn't captured as much, really, because of that.*
>
> *Belfast, police*

Public experiences and perceptions

In both cities, the general views on what enforcement should consist of differed from those of the police. As reported earlier in this chapter, the police services considered one of their key roles as implementation agents to be educating drivers. In contrast, discussions by focus group participants centred on the issuing of fines as the primary method for how the 20-mph intervention should be enforced. Indeed, enforcement of this nature was deemed critical to the success of the intervention:

> *Unless you enforce it, it seems to me like we've wasted a huge amount of money.*
>
> *Edinburgh, FG2*

In Edinburgh the overwhelming perception emerging from participants' experiences was that enforcement had been insufficient and inappropriate:

> *. . . but it's not getting policed. If the police were out there it might make a difference to people's speed.*
>
> *Edinburgh, FG1*

> *I've seen it being enforced on [location] when there was nobody there, and the police pulled someone over. I don't think they did anything, I think they just let them go, but I think they gave them a warning,*

> *but that was . . . it was quiet, there was only me and this other car on the road, and the police car, obviously, and so it was kind of a pointless stop, if you like.*
>
> *Edinburgh, FG4*

Views on these different issues related to enforcement were also shared by those Belfast participants who reported being aware of the intervention. First, there was no perceived enforcement by the police service, and, second, the visual enforcement of issuing fixed-penalty fines to drivers breaking the speed limit would act as a deterrent:

> *We are going to have to see police actually patrolling the areas and saying 'you did more than 20 mph; there is a ticket', but nobody is doing that so people are just ignoring the 20-mph zone. They're going as fast as they can.*
>
> *Belfast, city-centre worker*

However, consistent with views gathered from the police service representatives, focus group participants acknowledged that a lack of resources had implications for the extent to which the intervention was being enforced:

> *But, the idea of having police and other officials standing at the roadside picking off one by one people, the resource requirement for that is just massive and that's never going to work.*
>
> *Edinburgh, FG3*

It was also acknowledged by some participants in Edinburgh that if enforcement (in terms of issuing of fines) was implemented to the extent that was required to act as a deterrent, then this may potentially lead to an unintended consequence: a negative public attitude towards enforcement:

> *I mean obviously the problem is going to be you're going to have an enormous amount of public outrage if you really do enforce a lot of these things.*
>
> *Edinburgh, FG13*

Partnership involvement and working: stakeholders

A key theme generated relating to implementation from the stakeholders' perspective was partnership involvement and working. This theme was important in describing the role of the implementation agents involved, but was also a key barrier to or enabler of implementation, depending on the city and agents who discussed it.

In Edinburgh, there were multiple implementation agents engaged in delivering the intervention activities. The process started with the creation of a dedicated '20-mph team' (a programme manager and a professional officer) within the local authority with associated ring-fenced funding. This team was viewed as being essential, given the scale of the intervention:

> *. . . basically, it was a much bigger job to do it to the whole city, so it required a separate team, it was more than our team could handle, so there's a separate team dealing with that . . . It's just, literally, workload logistics, all sorts of things, you need somebody who is overseeing the whole thing and not doing other things.*
>
> *Edinburgh, council*

The '20-mph team' worked closely with teams within the transport department, including media and communications, active travel, and road safety, and with external partners (i.e. outsourced contractors, Police Scotland, Sustrans and a range of local partners). In addition, a 20-mph steering group and a specific 20-mph communications steering group were created in the local authority to guide implementation and to share ideas, resources and networks. These agents worked closely on the different intervention activities, developing strong relationships and establishing clear lines of

communication. This partnership working was consistently cited as an important enabler of effective implementation of intervention activities, ensuring that efforts were in tandem and supportive:

> *I think the relationship that we've had with schools has helped, actually. Partly because we have two officers, road safety officers, who liaise with the schools on a regular basis. So we've been able to tap in to that audience really well.*
>
> *Edinburgh, council*

> *I think so. It's certainly been done in partnership really well. You know, it's one o' the main things I would think back of over the last few years, other than some significant events that have been run in Edinburgh where there's been that real cohesive work between the local authority and the police to push a safety programme . . . Yeah, I think so. It's been really first class, actually. And it's been hand in glove. It's not something the council have implemented on their own and we've come along later on to look at the bit that 'Oh, we'll be enforcing some of this'. Actually, it's not – it's been a sort o' real partnership approach and I do think they've done a first-class job around that.*
>
> *Edinburgh, police*

In Belfast there was no direct involvement from the local council or external organisations in implementing the intervention, potentially owing (in part) to the intervention scale. Implementation was solely under the control of the roads team in the Department for Instructure. There was evidence that the creation of a dedicated and collaborative team would have acted as an important implementation enabler, providing additional resources and knowledge. This lack of stakeholder involvement was perceived as a barrier to implementation of some of the intervention activities (i.e. the education and awareness-raising campaign). The formation of a steering group was also viewed as being beneficial to guide implementation, create public 'buy-in' and counter any noted negative public perceptions:

> *If I was doing it again, I think what would be useful to have would be almost a small steering group committee which ensured a better buy-in. They wouldn't have done any work but you could say 'oh this was implemented by a steering group comprising of Police Service [of] Northern Ireland, Department for Infrastructure, Belfast City Council, Belfast Chamber of Trade and Commerce, Belfast City Centre' . . . Yes, because it wouldn't be big government . . . it would be this is not just the road service, this was all of those organisations saying this is a good idea.*
>
> *Belfast, government department*

Other influencing factors: stakeholders

There were several factors identified as having the potential to influence the 20-mph speed limit interventions. From a political context, the Belfast intervention was implemented when the Northern Ireland Assembly was not in session, an issue described by agents as a barrier to sustainable transport promotion:

> *Unfortunately, it would be the budget situation that would keep us back, because without a government it's really difficult . . . with the budget being what it is, we have a difficulty around pace [of sustainable transport delivery].*
>
> *Belfast, government department*

In addition, other transport interventions (i.e. the Belfast Rapid Transit scheme, and the Belfast on the Move project) were being delivered during the implementation of 20-mph speed limit interventions, with many schemes involving several of the same agents as those implementing 20-mph speed limits, such as the local authority and the police:

> *. . . the impact of the Belfast on the Move project, which was we're putting in more bus lanes and cycle lanes and all, it included measures to deter through traffic in Belfast, it constructed a new link road just to keep traffic away from the city centre and that has resulted in reduced traffic levels.*
>
> *Belfast, government department*

> *I think it's [police involvement with cycling safety] been driven unintentionally probably by all the extra work we've done on the 20s, even doing the Close Pass, we're doing a whole range of cycle safety things and the like, that actually it's just a . . . we've got a sort of nice overview in the city.*
>
> *Edinburgh, police*

Strengths and limitations

One of the strengths of the qualitative work is the range of implementation agents recruited from both cities, which allowed us to examine in-depth how the interventions were implemented and who was involved, as well as how the interventions were experienced by those affected (i.e. residents and commuters within the cities). This is an important strength, as examination of the processes involved in implementation of 20-mph speed limit interventions has not been a focus of previous evaluations.[22,77] Our programme theory allowed for clear identification of certain processes thought to be integral to implementation to be examined, acknowledging that it may not be possible to investigate all plausible causal assumptions, or uncertainties, around a complex intervention. Thus, we adapted interview schedules and topic guides in an iterative manner, focusing on specific areas of the programme theory and allowing different implementer roles and population subgroups and contexts to be considered. These nuanced, rich data are complementary to the quantitative impact and outcome evaluation, as described in *Chapter 4*.

We acknowledge a number of limitations. The process and outcome teams were not fully separated, with some researchers involved in both, and thus aware of emerging outcomes. However, it was not possible to delay outcome analysis until the process evaluation was complete, and in fact this was not desirable as, originally, it was anticipated that focus group sampling would be informed by differential impacts of the 20-mph interventions (i.e. by geographical area of population subgroup). This sampling by differential impacts on key health outcomes was ultimately not possible. We also found it challenging to recruit groups from socioeconomically deprived areas; thus it was not possible to qualitatively examine the impact of the interventions on health inequalities as originally intended. A further limitation was that, as noted, funding for this evaluation was received post implementation in Belfast and during implementation in Edinburgh; therefore, this may have led to an element of recall bias.

Chapter 4 Quantitative evaluation of the impacts of the Edinburgh and Belfast 20-mph speed limit schemes

Introduction

The objective for this package of work within the project was to assess the impacts (reduced speeds, increased liveability) and outcomes (fewer, less severe collisions and casualties, and increased cycling and walking) of introducing citywide 20-mph speed limits in Edinburgh and a city-centre speed limit in Belfast. To meet that objective, we sought to answer the following research questions:

- What is the impact of introducing 20-mph speed limits on driver perceptions, public support, and perceptions of the safety and pleasantness of their environment?
- Does introducing 20-mph speed limits using primarily signage result in reductions in the speed and/or volume of motorised vehicles?
- What is the impact of introducing 20-mph speed limits on the number and type of road collisions and casualties following implementation?
- What is the impact of introducing 20-mph speed limits on the number of people (journeys) cycling or walking to work or study?

The impacts and outcomes to be evaluated were identified from the initial programme theory detailed in the protocol (see *Figure 4*). As 20-mph limits apply to whole populations of road users, and the local authority in each city was implementing the limits in the most logistically feasible way, it was necessary to adopt a natural experimental approach to the evaluation. Administrative data were already available for outcomes such as collisions and casualties, and each of the local authorities was collecting speed and volume data; consequently, in the protocol for the project, we set out the data sets and methods we intended to use for each outcome (*Table 6*). Whenever possible, we sought to use similar data and methods for each city. In this chapter we outline the methods and findings for each city across five groups of outcomes in order of their proximity to the intervention: public perceptions, speed and volume, collisions and casualties, liveability, and active travel. When it was necessary to deviate from the protocol, this has been explained. We have also provided details of the main strengths and limitations of each method employed.

Analysis of public perceptions

Perceptions and beliefs as determinants of behaviours had been recognised within the initial study programme theory. Negative public opinion of transport policies in particular had been noted to curtail the policy implementation.[84–86] Consequently, a survey was developed from the one used by Tapp *et al.*[18] to collect data on general attitudes to the road, attitudes to 20-mph limits and perceived impacts of 20-mph limits alongside demographic and travel habit data.

Methods

The Speed Limits Perceptions Survey (SLiPS) developed for this study is provided in *Appendix 7*. Although the perception items were similar to those in the questionnaire developed by Tapp *et al.*,[87] additional sections on liveability, mode of transport and perceptions of 20-mph speed limits were developed using focus group data from Turner *et al.*[3] The survey was also adapted to investigate changes in relation to a specific intervention and to be more inclusive of non-drivers.

TABLE 6 Programme outcomes framework (including evaluation design)

Outcome	Data source (collector)	Sample	Sampling strategy	Time points for data collection[a]
Design: observational stepped wedge				
Walking	30 automatic fixed pedestrian counters (Sustrans)	Edinburgh residents	Previously identified key walking routes	Continuous, including several years of historical data
Cycling	Automatic fixed cycle counters (31 in Edinburgh and 14 in Belfast) (Sustrans)	Edinburgh and Belfast residents	Previously identified key cycling routes	Continuous, including several years of historical data
Public transport use	Routine bus data (Lothian buses and Translink NI)	Edinburgh and Belfast bus users	All routes in Edinburgh and Belfast	Continuous, including several years of historical data
Design: controlled before-and-after				
Walking, cycling and related attitudes	Route User Survey (Sustrans), Edinburgh only	Seven sites, up to 300 attitudes surveys per site and time point	Count all users (age, mode, gender) passing site, asking maximum for interview	Surveys conducted over both term time and school holidays
Travel behaviour	Scottish Household Survey (Scottish Government)	≈ 31,000 every 2 years across Scotland	Random postcode selection	Data made available every other year
Design: before-and-after				
Walking, cycling and related attitudes	Edinburgh Household Survey (CEC)	1215 households in Edinburgh	Systematic random sampling: ordered by urban–rural, SIMD and postcode	Baseline and 12 months post implementation (2019)
	Sport and Physical Activity Survey (Sport NI)	1037 households in Belfast	Stratified random sample of adults aged ≥ 16 years	2011 and repeated in 2017/18
Traffic speed and volume	Automatic sensors: 69 × 20-mph and 17 × 30-mph sites (Edinburgh); 23 sites (Belfast) (CEC and DRD, NI)	Edinburgh and Belfast road users	Mix of streets selected from area road managers, public consultation and random selection	Baseline and 2 and 12 months post implementation in Edinburgh; annual in Belfast
Collisions and casualties	STATS19 accident records (Police Scotland and PSNI)	Edinburgh and Belfast road users and pedestrians	All incidents reported to the police	Continuous (combined into tax years to give sufficient power)
Public support, behaviour and compliance	Survey developed by Tapp *et al.*[18] (research team)	500 residents in Edinburgh/Belfast per time point	Systematic random sampling: ordered by urban–rural classification, multiple deprivation measure and postcode	Baseline and 4, 12 and 18 months post implementation
Liveability	Google Street View (Google Inc., Mountain View, CA, USA) (research team)	76 streets in Belfast and 100 streets in Edinburgh	Belfast: each of the 76 20-mph streets Edinburgh: a stratified random sample from each of the seven 20-mph areas (calculated on the number of miles and metres of new 20-mph streets, rather than the size of the area)	Pre implementation of the 20-mph speed limits (Belfast, pre February 2016; Edinburgh, pre July 2016); the post-implementation time point for both cities was the closest date to the day of the audit

CEC, City of Edinburgh Council; DRD, Department for Regional Development (now known as the Department for Infrastructure); NI, Northern Ireland; PSNI, Police Service of Northern Ireland; SIMD, Scottish Index of Multiple Deprivation.
a Not all the data that were collected were analysed by the team. We focused on baseline and 18-month data.

As the project was not funded until after the 20-mph limits had been implemented in Belfast and part way through the implementation in Edinburgh, it was possible to collect pre-intervention perceptions data in only three of the implementation zones in Edinburgh (implementation zones 4, 5 and 6). Two of these implementation zones were next to each other (zones 4 and 5) and the policy was implemented in them on the same date; therefore, we treated them as a single site for the perceptions survey. The study (which used the perceptions survey) was reviewed and approved by the Moray House School of Education Ethics Subcommittee, University of Edinburgh (reference number 1114).

In Edinburgh data collection was repeated 6 and 12 months after implementation in three areas to explore long-term changes. In Belfast, the data were collected 2 years after the speed limit change. At each data collection time point, we aimed for 500 participants. To efficiently collect this number of data within a defined geography, it was decided to recruit visitors to amenities within each implementation zone in Edinburgh, in particular large shopping centres, sports/leisure centres and a hospital. In Belfast, data collection took place in the city centre and public transport hub. Dates of data collection and type of location are provided in *Appendix 8*, with local university students trained to collect the data. Prior to completing the survey, written informed consent was gathered from each participant. Participants were required to be aged > 16 years, and to able to provide consent and complete the survey in English. Assistance was provided if participants had reading or writing difficulties. Entry into a competition to win a £100 shopping voucher was the incentive offered at each data collection.

Each data collection was cross-sectional in line with the objective to evaluate public opinion, not to assess changes of opinions within individuals. Although this was an efficient method for collecting the data, the systematic random sampling, ordered by urban–rural classification, Scottish and Northern Irish Index of Multiple Deprivation rank and postcode, as specified in the protocol, was not feasible. Subsequently, the plan was to weight the responses received to support the validity of the comparisons between survey waves. These weightings would account for differences between samples and would not attempt to reflect the demographics of each city.

Confirmatory factor analysis had been conducted during the development of the survey to test the assessment of support for the policy. An exploratory factor analysis of the baseline pre-intervention responses was conducted as part of the final analysis of the survey. The SLiPS comprised 53 questions, 39 of which related to perceptions; therefore, factor analysis helped to minimise the number of variables for analysis. The exploratory factor analysis also revealed the main public perceptions related to 20-mph limits in each city within the responses. The challenges faced in the evaluation of liveability and active travel outcomes led to the inclusion of additional items in the perceptions survey on these outcomes. However, as these were not included until after first data collection, the responses could not be included in the factor analysis. When testing whether or not the inclusion of these additional items altered the factors identified, it was found that the variables loading into each factor remained consistent, with the loadings altering by, at most, ± 0.15. As the survey responses were either binary or ordinal, the factor analysis used a polychoric correlation matrix and promax rotation.

Perception findings: Edinburgh

Across the two sites and three time points in Edinburgh, survey responses were collected from 3485 members of the public. Once linked through their home postcode to the Scottish Index of Multiple Deprivation of their data zone, complete data on the perceptions questions were available for 2253 (64.6%) of respondents. The demographic characteristics and travel habits of participants are summarised in *Table 7*. Full details regarding the responses to each of the perceptions questions are provided in *Appendix 9*.

The polychoric correlation matrix of the perceptions responses is given in *Appendix 10*. Five factors were identified with eigenvalues of > 1. The loadings for each question into each factor are provided in *Appendix 10*. The table in *Appendix 12* lists the loading values for each question into the five factors; when a question made only a minor contribution to the factor (loading value of < 0.3), it was removed,

TABLE 7 Participant demographics and travel habits

Characteristic	Time point		
	Baseline	6 months	12 months
Complete sample size (*N*)	1018	599	636
Decade of birth, % (*n*)			
Pre 1950	15.3 (151)	13.6 (79)	9.44 (58)
1950s	18.8 (186)	19.4 (113)	15.6 (96)
1960s	23.5 (233)	26.8 (156)	21.6 (133)
1970s	16.1 (159)	19.0 (111)	20.6 (127)
1980s	12.4 (123)	11.2 (65)	13.8 (85)
Post 1989	13.9 (138)	10.1 (59)	19.0 (117)
Missing, *n*	28	16	20
Gender, % (*n*)			
Male	47.1 (470)	48.7 (289)	47.3 (292)
Female	52.9 (528)	51.4 (305)	52.7 (325)
Missing, *n*	20	5	19
Disability, % (*n*)	6.0 (60)	5.5 (32)	4.6 (28)
Missing, *n*	23	18	26
Ethnic minority, % (*n*)			
Non-white	5.0 (49)	6.3 (37)	10.0 (62)
Missing, *n*	31	11	17
SIMD16 quintile, % (*n*)			
Quintile 1 (most deprived)	9.4 (69)	8.2 (33)	5.5 (26)
Quintile 2	12.0 (88)	11.9 (48)	12.5 (59)
Quintile 3	13.0 (95)	9.6 (39)	13.1 (62)
Quintile 4	16.1 (118)	19.8 (80)	20.6 (97)
Quintile 5 (least deprived)	49.5 (362)	50.6 (205)	48.3 (228)
Missing, *n*	286	194	164
Not working, % (*n*)	48.9 (392)	64.9 (362)	72.3 (405)
Missing, *n*	217	41	76
Full UK driving licence, % (*n*)	94.3 (957)	94.8 (565)	90.4 (571)
Missing, *n*	3	3	4
Driving experience (years), % (*n*)			
< 5	10.2 (95)	8.0 (43)	12.6 (68)
5–10	10.1 (94)	6.7 (36)	9.4 (51)
10–20	17.8 (165)	14.2 (76)	16.1 (87)
20–40	44.8 (416)	50.5 (270)	46.2 (250)
> 40	17.1 (159)	20.6 (110)	15.7 (85)
Missing, *n*	89	64	95

TABLE 7 Participant demographics and travel habits (*continued*)

Characteristic	Time point		
	Baseline	6 months	12 months
Motorcycle user, % (*n*)	5.3 (49)	5.9 (32)	4.8 (27)
Missing, *n*	99	59	70
Are the roads near your home or work 20 mph?, % (*n*)			
No	19.9 (201)	12.2 (72)	12.6 (79)
Yes	75.2 (760)	84.7 (499)	84.0 (525)
Do not know	5.0 (50)	3.1 (18)	3.4 (21)
Missing, *n*	7	10	11
Are you aware of any (more) plans for 20-mph limits in the area where you live?, % (*n*)			
No	45.6 (460)	53.1 (317)	54.2 (341)
Yes	37.6 (379)	28.1 (168)	18.9 (119)
Do not know	16.9 (170)	18.8 (112)	26.9 (169)
Missing, *n*	9	2	7
Frequency of use of bus, train or tram, % (*n*)			
Every day	11.9 (118)	11.9 (69)	13.5 (84)
Several times a week	21.6 (214)	22.0 (128)	23.8 (148)
About once a week	16.8 (167)	19.1 (111)	17.5 (109)
About once a fortnight	12.0 (119)	12.9 (75)	12.2 (76)
About once a month	13.4 (133)	11.9 (69)	13.2 (82)
Less than once a month	15.9 (158)	13.9 (81)	14.1 (88)
Never	8.5 (84)	8.3 (48)	5.8 (36)
Missing, *n*	25	18	13
Frequency of use of car or van, % (*n*)			
Every day	46.4 (462)	44.5 (259)	42.0 (261)
Several times a week	33.7 (335)	34.0 (198)	30.0 (186)
About once a week	10.0 (99)	9.5 (55)	11.9 (74)
Less than once a week	4.8 (48)	8.3 (48)	9.5 (59)
Never	5.1 (51)	3.8 (22)	6.6 (41)
Missing, *n*	23	17	15
Frequency of use of taxi or Uber (Uber Technologies, Inc., San Francisco, CA, USA), % (*n*)			
Less than once a fortnight	8.7 (81)	7.2 (39)	11.4 (66)
About once a fortnight	9.8 (91)	9.7 (53)	9.0 (52)
About once a month	14.3 (133)	15.8 (86)	17.8 (103)
Less than once a month	32.3 (301)	34.5 (188)	33.2 (192)
Never	35.1 (327)	32.8 (179)	28.7 (166)
Missing, *n*	85	54	57

continued

TABLE 7 Participant demographics and travel habits (*continued*)

Characteristic	Time point		
	Baseline	6 months	12 months
Cycling frequency, % (*n*)			
Several times a week	9.4 (89)	11.5 (64)	12.5 (74)
Several times a month	10.6 (100)	11.7 (65)	9.8 (58)
Less than once a month	9.1 (86)	9.9 (55)	11.8 (70)
Never	71.0 (672)	67.0 (374)	65.9 (391)
Missing, *n*	71	41	43
Walking or running frequency, % (*n*)			
Every day	34.5 (338)	42.3 (242)	41.7 (254)
Several times a week	31.1 (304)	29.9 (171)	29.2 (178)
About once a week	11.1 (109)	9.4 (54)	10.8 (66)
Less than once a week	10.0 (98)	8.9 (51)	9.9 (60)
Never	13.3 (130)	9.4 (54)	8.4 (51)
Missing, *n*	39	27	27

SIMD, Scottish Index of Multiple Deprivation.

to highlight the questions contributing most to each factor. Factor names were created based on the questions loading into each factor and the direction of the loading. Those perceptions assessed on a five-point Likert scale were scored from 1 'strongly agree' to 5 'strongly disagree', meaning that negative loadings reflect agreement with the perception statement.

The five names chosen for the factors were as follows:

- factor 1 – detraction and resistance
- factor 2 – support (for the implementation of 20-mph speed limits)
- factor 3 – rule-following
- factor 4 – child safety
- factor 5 – walking safety.

With the factors deriving from categorical survey responses, the five factors were not normally distributed; consequently, it was not possible to apply weightings to increase the validity of the comparisons between survey waves. Kruskal–Wallis tests were used to compare perception factor scores across the three time points (*Figure 14*). Detraction and resistance (factor 1) decreased, while support (factor 2) and rule-following (factor 3) increased. Factors 4 and 5, child and walking safety, did not change significantly.

Perception findings: Belfast

Survey responses were collected from 490 members of the public. The mean age of the sample was 37.43 years (SD 17.22 years), with a median age of 32.00 years. The majority of participants were under the age of 40 years ($n = 273$, 55.7%), female ($n = 212$, 43.3%), with no disability or medical conditions ($n = 381$, 77.8%) and reported their ethnicity to be white ($n = 402$, 82.0%) (for complete details, see *Appendix 11*).

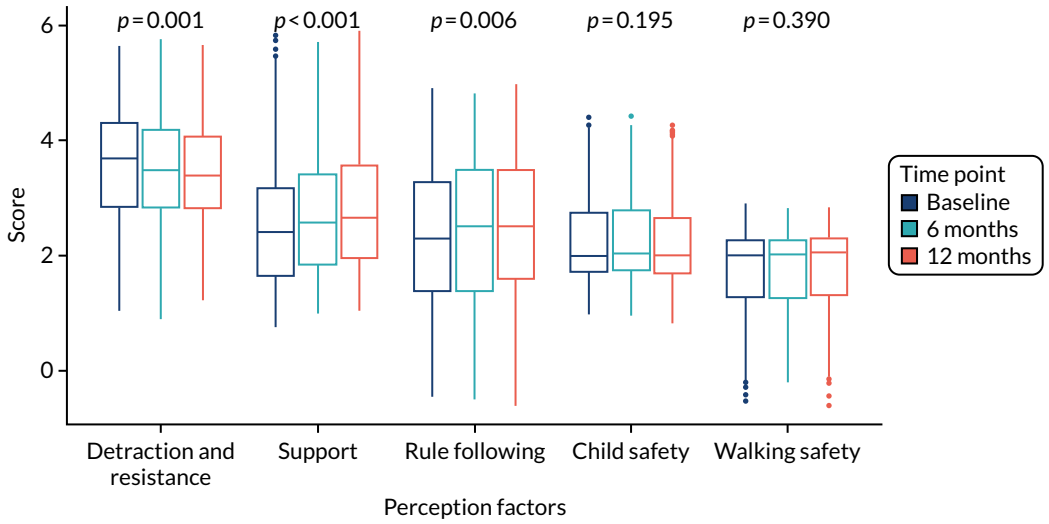

FIGURE 14 Box plots of each perception factor at baseline and at 6 and 12 months. *p*-values based on Kruskal–Wallis tests.

The majority of participants (62.1%, *n* = 304) reported that the 20-mph speed limits would make people drive more slowly (strongly, or tend to, agree), but 58.7% (*n* = 288) agreed that 20-mph speed limits were needed only where safety is an issue. The majority (60.8%, *n* = 298) also agreed that, although the speed limits will take time to get used to, they will eventually be accepted as the normal speed. There were mixed views as to whether or not a 20-mph speed limit would increase cycling and walking, but there was a slight tendency towards perceiving that it would (see *Table 8* and *Appendix 12*).

Participant reports were generally positive in response to traffic-related outcomes, including agreeing that there would be a decrease in the number of collisions (46.8%, *n* = 229) and in the number of severe collisions (53.1%, *n* = 261), and better traffic flow (31.2%, *n* = 153). However, there was a tendency to think that there would be no difference in vehicle noise. For three of the (unintended) traffic-related outcomes, the majority of participants had no strong views on whether there would be more congestion (36.5%, *n* = 179), more air pollution (41.0%, *n* = 201) or a decrease in fuel efficiency (45.1%, *n* = 221). In contrast, 52.5% (*n* = 258) of participants agreed that journey times would be longer with 20-mph speed limits (*Table 9*).

TABLE 8 Key responses from the Belfast perception survey

	Response, % (*n*)					
20 mph will . . .	**Strongly disagree**	**Tend to disagree**	**Neither agree nor disagree**	**Tend to agree**	**Strongly agree**	**Missing**
Increase the number of people cycling	5.5 (27)	12.2 (60)	42.4 (208)	21.8 (107)	10.8 (53)	7.1 (35)
Increase the number of people walking	4.5 (22)	12.2 (60)	35.7 (175)	25.9 (127)	12.0 (59)	9.6 (47)
Decrease the number of severe collisions	2.4 (12)	6.5 (32)	30.8 (151)	36.9 (181)	16.2 (80)	6.9 (34)
Decrease the number of collisions	2.9 (14)	8.0 (39)	34.5 (169)	33.5 (164)	13.3 (65)	8.0 (39)
Improve traffic flow (less stopping and starting)	9.2 (45)	20.8 (102)	29.2 (143)	22.2 (109)	9.0 (44)	9.6 (47)
Reduce noise from vehicles	4.3 (21)	17.3 (85)	39.6 (194)	22.2 (109)	7.6 (37)	9.0 (44)
Increase congestion	2.2 (11)	15.5 (76)	36.5 (179)	24.3 (119)	11.8 (58)	9.6 (47)
Increase air pollution	3.7 (18)	14.9 (73)	41.0 (201)	19.8 (97)	10.4 (51)	10.2 (50)
Increase journey times	2.2 (11)	11.4 (56)	24.5 (102)	37.1 (182)	15.5 (76)	9.2 (45)
Cause a decrease in fuel efficiency	2.0 (10)	12.2 (60)	45.1 (221)	20.0 (98)	8.8 (43)	11.8 (58)

TABLE 9 Responses to 20-mph speed limit traffic-related outcomes (negative outcomes)

	Traffic-related outcomes, *n* (%)			
Response	More congestion	More air pollution	Longer journey times	Decrease in fuel efficiency
Strongly agree	58 (11.8)	51 (10.4)	76 (15.5)	43 (8.8)
Tend to agree	119 (24.3)	97 (19.8)	182 (37.1)	98 (20.0)
Neither agree nor disagree	179 (36.5)	201 (41.0)	120 (24.5)	221 (45.1)
Tend to disagree	76 (15.5)	73 (14.9)	56 (11.4)	60 (12.2)
Strongly disagree	11 (2.2)	18 (3.7)	11 (2.2)	10 (2.0)
Missing	47 (9.6)	50 (10.2)	45 (9.2)	58 (11.8)

The majority of respondents reported that the 20-mph speed limit would increase how pleasant the area is to live or work in (38.5%, $n = 189$) and make the streets safer (66.1%, $n = 324$), but were ambivalent as to whether or not it would provide more opportunities to socialise (43.9%, $n = 215$). In terms of active travel, approximately 10% said that they would cycle more, walk more or let children walk more if more roads had 20-mph speed limits

Comparing the findings of the perceptions surveys in Edinburgh and Belfast

Despite the absence of baseline data from Belfast, the collection of the data 2 years after the implementation in Belfast helped to gain some insights into the longer-term impact of 20-mph limits. Across the statements reported in *Table 9*, the responses from Belfast were less negative (strongly disagree) than those from Edinburgh (at any time point), usually with an increase in 'strongly agree' responses. However, there was also an increase in 'neither agree nor disagree' responses, particularly in terms of cycling, walking and collisions, for which the respondents in Belfast were more likely than those in Edinburgh to agree that there had been a positive change. For the statements related to traffic flow, noise, congestion, air pollution, journey times and fuel efficiency, the responses from Edinburgh showed more agreement with these statements, whereas Belfast respondents were more ambivalent. When the factor loadings from Edinburgh were applied to the Belfast data, detraction and resistance scores were lower in Belfast and support scores were higher, but the other factors did not differ markedly. These comparisons could reflect an ongoing positive shift in the norms relating to 20-mph speeds. However, they might also reflect sociocultural differences in the cities, or the distinct effect of the different scales of intervention. The limited area of the Belfast intervention meant that respondents had a lower dose of the intervention than people in Edinburgh.

Strengths and limitations of the perceptions survey

The SLiPS offers a robust method for evaluating relevant public perceptions of speed limit interventions. Repeat data collection before and after (in three implementation areas) the policy change has provided useful insights into the changes in public perceptions, although this was not possible in Belfast. The data collection methods and sample size limited the extent to which the data could be weighted or considered representative of the city population. Consequently, we cannot be highly confident that the changes (or lack of) in perception observed are not the result of differing samples at each time point. However, the use of repeat cross-sectional data collection is in line with the objective to assess public perceptions. Finally, prior to the perceptions survey data collection in Edinburgh, > 50% of roads in the city had historically been 20 mph, and three zones had been converted to 20 mph as part of the intervention being evaluated. Consequently, at baseline we were not assessing the perceptions of people who had not experienced the intervention. Therefore, different or larger changes in perceptions may be observed in locations where 20-mph limits were being implemented for the first time.

Speed and volume

For this section of the evaluation, analyses of repeated cross-sections of data (two for each implementation zone) for traffic speed and traffic volume at (1) 1 week pre implementation and (2) 12 months post implementation were conducted (an additional time frame of 3 years post implementation was considered for Belfast). The design matched what Leatherdale[88] described as a repeat cross-sectional pre–post quasi-experiment.

Methods

The overall statistical summaries employed in this trial included measures of central tendency, dispersion and basic *t*-tests. More statistical summaries are presented for Edinburgh because more streets were analysed, and the data set was richer.

Results for speed and volume: Edinburgh

Overall city-level changes

The mean and median speeds reduced by 1.34 mph and 0.47 mph, respectively, when comparing pre with post data at 12 months. There were also reductions across the distribution of speeds [interquartile range, and range (maximum to minimum)]. The greatest reductions were observed for the maximum speed observed (1.79 mph) and the third quartile (1.78 mph). A box plot summary of the speed distributions at a city level before and after implementation is shown in *Figure 15*. This illustrates the way the distribution of speeds shifted 'down' to reflect lower post-implementation speed.

These distributions are further presented as frequency plots at 1-mph intervals in *Figure 16*. The speed distribution both before and after the 20-mph speed limits appears to be bimodal. Comparison of the distributions shows how the right-hand peak has shifted left in the post implementation distribution, indicating reductions in the frequency of higher traffic speeds being observed. It also suggests that the left-hand peak has shifted from 22 mph to 20 mph, indicating a reduction in speeds at these lower speeds.

In terms of traffic volume, the results show an average, per measurement site, of 3641, a reduction of 87 in the average number of vehicles per day at each site. Overall, the difference in vehicular volume after the speed limit implementation was minimal (reduction of 2.4%) and non-significant (*Table 10*).

Changes in speed by day of week and time of day

When the times were categorised into periods of the day (early morning, working day and night), the reductions in average speed were again found to be very similar in magnitude. Specifically, the average pre–post differences in speed for early morning, working day and night were found to be −1.29 mph [95% confidence interval (CI) −1.43 to −1.16 mph], −1.35 mph (95% CI −1.42 to −1.28 mph) and −1.36 mph (95% CI −1.45 to −1.26 mph), respectively. *Figure 17* shows the change in average speed with time of day

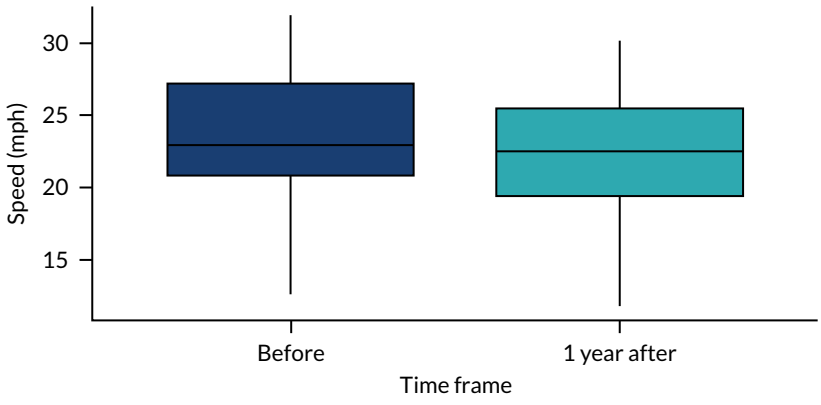

FIGURE 15 Box plots for before-and-after speed distributions using the combined records for all 66 monitored streets.

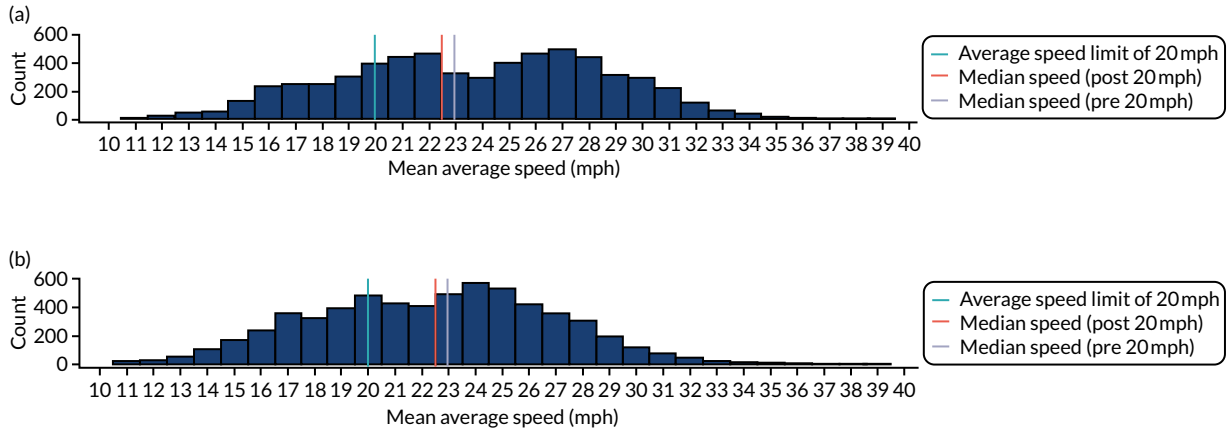

FIGURE 16 Histogram of average speeds on 20-mph streets in Edinburgh for each of the 66 monitored sites ($n = 12{,}672$ observations): (a) before 20-mph speed limits; and (b) after 20-mph speed limits.

TABLE 10 Summary statistics of (7-day) average vehicle volume per site

Category	Mean	SD	Median	Interquartile range (first to third quartiles)	Minimum, maximum
Volume before	3641	2633	3738	743–5862	144, 9343
Volume after	3555	2592	3391	716–5860	154, 9788
Difference	−87	810	−347	First quartile: −27	Minimum: 10
				Third quartile: −2	Maximum: 446

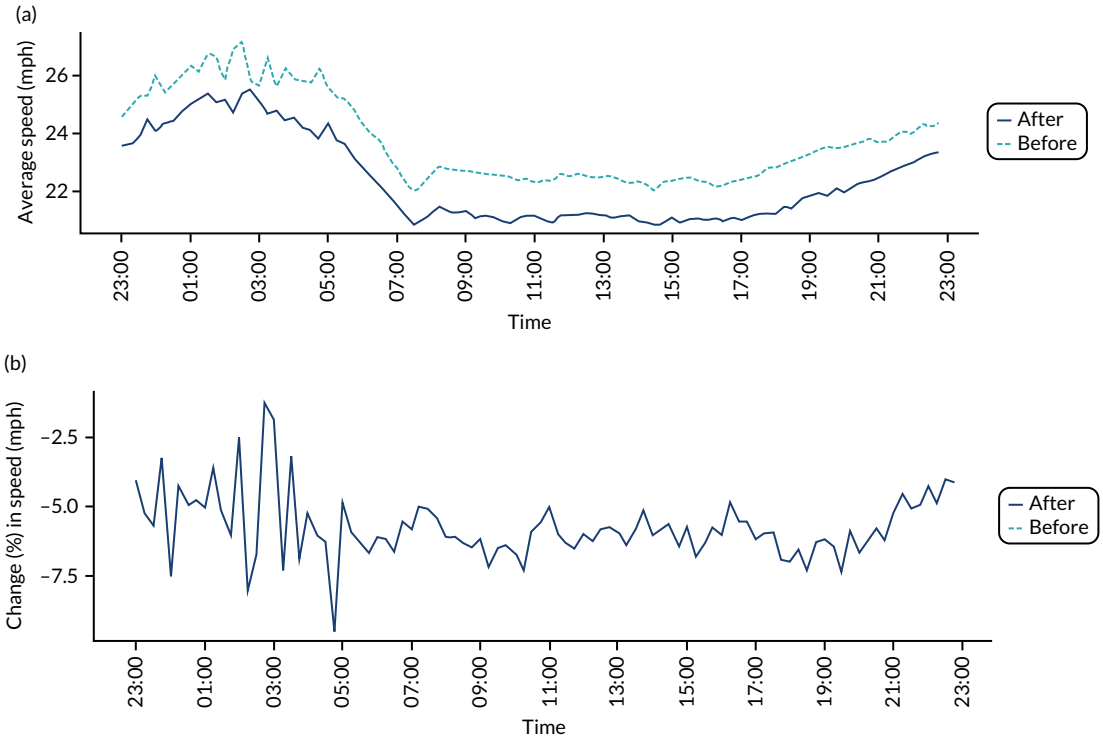

FIGURE 17 (a) Average speeds on 20-mph streets in Edinburgh, with time of day as a continuous variable (from 00:00 to 23:45 by 15-minute intervals); and (b) percentage difference in average speeds before and after implementation. Note that, for each plot, the data were aggregated over 96 time points by two time frames ($n = 192$).

treated as a continuous variable. Here, it is apparent that relatively higher average speeds are observed between the times of 01:00 and 06:00. *Figure 17* also depicts the trend in the percentage difference in the average speed before and after implementation, with the greatest variation occurring between 01:00 and 06:00.

Changes by pre-implementation mean speed

Reductions in mean speed (in mph) were also observed for the streets with pre-implementation speeds in the categories of < 24 mph and ≥ 24 mph. These reductions were both found to be statistically significant. A larger reduction (of 2.03 mph) was observed for the ≥ 24 mph category than for the < 24 mph category (reduction of 0.72 mph). *Table 11* shows the percentage of observations before and after implementation within specific speed ranges, with relative and absolute changes. After the implementation there were fewer observations in the higher-speed ranges '> 30 mph' and '25–30 mph', and more observations in the lower-speed ranges '< 20 mph' and '20–24 mph'.

Changes by implementation zone and by street type

The summary of mean speed for each 20-mph implementation zone is shown in *Table 12*. These results indicate statistically significant reductions in average speed for five of the seven zones (zones 1a, 1b, 2, 3 and 5). A reduction in average speed was observed for zone 4, but was not found to be statistically significant. A non-significant and small increase in average speed was observed for zone 6. When streets were categorised into main and residential, the average difference in speed post 20-mph speed limits was larger for main streets (−1.59 mph, 95% CI −1.16 to −2.02 mph) than for residential streets (−1.38 mph, 95% CI −0.98 to −1.78 mph). In both cases, the observed changes were found to be statistically significant.

TABLE 11 Speed bin summaries showing the percentage of observations ($n = 12{,}672$) in four speed bins (ranges) before and after the 20-mph speed limit implementation

	Speed bin[a] (%)			
Implementation of 20-mph speed limit	< 20 mph	20–24 mph	25–30 mph	> 30 mph
Before	19.2	35.5	38.1	7.2
After	24.5	44.4	28.0	3.1
Absolute % change	5.3	8.9	−10.1	−4.1
Relative % change	27.6	25.1	−26.5	−56.7

a Speed bins derived from the raw speed observations.

TABLE 12 Summary of average speed (mph) overall and by 20-mph implementation zone

Category	Before	After	Difference	SD	95% CI	*p*-value
All zones	23.63	22.29	−1.34	1.57	−1.72 to −0.95	0.00
Zone 1a	24.14	22.07	−2.07	1.58	−3.54 to −0.61	0.01
Zone 1b	23.84	21.43	−2.41	1.00	−3.46 to −1.36	0.00
Zone 2	23.53	22.20	−1.33	1.57	−2.11 to −0.55	0.00
Zone 3	25.40	23.89	−1.51	1.32	−2.28 to −0.75	0.00
Zone 4	26.54	25.75	−0.79	1.15	−1.86 to 0.28	0.12
Zone 5	20.14	18.97	−1.18	1.39	−2.24 to −0.11	0.03
Zone 6	20.25	20.66	0.41	2.40	−2.57 to 3.39	0.72
Main	24.26	22.68	−1.59	−1.16	−2.02 to −1.16	0.47
Residential	23.61	22.23	−1.38	−0.98	−1.78 to −0.98	0.19

Table 13 shows the changes in vehicle volume by zone and road type; however, none of these is statistically significant. Increases in traffic volume were observed in zone 5 and on residential streets, whereas the volume reduced in the other zones and on mains streets.

Overall, the model results quantify the odds of speed being reduced (post 20-mph speed limits) for key variables. We note, in particular, that the odds of speed reduction of > 0.5 mph are increased (10-fold) when considering streets with an average speed of > 30 mph pre 20-mph speed limits (vs. streets with average speeds of between 20 and 24 mph pre 20-mph speed limits). The CI for this estimate is, however, relatively large, indicating low precision. Further details on the results of the model are provided in *Table 14*.

TABLE 13 Summary of average vehicular volume (*n*) overall and by 20-mph implementation zone and street type

Category	Before	After	Difference	% Difference	95% CI	*p*-value
Average for all sites	3641	3555	−87	−2.36	−112 to 286	0.387
Average for sites in zone 1	4091	3989	−102	−2.49	−887 to 1091	0.826
Average for sites in zone 2	4423	4279	−144	−3.26	−78 to 367	0.190
Average for sites in zone 3	4169	3962	−207	−4.97	−80 to 494	0.143
Average for sites in zone 4	3035	2954	−82	−2.67	−81 to 245	0.266
Average for sites in zone 5	2163	2415	252	11.65	−658 to 154	0.191
Average for sites in zone 6	1690	1569	−121	−7.16	−109 to 351	0.219
Average for main streets	5750	5512	−238	−4.14	−219 to 695	0.295
Average for residential streets	1896	1924	28	1.48	−142 to 86	0.620

TABLE 14 Results for logistic regression model for quantifying the odds of speed reduction

Parameter	Odds ratio	95% CI
Intercept	0.44[a]	0.33 to 0.57
Zone 1a/**zone 6**	3.11[a]	2.26 to 4.28
Zone 1b/**zone 6**	12.6[a]	8.4 to 19.34
Zone 2/**zone 6**	1.97[a]	1.51 to 2.56
Zone 3/**zone 6**	1.64[a]	1.24 to 2.17
Zone 4/**zone 6**	0.64[a]	0.47 to 0.88
Zone 5/**zone 6**	2.8[a]	2.11 to 3.73
Phase: night/**early morning**	1.82[a]	1.52 to 2.18
Phase: working day/**early morning**	2.42[a]	2.05 to 2.87
Speed bin: < 20 mph/**20–24 mph**	0.46[a]	0.38 to 0.54
Speed bin: 25–30 mph/**20–24 mph**	5.02[a]	4.19 to 6.02
Speed bin: > 30 mph/**20–24 mph**	10.3[a]	7.1 to 15.31
R^2	0.189	

a Denotes statistical significance (alpha = 5%).

Note
Reference categories are in bold.

Speed and volume findings: Belfast

Paired *t*-tests pre and post 20 mph

In *Table 15*, the pre- and post-20-mph data sets were combined to obtain a data set with paired streets. Some of the streets in the pre-20-mph data set were removed because there was no corresponding street in the post-20-mph 1-year data. The results show that there was a non-statistically significant decrease in average speed of 0.19 mph. A similar analysis was conducted with post-20 mph 3-year data. As before, a non-statistically significant decrease in average speed was found ($p = 0.40$).

In terms of traffic volume, a statistically significant change (decrease in 93 vehicles per week) was observed when considering pre and post (1 year) comparisons for matched streets. There was also a statistically significant decrease in volume when comparing all sites pre and post implementation (3 years) (134 vehicles per week).

Strengths and limitations of speed and volume analyses

For Edinburgh, it was not possible to include comparison or control streets in the analysis. If this were possible, it could have helped to identify the independent effects of the intervention. The analysis here cannot rule out that changes in speeds could have happened anyway (secular trends), or determine how much of the observed changes can be attributed to the intervention (rather than other events or interventions within the time frame under analysis).

However, the theory-based approach that we utilised in our evaluation, the pre-stated protocol[52] and the logical proximal relationship between speed limits changing and traffic speed changing mean that the results presented here add substantial weight to the evidence base for 20-mph limits leading to reduced speeds at 12 months.

Collisions and casualties

Methods

The methods employed for this study were as follows:

- monthly comparisons of the mean number of casualties and collisions before and after the 20-mph limit change in Edinburgh
- data visualisations of trends
- rate calculations
- modelling of road traffic collisions and casualties (Edinburgh).

The data visualisations focused on the time series of road traffic collisions and casualties, and on the trend in collisions by time of day. Rate calculations were performed to compare collision rates overall and at various aggregations, such as implementation zones and road categories. For casualties, rate calculations were performed by level of casualty severity and for vulnerable groups.

TABLE 15 Paired *t*-tests for traffic speed pre and post 20 mph at 1 year (Belfast)

Comparison	Estimate	Before	After	*p*-value	95% CI	Method
Pre (all) vs. post (3 years)	−0.98	20.36	19.38	0.27	−0.78 to 2.73	Welch two-sample *t*-test
Pre (all) vs. post (1 year)	−0.91	20.36	19.45	0.38	−1.18 to 3.01	Welch two-sample *t*-test
Post 1 year vs. post 3 years	−0.07	19.45	19.38	0.95	−1.88 to 2.01	Welch two-sample *t*-test
	Difference					
	0.19			0.7	−0.89 to 1.27	Paired *t*-test

The models considered in this study are Elvik's power and exponential models,[89] generalised linear models, generalised additive models[90] and hidden Markov models.[91] The Elvik models estimate the rate of collisions given the observed change in traffic speed, whereas the generalised additive models and the hidden Markov models focus on the features of the overall temporal trend of road traffic collisions. The generalised linear model was used to model the observed road traffic casualties with key explanatory variables being age of driver, accident severity and time of day. Overall, the approach taken for analysing road traffic collisions and casualties is multipronged, with analysis of trends, rates and counts, with data visualisation.

As collision and casualty data were collected across the whole of Scotland and Northern Ireland, it was possible to identify control zones. As described in the protocol, the control zones were matched using the separate domains for the Scottish Index of Multiple Deprivation (2016)[92] and the Northern Ireland Multiple Deprivation Measure (2017),[93] the urban–rural classification of the area and the population density. As each of the intervention areas include more than one data zone (Scotland), or output or small area (Northern Ireland), the mean, median or mode of each of the matching variables was used depending on the nature and distribution of the variable.

The 20-mph limits in Belfast were implemented across roads in 10 small areas and 11 output areas; matching across the variables listed above identified Ward Central as the most appropriate control zone. The implementation zones in Edinburgh varied in size from being equivalent to 21 data zones up to 173 data zones. Owing to their size, it was not possible to find a matched control for the largest implementation zones, South Central/East. But approximately suitable matches were found for the other implementation zones, allowing the evaluation of collisions and casualties to be compared against secular trends from matched areas (difference in differences).

Results: Edinburgh

Here we discuss the results relating to the observed road traffic collisions and casualties for the study period. For the citywide calculations, the number of years considered pre 20-mph speed limits is 3 years, and the number of years considered after 20-mph speed limits is 3 years and 10 months. The following results build a narrative to link the observed changes in traffic speed with observed changes in the number of road traffic collisions and casualties within a polyphonic evaluation process. The results (*Table 16*) found that there were statistically significant reductions in counts of casualties and collisions across road types and speed limits, with the largest reduction being observed for main streets that switched to 20 mph. In particular, we note a statistically significant average reduction of 14 collisions (and 16 casualties) on main roads that switched to 20 mph, four collisions (and five casualties) on local roads that switched to 20 mph and eight collisions (and nine casualties) on roads that remained at 30 mph.

Overall, a 40% reduction in road traffic collision rates was observed when considering the pre-20-mph period of 3 years (2013–15), and for the post-20-mph period of 3.72 years (2016–19). When the secular trend within the pre- and post-20-mph periods was incorporated, the resulting percentage change in road traffic collisions was 36%.

We employed the impact model (power and exponential models) proposed by Elvik[89] to investigate the causal link between traffic speed reduction and road traffic collision rates. Both models, power and exponent, indicated a reduction in road traffic collisions. The predicted percentage rate reductions are 11% and 1% for the exponent and power models, respectively. For these models, the prediction of road traffic collision rates is lower than that observed; these predictions, however, provide a 'finger on the pulse' on the direction of impact of the observed changes in traffic speed. A larger reduction in collisions and casualties than would be expected based on the change in speed is supportive of an intervention effect.

TABLE 16 Monthly analysis of collisions and casualties in Edinburgh

Road type	All months	January[a]	February[a]	March	April	May	June	July	August	September	October	November	December
Difference in mean number of casualties after limit change, compared with before													
All Edinburgh													
20 mph, existing streets	**−4.49**	−6.67	−10.00	−3.83	−0.50	−6.50	−7.33	−4.83	−6.33	−2.67	−3.00	−5.00	−1.00
20 mph, local streets	**−5.04**	−5.67	−4.33	−0.17	−1.17	−2.50	−3.50	−3.83	−5.00	−5.67	**−10.17**	−10.50	−8.33
20 mph, main streets	**−15.87**	−9.67	−9.00	**−15.67**	−15.83	**−26.00**	−13.17	−16.17	−12.00	−13.83	−9.50	**−13.83**	**−34.83**
30 mph	**−8.78**	−10.00	−10.67	−8.50	−7.00	−10.83	−10.33	**−14.67**	**−8.67**	−2.33	**−10.33**	−5.50	−9.67
Zones 1a, 1b, 3, 4, 5, 6[b]													
20 mph, existing streets	**−3.43**	−8.33	−5.67	−1.50	−0.83	−4.83	**−7.00**	−5.33	−3.67	−2.83	−1.67	−3.50	0.50
20 mph, local streets	**−4.53**	−6.00	−3.00	−3.83	−0.50	−1.67	−2.00	−5.00	−4.17	−3.83	−4.33	**−9.50**	−10.83
20 mph, main streets	**−11.36**	−8.33	−10.33	−11.17	−10.00	**−20.00**	−8.17	−10.17	−12.67	−13.00	−2.50	−9.83	−22.33
30 mph	**−7.27**	−10.33	−9.67	−9.00	−6.83	−3.00	−8.67	−8.83	**−9.50**	−0.17	−8.50	−6.67	−8.00
Control 20 mph[a]	**2.24**	–	–	0.33	1.67	2.67	1.67	0.00	5.00	1.00	2.67	2.33	4.67
Control 30 mph[a]	**−20.29**	–	–	−32.00	−5.33	−16.00	−12.33	−25.00	−25.00	−17.00	−21.67	−12.00	−27.67
Difference in mean number of collisions after limit change, compared with before													
All Edinburgh													
20 mph, existing streets	**−4.33**	−9.00	−6.33	−4.83	−1.00	−6.00	−5.50	−4.50	−6.67	−3.00	−3.33	−5.00	−1.33
20 mph, local streets	**−4.30**	−6.00	−3.33	−2.50	−0.17	−0.83	**−5.00**	**−4.67**	−3.33	−3.83	**−8.17**	**−9.00**	−6.67
20 mph, main streets	**−14.28**	−8.00	−9.00	**−12.33**	−13.33	**−21.67**	−14.83	−10.00	−11.50	−12.50	−14.00	−10.67	**−31.50**
30 mph	**−7.60**	−4.33	−8.33	−6.00	−4.83	−9.83	−10.33	**−11.50**	−10.33	−1.33	**−8.67**	−5.50	−10.83

continued

TABLE 16 Monthly analysis of collisions and casualties in Edinburgh (*continued*)

Road type	All months	January[a]	February[a]	March	April	May	June	July	August	September	October	November	December
Zones 1a, 1b, 3, 4, 5, 6[b]													
20 mph, existing streets	**−3.37**	−7.67	−2.67	−2.50	−1.33	−4.67	**−5.83**	−5.00	−4.33	−3.17	−2.67	−3.50	0.17
20 mph, local streets	**−3.67**	−5.33	−2.67	−4.00	0.17	0.00	−3.00	**−4.83**	−2.50	−3.00	**−3.67**	−8.00	−8.17
20 mph, main streets	**−10.49**	−7.67	−10.33	**−8.17**	−8.17	**−16.33**	−10.17	−8.33	−11.00	−11.17	−7.17	−8.50	**−21.00**
30 mph	**−6.31**	−5.00	−7.67	−6.67	−5.33	−3.33	−9.50	−8.17	−10.00	1.00	**−6.67**	−5.67	−9.17
Control 20 mph[a]	**2.15**	–	–	0.33	0.67	2.00	1.67	0.67	5.00	1.00	2.67	2.67	4.67
Control 30 mph[a]	**−15.47**	–	–	−24.33	−6.00	−9.67	−9.67	−17.00	−18.00	−14.33	−19.67	−10.00	−18.67

a Only one post-intervention observation, so unable to undertake *t*-test.
b As it was not possible to identify a control zone for zone 2, these rows combine the other intervention zones and their matched control zones.

Notes
Basic analysis comparing the mean number of casualties and collisions before and after the 20-mph limit change in Edinburgh. The data before the limit changes relate to the period from August 2013 to July 2016, whereas the after data relate to the period from March 2018 to December 2019. Figures in bold are statistically significant differences ($p < 0.05$) according to a two-sample *t*-test with unequal variances.

When considering the individual road types and speed limits within the city of Edinburgh, we note that the roads that retained limits of 30 mph experienced the smallest (in magnitude) percentage reduction in rates. The largest percentage reduction in rates was observed for 20-mph main roads. The road types and speed limits in this comparison were 20-mph existing streets, 20-mph residential streets, 20-mph main streets and 30-mph streets. In terms of the time of day, the largest percentage reduction in road traffic collision rates was observed for the period 08:00–18:00 (45%).

Of the seven implementation zones considered, the largest percentage reduction in road traffic collision rates was observed in zones 5 and 6, with 47% and 45% reductions, respectively. Zones 5 and 6 represent Edinburgh West and Edinburgh South. Reductions in road traffic collisions were observed for all the implementation zones.

We employed two different approaches to model the trend and seasonality of the road traffic collisions as well as to investigate the effect of the introduction of the 20-mph policy.[94] In our analysis we detected a switch from a slow-declining to a fast-declining state shortly after the introduction of the 20-mph policy. In addition, we detected a faster decline in road traffic collisions post 20 mph with a significant 'implementation effect' observed when the intervention was modelled using the generalised additive models referred to previously.

The main findings were that, when controlling for other variables in the model, the log of the number of road traffic casualties (1) increased by 0.14 when considering males (vs. females), (2) decreased by 0.005 when age of casualty considered was increased by 1 year, (3) reduced by 0.723 when considering rural locations (vs. urban), (4) decreased by 0.738 after the speed limit implementation (vs. before the implementation) and (5) decreased by 0.344 when considering local streets that switched from a limit of 30 mph to one of 20 mph (vs. streets that remained at 30 mph before and after the 20-mph speed limit implementation). Further details can be found in *Table 17*.

After the 20-mph speed limit implementation, there was also a reduction in the number of road traffic casualties (*Table 18*). Reductions in casualty rates were observed citywide, at each casualty severity level, and for each vulnerable road user considered in this study. In particular, the overall percentage reduction in casualty rates was 39% (40% was observed for collision rates). The percentage reduction for each level of severity was 23%, 33% and 37% for casualty levels fatal, serious and slight, respectively.

TABLE 17 Modelling road traffic casualties (Poisson generalised linear model)

Variable	Estimate	95% CI
Intercept	−0.873	−1.305 to −0.478
Sex: male	0.141	0.071 to 0.213
Age	−0.005	−0.006 to −0.003
Intervention: before	0.738	0.64 to 0.838
Accident severity: serious	0.067	−0.298 to 0.475
Accident severity: slight	0.773	0.419 to 1.171
Urban or rural area: rural	−0.723	−1.003 to −0.465
Phases: night	0.267	0.14 to 0.395
Phases: working day	0.625	0.51 to 0.742
Speed limit trajectory: 20 mph local streets	−0.344	−0.447 to −0.243
Speed limit trajectory: 20 mph main streets	0.146	0.068 to 0.224

Note
Statistically significant parameters are in bold font.

TABLE 18 Edinburgh citywide average annual casualty severity rates[a]

	Casualties (*n*)		Rate					
Aggregation	Pre implementation	Post implementation	Pre implementation	Post implementation	Difference rates	% difference rates	Secular trend	Adjusted difference in rates
Citywide	3105	1146	1035	626	−409	−39 (−29)	−4 (−2)	−35 (−27)
Fatal	14	3	11	5	4	−1		−23
Serious	365	68	297	122	82	−40		−33
Slight	2726	474	2252	909	571	−338		−37
Children	287	89	96	49	−47	−49		
Elderly	368	108	123	59	−64	−52		
Driver/rider	1620	404	540	221	−319	−59		
Passenger	657	213	219	116	−103	−47		
Pedestrian	828	237	276	130	−146	−53		

a Figures in brackets relate to the aggregated geographic control zones.

Results: Belfast

Overall, there was a reduction of 2% in collision rates in Belfast when considering the study time frames (*Table 19*). Reductions in road traffic casualties were also observed for fatal and slight severities, and for pedestrians. Interestingly, an increase in road traffic casualties for motorcyclists and pedal cyclists was observed.

Strengths and limitations

The nature of this study, being a natural experiment evaluation, presents researchers with the need to acknowledge confounding variables and make adjustments in analyses when possible. The main confounder in this natural experiment is related to the citywide efforts to increase active travel during the study period. The attribution of a quantified impact of these efforts on road traffic collisions and casualties has been a challenge as representative data on active travel for the purposes of this study were not available.

Further work will involve a multiagency effort at designing efficient data collection of active travel data using emerging technology such as used in the 'track and trace' NHS applications. We are in the process of seeking funding with other collaborators on this venture. The data generated will facilitate the incorporation of a proxy for the attribution of the impact of active travel promotions on road traffic collision and casualties. In addition, the incorporation of prior knowledge such as estimates from Elvik's models and from relevant systematic reviews within a Bayesian framework will allow for a broader modelling approach to the evaluation of the impact of 20-mph speed limits on road traffic collisions.

Liveability

Liveability is a complex concept, connecting the fields of public health and urban planning, and comprises a series of interlinking and interconnecting constructs that include (but are not limited to) accessibility, health, safety and sustainability.[95] Investigations examining liveability provide researchers, policy-makers and practitioners with important information regarding both macro- and microlevel environmental attributes and at varying geographical scales (i.e. street, neighbourhood, city, region). Such information is considered vital when making recommendations for changes to the built environment and/or the design, development and implementation of built environment interventions.[96,97]

TABLE 19 Belfast city centre average annual casualty severity rates

	Casualties (*n*)		Rate			
Aggregation	Pre implementation	Post implementation	Pre implementation	Post implementation	Difference rates	% difference rates
City centre	238	304	79	78	−2	−2
Fatal	11	8	3.7	2.0	−1.7	−44.3
Serious	310	334	103.3	85.2	−18.1	−17.5
Slight	5482	5361	1827.3	1367.6	−459.7	−25.2
Children	29	27	10	7	−3	−29
Elderly	29	36	10	9	0	−5
Pedestrian	80	72	27	18	−8	−31
Motorcyclist	5	9	2	2	1	38
Pedal cyclist	8	14	3	4	1	34

One construct that has been reported to have the capacity to result in a range of negative impacts on liveability, and consequently health and well-being, is traffic/transport.[98] Specifically, factors relating to traffic speed, noise, air pollution, road safety and congestion have all been reported to affect health and well-being through collisions and casualties, reduced physical activity and active travel, increased sedentary behaviour, and poorer mental health and well-being.[26,98] However, the current evidence base is limited, with a metanarrative review into the effectiveness of 20-mph speed limits on public health outcomes reporting ambiguous findings and limited evidence relating to liveability.[98]

Consequently, in a bid to supplement the current evidence base, a survey was adapted for use with Google Street View [(GSV) Google Inc., Mountain View, CA, USA] to assess liveability pre and post implementation of the 20-mph speed limit interventions in both Belfast (city centre) and Edinburgh (citywide).

Methods

Microscale Audit of Pedestrian Streetscapes-Liveability

On review of current measurement tools, no existing tools were considered feasible and appropriate for the assessment of liveability following the implementation of the 20-mph speed limit interventions. Specifically, the research team found that there was a lack of measurement tools that had the capacity to assess liveability at lower geographical levels (i.e. the street) and that included an examination of microlevel features [i.e. road features (e.g. speed signage, cycle lanes), parks, amenities, street lighting]. However, when existing environmental audit tools were examined, the Microscale Audit of Pedestrian Streetscapes (MAPS)-Full tool was deemed to be an appropriate starting point to develop a liveability tool.[99] The development process was implemented in four stages: (1) a review of existing liveability literature to develop a comprehensive list of liveability characteristics, (2) a cross-comparison of MAPS-Full with the list from stage 1, (3) adaption of MAPS-Full to MAPS-Liveability to include any missing items established within stage 2 and (4) reliability testing of MAPS-Liveability.[98] It was decided by the research team that MAPS-Liveability would be implemented via GSV to provide researchers with the opportunity to access current and historical environmental data and the ability to collect data in a safe and inexpensive way.[100] Minimal adaptions were made to MAPS-Full for the purposes of developing MAPS-Liveability. The key changes included (1) the addition of three qualitative open-ended questions, (2) the addition of 12 proxy indicators of behaviour (including active travel behaviour), (3) the audit starting point, (4) the length of the audit area, (5) auditing of one route rather than a segmented route and (6) the removal of questions that required the auditor to be present on the street (i.e. noise levels).[98]

Changes to the scoring protocol enabled a total score for liveability and nine individual liveability construct scores (i.e. health, education, sustainability, inclusivity, places, safety, traffic/transport, roads and pavements) to be calculated.[98] When reliability testing was implemented, results showed that MAPS-Liveability provides a reliable assessment with excellent inter-rater reliability for total liveability and good–excellent inter-rater reliability for the nine liveability constructs and proxy indicators of behaviour.[98]

Data collection

Data collection for Belfast was implemented by three trained researchers between April and July 2019 and covered each of the 76 streets involved in the 20-mph speed limit intervention. Data collection in Edinburgh involved three different trained researchers and took place between February and March 2020. One hundred streets across the seven 20-mph speed limit zones were audited in Edinburgh, with sampling taking a stratified approach based on the length (in m) of the 20-mph streets within each implementation zone and by selecting streets at random.

Historical images were accessed via GSV for pre-implementation data collection for both Belfast (i.e. pre February 2016, closest date possible) and Edinburgh (i.e. pre July 2016, closest date possible) and post-implementation data collection used current images (i.e. as close to a date between the start of February and the end of March 2020 as possible).

Data analysis

Data were cleaned and scored (i.e. total liveability and nine constructs of liveability) by the research team prior to analysis. Statistical analysis was performed using IBM SPSS Statistics version 23 (IBM Corporation, Armonk, NY, USA) for both Belfast and Edinburgh and included (1) descriptive statistics (pre and post implementation) for total liveability, the nine liveability construct scores and the proxy indicators of behaviour; and (2) change following the implementation of the intervention (i.e. post intervention minus pre intervention), with Wilcoxon signed-rank tests determining the level of significance pre and post implementation for total liveability, the liveability construct scores and the proxy indicators of behaviour. Significance was set at $p < 0.05$.

As the Belfast city-centre 20-mph speed limit intervention differed from Edinburgh's citywide intervention in terms of scope, investment, intervention activities and the intervention implementation timeline, the results (i.e. total liveability, liveability constructs and the proxy indicators of behaviour) will not be directly compared between cities, but will be presented as two separate case studies.

Liveability findings

For Edinburgh, GSV data were available for 91 of the 100 streets (91.0%) pre intervention, 80 of the 100 streets (80.0%) post intervention and a total of 76 streets (76.0%) at both time points (i.e. pre and post intervention).

Results showed that the mean liveability score in Edinburgh prior to the implementation of the 20-mph speed limit intervention was 56.80 (SD 8.13) (*Table 20*). This score was found to have increased significantly, to 58.93 (SD 8.92), when assessed post intervention. The mean change between time points was 2.38 (SD 3.31), which was found to be significant at the level of $p = 0.000$ (see *Table 20*).

When the analysis was performed for each of the nine constructs of liveability, three constructs were found to have statistically increased from pre to post intervention: (1) places (i.e. presence of amenities and facilities, and building maintenance and aesthetics) ($p = 0.017$), (2) traffic/transport (as above) ($p = 0.000$) and (3) pavements (i.e. street amenities, litter, obstructions to walking, street lights, crossings, pavement presence and quality, buffer presence and quality, and pavement obstructions) ($p = 0.036$) (see *Table 20*). Finally, when the proxy indicators of behaviour were investigated, no significant changes were found ($p > 0.05$) (*Table 21*).

For Belfast, GSV data were available for 68 of the 76 streets (89.5%) pre intervention, 73 of the 76 streets (96.1%) post intervention and 68 streets (89.5%) at both time points (i.e. pre and post intervention). The results showed that the mean liveability score in Belfast prior to the implementation of the 20-mph speed limit intervention was 65.93 (SD 18.31) (see *Table 20*). This score was found to increase significantly, to 66.22 (SD 18.52), when assessed post intervention. The mean change between time points was 1.38 (SD 3.08), which was significant at the level of $p = 0.000$.

When analysis was performed for each of the nine constructs of liveability, (1) traffic/transport (i.e. presence of public transport facilities, speed signage, speed-calming measures and traffic lanes) ($p = 0.000$) and (2) places (i.e. presence of amenities and facilities and building maintenance and aesthetics) ($p = 0.041$) were found to have increased significantly, pre to post intervention (see *Table 20*). Finally, when the proxy indicators of behaviour were investigated, a significant increase was found in relation to bicycle rack capacity ($p = 0.028$) and significant decreases were found for the number of parked cars ($p = 0.037$) and the total number of cars (i.e. moving and parked) ($p = 0.035$) (see *Table 21*).

Strengths and limitations

Strengths include the implementation of MAPS-Liveability, a reliable tool specifically designed to assess liveability at the level of the street and to include information regarding microlevel environmental features. In addition, as MAPS-Liveability was found to have good–excellent reliability for use with GSV, this enabled historic, pre-intervention implementation data to be collected, allowing pre- and

TABLE 20 Results for total liveability and the nine constructs of liveability in Belfast and Edinburgh

Liveability and the nine constructs of liveability	Belfast						Edinburgh					
	Pre intervention		Post intervention		Change		Pre intervention		Post intervention		Change	
	n	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)
Total liveability score	68	65.93 (18.31)	73	66.22 (18.52)	68	1.38 (3.08)*	91	56.80 (8.13)	80	58.93 (8.92)	76	2.38 (3.31)*
Nine constructs of liveability												
Safety	68	11.07 (2.66)	73	11.10 (2.92)	68	0.09 (0.73)	91	12.84 (1.57)	80	12.80 (1.80)	76	0.07 (1.15)
Health	68	7.72 (2.56)	73	7.68 (2.47)	68	0.06 (0.49)	91	6.41 (2.48)	80	6.51 (2.56)	76	0.08 (0.76)
Sustainability	68	11.22 (4.74)	73	10.90 (4.74)	68	0.00 (0.79)	91	13.79 (2.90)	80	13.75 (2.95)	76	0.14 (1.22)
Inclusivity	68	1.25 (0.74)	73	1.21 (0.74)	68	0.00 (0.00)	91	3.97 (1.03)	80	4.04 (1.16)	76	0.03 (0.28)
Places	68	12.68 (5.11)	73	12.68 (5.69)	68	0.29 (1.43)*	91	10.73 (2.93)	80	11.10 (3.24)	76	0.21 (0.75)*
Education	68	0.13 (0.38)	73	0.12 (0.37)	68	0.00 (0.00)	91	0.14 (0.38)	80	0.11 (0.36)	76	−0.01 (0.12)
Traffic/transport	68	1.63 (1.37)	73	2.48 (1.83)	68	0.96 (1.09)*	91	3.01 (1.39)	80	4.59 (1.22)	76	1.45 (0.93)*
Roads	68	12.96 (5.06)	73	12.19 (5.63)	68	−0.03 (0.55)	91	12.04 (3.71)	80	12.50 (3.81)	76	0.11 (0.58)
Pavements	68	25.16 (6.92)	73	25.22 (6.27)	68	0.09 (2.58)	91	24.38 (3.27)	80	24.60 (3.70)	76	0.38 (1.43)*

*$p < 0.05$.

TABLE 21 Results for the 12 proxy indicators of behaviour (including active travel) in Belfast and Edinburgh

	Belfast						Edinburgh					
	Pre intervention		Post intervention		Change		Pre intervention		Post intervention		Change	
Proxy indicators	*n*	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)
Number of bicycle racks	68	1.76 (3.07)	73	1.92 (3.30)	68	0.18 (0.81)	91	0.53 (2.34)	80	0.68 (2.84)	76	0.11 (0.92)
Bicycle rack capacity	31	9.65 (7.95)	35	11.14 (9.41)	31	1.52 (3.52)*	8	10.75 (12.33)	7	13.29 (13.67)	7	1.29 (4.35)
Number of bicycles in the racks (total)	31	3.03 (4.48)	35	3.63 (4.54)	31	0.23 (4.18)	8	4.25 (5.42)	8	2.50 (2.00)	7	−1.43 (5.26)
Number of cyclists	68	0.24 (0.60)	73	0.30 (0.72)	68	0.12 (0.68)	91	0.23 (0.75)	80	0.20 (0.46)	76	0.01 (0.66)
Number of pedestrians	68	24.41 (37.52)	73	28.03 (49.65)	68	3.03 (33.77)	91	4.55 (8.66)	80	5.34 (10.65)	76	0.59 (5.50)
Number of moving cars	68	3.44 (5.40)	73	2.92 (5.11)	68	−0.31 (3.33)	91	2.12 (4.76)	80	2.65 (5.11)	76	0.20 (2.41)
Number of parked cars	68	10.37 (12.34)	73	7.55 (9.35)	68	−1.74 (6.54)*	91	20.36 (21.91)	80	23.56 (26.27)	76	2.24 (13.84)
Total number of cars (moving and parked)	68	13.81 (15.48)	73	10.41 (12.22)	68	−2.10 (7.62)*	91	22.48 (22.47)	80	26.21 (27.31)	76	2.28 (14.64)
Number of individuals exercising	68	0.00 (0.00)	73	0.14 (0.12)	68	0.01 (0.12)	91	0.24 (1.55)	80	0.03 (0.16)	76	−0.17 (1.62)
Total number of activities being performed	68	0.00 (0.00)	73	0.01 (0.12)	68	0.01 (0.12)	91	0.07 (0.33)	80	0.03 (0.16)	76	−0.01 (0.31)
Presence of large groups of people	68	0.03 (0.24)	73	0.05 (2.83)	68	0.03 (0.30)	91	0.11 (0.35)	80	0.04 (0.19)	76	−0.08 (0.39)
Presence of people static	68	0.37 (2.34)	73	0.51 (2.76)	68	0.18 (3.02)	91	0.56 (1.39)	80	0.80 (2.11)	76	0.22 (2.24)

*$p < 0.05$.

post-intervention comparisons to be performed. Furthermore, each of the 76 20-mph streets in Belfast, and a stratified sample of 20-mph streets in Edinburgh, was assessed for liveability, using the nine liveability constructs and the proxy indicators of behaviour. Limitations of the study using GSV include the following: it is not possible to assess variables such as air or noise pollution, or perceived safety; temporality (i.e. an image is from one point in time and it is not possible to know time, day or date); and contemporality (i.e. time lapses between GSV images and data collection).

Active travel

As planned, the team conducted an audit of the available active travel data in Edinburgh and Belfast, with a view to assessing the impact of the 20-mph intervention on walking and cycling outcomes. This took place in late 2019 and is presented in *Table 22*.

Based on the above audit and assessment of available data, it was decided not to proceed with analysis of these outcomes. There is no single reason for this, but rather a number of associated reasons that all point towards this decision. These are summarised in the following paragraphs.

The available active travel data have been collected by third parties for reasons other than the evaluation of 20-mph speed limits in Edinburgh and Belfast. As a result, they have generally been collected in a way that does not aid assessment of 20-mph implementation in terms of timing and location of collection in relation to the implementation areas. The primary exception to this was the cycle counters, which were viewed as key data sources. They should have provided a continuous and historical record of pedestrian and cyclist numbers on key routes. However, once we received these data and processed the raw files, it transpired that there were far fewer counters than we had been originally informed, and some had been out of commission (broken) for long periods, and therefore not collecting data. We received no data on pedestrian counters, which we were informed were being used during the proposal and planning phase.

There are some citywide annual data (Edinburgh People Survey, Scottish Household Survey, Scottish Health Survey, Belfast Residents' Survey) that include questions on walking and cycling. These would allow crude annual trends to be explored. However, in the complex and dynamic system of a city, the attribution of any changes year on year to 20-mph speed limits from simple pre–post analysis was deemed to be inappropriate when multiple other factors have been at play.

As reported in earlier sections, we had collected our own data on perceptions, attitudes and intentions for active travel using a design and methods (including timing and location) that allow assessment (and between-zone assessment) of the impact of 20-mph limits on these outcomes. The level of attribution to 20 mph was assessed to be much higher as a result; perceptions, attitudes and intentions are known determinants (antecedents in the logic model) of walking and cycling, and were therefore seen as priorities to analyse.

We also had MAPS-Liveability, which included proxy measures of walking and cycling behaviours: number of bicycle racks as a whole unit, number of bicycles that the racks can hold (total), number of bicycles in the racks (total), number of cyclists, number of pedestrians, number of moving cars, number of parked cars, total number of cars on the road (moving or parked), number of individuals exercising (not walking or cycling), total number of activities being performed, presence of large groups of people (yes/no), and number and presence of people static (e.g. waiting for a bus, talking). This gave further indication of changes in the active travel environment.

Therefore, owing to limited time and person-resource, combined with assessment of methodological rigour, it was agreed by consensus to focus on analysis of the perceptions data and liveability data, and not proceed any further with the analysis of additional active travel outcomes.

TABLE 22 Audit of active travel outcome data

Details				Analysis				
Outcome	Data source	Pre–post 20 mph	Control for seasonality?	Between-implementation zone comparison possible?	Synthetic control area(s) available?	Other control area(s) available?	National trend data available?	Attribution of change to 20 mph
Walking and cycling counts (Edinburgh)	Automatic counters	Yes	Yes (as continuous)	Yes (subject to location of counters)	No	No	No	Moderate
Numbers of cyclists and pedestrians on key routes and cycle paths (Edinburgh)	Route User Intercept Surveys (Sustrans)	Limited (unclear if any locations will have pre–post)	Unlikely as surveys not conducted annually at same locations	No (owing to timing of surveys)	No	Yes	Yes	None
Numbers of walk, cycle, public transport and motor vehicle trips/users								
Edinburgh	Scottish Household Survey (Scottish Government)	Yes (basic annual comparison)	Yes (as annual totals)	Possible if start/end of journeys used	No	Data for rest of Scotland available	Yes	Weak–moderate
Belfast	Belfast Resident's Survey	Yes (basic annual comparison)	Yes (as annual totals)	N/A	No	No	No	None–very weak
	Belfast Travel Survey	Yes (basic annual comparison once post data received)	Yes (as annual totals)	N/A	No	No	No	None–very weak
Self-reported mode of travel to school (Edinburgh)	Hands Up Scotland Survey (Sustrans)	Yes	Not clear	Yes	No	Yes	Yes	Moderate (weak if no control for seasonality) Only among school children
Public transport use	Routine bus data (Lothian buses and Translink NI)	Yes	Yes (as continuous)	Yes (subject to considering journey start/end in different zones)	No	Yes	No	None–very weak, as active travel inferred and not quantified
Cycling levels and cyclist perception of road safety (Edinburgh and Belfast)	Bike Life (Sustrans)	Only 2015 and 2017 data	Not clear	Not clear	Not clear	Not clear	Not clear	None–very weak
Parked bicycle counts (Edinburgh)	Sustrans	Yes	No	Not clear	Not clear	Not clear	Not clear	Not clear

N/A, not applicable; NI, Northern Ireland.

This process gave rise to important considerations for future research, particularly the evaluation of natural experiment-type events on active travel. Many members of the 20's Plenty for Health team are involved in ongoing and planned similar evaluations, and learning from this data audit has informed thinking about future data collection and study design. It is clear that routine, continuous monitoring of walking and cycling behaviour is required to answer complex questions such as the impact of 20-mph interventions at city level.

The audit of the active travel data sources has raised some important points about the difference between routinely and non-routinely collected data in terms of timing, frequency and location, and how this can affect the evaluation of natural experiments. Of course, such monitoring has to be low burden and low cost for all stakeholders. The required quality of these data combined with the more distal pathway from intervention (compared with, e.g., proximal outcomes such as speed or collisions) raises crucial methodological challenges for future evaluation work.

Air pollution

We did not include air pollution as an outcome measure in this evaluation primarily because previous research did not show any significant impacts of 20-mph zones on a range of air-quality variables,[101] and it would have been very costly to collect accurate data for a whole city. These issues, combined with the difficulties of attributing any effect to the 20-mph speed limits (rather than other factors such as 'greener cars'), made it unfeasible for this study. However, the SSC was very keen for us to undertake some work if possible. One of the SSC members (Dr Stefan Reis, who had originally advised us not to include it in the evaluation) agreed to have two master's students undertake some work for their dissertations. The first dissertation looked at how the speed limit may have affected emissions. To calculate the effect of changes in speed, a very simple spreadsheet model was used, based on the official COPERT road traffic emission model (Emisia SA, Thessaloniki, Greece; www.emisia.com/utilities/copert/). The study found that it is possible to assess the (theoretical) change of emissions due to changes in average speed, based on established models; however, context [volume/composition change, local conditions (traffic lights, bus stops)] may have a substantial effect on the direction of change. The second dissertation looked at the change in nitrogen dioxide monitoring data before/after the implementation of speed limit changes for selected roads. The key challenge was that, for some of the locations in Edinburgh where automatic monitoring of nitrogen dioxide happens, data were available for only a short period post implementation of the 20-mph speed limit. This substantially influences what we can tell about any 'trend'.

Chapter 5 Qualitative exploration of the outcomes of the 20-mph implementation in both studies

Introduction

The methods for the results described here are reported in full in *Chapter 3*. In brief, focus groups were conducted by one lead researcher in each site (CC in Belfast and KT in Edinburgh). Focus groups took place at locations convenient for the participants. Following an overview of the 'Is 20 mph Plenty?' study, participants read the participant information sheet and were given the opportunity to ask questions before providing written informed consent. Participants also completed a short demographic questionnaire (e.g. gender, age and ethnicity). When possible, a second researcher was present to facilitate and take written field notes. All discussions were audio-recorded with participants' consent. Recruitment continued until data saturation occurred. The final sample was 159 participants: 99 participants took part in 15 focus groups in Edinburgh and 60 participants took part in nine focus groups in Belfast (see *Appendix 3* for focus group composition). Broadly, the focus groups sought to investigate the public's attitudes to, and perceptions of, 20-mph speed limits; to investigate their experiences of, and behavioural responses to, the implemented 20-mph speed limit intervention activities (see *Chapter 3*); and to explore the mechanisms through which any behaviour change occurred. The key health-related outcomes of interest included traffic speed, active transport (walking and/or cycling) and liveability. Specifically, the topics included in the guide that are discussed in this chapter are as follows:

- attitudes towards the 20-mph speed limit intervention
- behaviour change across a range of outcomes
- views on the impact on liveability.

In this section, we draw from key themes to present findings related to each major aspect of investigation from the topic guide: attitudes towards 20-mph speed limits, how and why behaviour change occurred or did not occur across a range of outcomes, and liveability.

Attitudes towards the 20-mph limit interventions

Mixed views were expressed on the rationale for the intervention being implemented in Edinburgh, with the most common view being that this was a road safety measure:

> *I think it's sensible, because there is so many, like, pedestrians and, like, tourists around that I can think honestly, like, the slower people go the safer it is.*
>
> *Edinburgh, FG10*

Other perceived reasons for the introduction of the scheme included reduced car usage, to encourage active transport (cyclists and/or pedestrians) and to reduce pollution; this last point was particularly contested between participants. Participants in Edinburgh consistently viewed the communication of the intervention positively (i.e. awareness-raising that 20-mph limits were to be introduced). However, there was a view, expressed in some but not all of the groups, that the communication of the underlying rationale for the introduction of the new speed limit by the local council had not been sufficient.

In Belfast, participants felt that there was no need to introduce a 20-mph speed limit in the city centre because of the slow traffic speed already observed, particularly during specific times of the day (e.g. rush hour):

> *I think as well though, because in peak times, so like 9 a.m. and 5 p.m., generally it's a car park anyway, you're sitting and stopped. So, in that respect, the 20 mph becomes a bit futile at those times.*
>
> *Belfast, student*

There was considerable discussion among Edinburgh participants about the citywide nature of the 20-mph speed limit, described by many participants as a 'blanket limit' that, overall, was viewed negatively. The rationale or need for this scale of intervention was not clearly understood, with many participants viewing this as unnecessary. A more targeted approach, focused on certain areas, time of day or where more vulnerable groups may be located, was reported to be more appropriate:

> *My impression is it's like a blanket thing, Edinburgh Council, we are doing 20s across all of our area, without actually really looking at the differences within the areas and tailoring it to how it would maybe fit better, because I don't think it's been done very well here.*
>
> *Edinburgh, FG2*

> *For 20-mph speed limits in housing areas, built-up areas, narrow streets, school areas, hospitals, etc., but, yes.*
>
> *Edinburgh, FG1*

> *Having it 24 hours a day, it's a bit strange, you know, there's no traffic on the roads early in the morning, but there's a 20 mile an hour speed limit at half four, five o'clock. If you're doing 20 miles an hour through the city centre, and you've got a guy in the back seat, why you doing 20 mile an hour – it's the speed limit.*
>
> *Edinburgh, FG14*

In Belfast, there was agreement that a targeted approach near where vulnerable groups may be located (such as around hospitals) would be preferable. However, there were conflicting views expressed on whether or not the new speed limit should be in operation 24 hours per day. Those in opposition cited a possible lack of support owing to a lack of rationale and understanding by the public, whereas there was support voiced for the speed limit being in operation all the time to help avoid confusion:

> *Oh yes, because if you have different times, it's confusing enough with all this going, and they'll think, 'oh, it's five to six, good, I can put my foot down!' 'Five past six, no, I mustn't', you know, I can't see people doing that.*
>
> *Belfast, older adult*

Participants demonstrated awareness of the phased roll-out of the scheme in Edinburgh; however, some participants also expressed confusion and frustration related to which exact geographical areas were having the 20-mph speed limit implemented:

> *I mean, it was introduced in stages so there was different areas had different start dates and I think that was quite confusing for people because you didn't know at what stage that bit of road you're on was going to come into effect.*
>
> *Edinburgh, FG1*

In Edinburgh, several negative attitudes were also presented towards both the specific 20-mph intervention activities and the main implementation agent: the City of Edinburgh Council. Although not consistent across the sample, some participants viewed the specific intervention activities as 'a cheap option', implemented in a manner consistent with a lack of financial resources available. These participants also suggested that more substantive resources should be put towards other initiatives perceived as having greater impact on traffic safety, namely improvements to existing infrastructure and new transport infrastructure. An issue also

discussed by several groups (particularly local community councils and professional drivers) was that road safety initiatives implemented by the city council are typically 'ill-thought out' (Edinburgh, FG14) and done 'in a rather haphazard kind of way' (Edinburgh, FG8).

Behaviour change

Driving behaviour

Overall, there were inconsistent views concerning the impact that the 20-mph intervention had on driving behaviour. In Edinburgh, there was some evidence of a positive impact on driver behaviour, with several participants reporting that they were adhering to the limits, expressed by some as simply sticking to the rules. A small number of participants discussed utilising features within the car such as 'cruise control' and satellite navigation systems to aid in monitoring speed and adhering to the speed limit.

In Belfast, there was no evidence that driving behaviour had changed, and in Edinburgh some participants also reported not adhering to the limits. There were several reasons proposed for this, including that 20 mph was perceived as being a difficult and unnatural speed to drive at, and road conditions, driver skill and knowledge were deemed to be more important factors influencing driver speed through the areas of new limits:

> *I think it is, especially if the roads are clear and it's an off-peak time, to drive at 20 mph is very frustrating. You think, 'why am I going so slow? There's nobody here to go slow for'. That puts me off a wee bit.*
>
> *Belfast, city-centre worker*

Some participants also reported a social pressure to drive at speeds in excess of 20 mph, thus affecting their compliance with the limit:

> *At the moment I think it's 'cause so many other people are doing it [driving at > 20 mph], you don't feel bad, you know, going above the speed limit 'cause you feel like you have to. You have to go above speed limit for people behind you.*
>
> *Edinburgh, FG11*

There were also mixed reports from professional drivers in Edinburgh, with some stating that they had not adhered to the new limit, whereas others viewed driving to the local limits and conditions as part of their role: '[w]e have to slow down. It's our job. We have to do that' (Edinburgh, FG15).

There was evidence that the intervention had increased people's awareness of both their own driving behaviour and the driving behaviour of others. In relation to perceptions of other drivers' behaviour, there was a consistent, but not conclusive, view from participants that other drivers were adhering to the limits, particularly in certain areas such as residential streets. Again consistently, it was perceived that driving at precisely 20 mph was being done by only a minority, but what the intervention had succeeding in doing was reducing the overall traffic speed within the city by a smaller extent, often from a speed that had been in excess of the previous limit:

> *I didn't note carefully what speed people drove at beforehand, but I have a feeling it was, you know, it was maybe, well often it would be 30, a wee bit over 30, you know. My . . . you know, having been a wee bit more observant of what speed people are actually driving at since it came in, I would say quite often it's 23, 24, 25.*
>
> *Edinburgh, FG3*

As noted above, there was no evidence of 100% compliance with driving at a reduced speed (i.e. not all drivers were adhering to the new limits). Several conflicting views were expressed about this. For example, some professional drivers stated that they complied with the speed limit, but perceived the general public not to, whereas members of the public expressed an opposing view that professional drivers were among the worst offenders for not adhering to the reduced speed limit:

> Edinburgh, FG2: *. . . and the buses are under huge pressure to stick to their timetables, and they don't go at 20, and it would be safer for cyclists if the buses did go at 20.*
>
> Interviewer: *So they go higher than 20?*
>
> Edinburgh, FG2: *Oh hell, aye, regularly.*

In both cities, there was also the perception that driving behaviour had worsened as an unanticipated consequence of the 20-mph interventions. For example, participants discussed observing an increase in overtaking as a result of increased frustration with the slower-moving traffic, with the perception that this may have a negative impact on the number of collisions and casualties:

> *If everyone was doing 30, you wouldn't get the overtaking that you do when people are doing 20 [. . .] if we did 20 mph, people would pass us.*
>
> *Edinburgh, FG14*

> *Yes, they're pushing you on, beeping the horn or getting road rage or speeding past you.*
>
> *Belfast, multimodal transport user*

This issue involved both motor vehicle drivers and cyclists, with the reduced on-road speed differential causing potentially dangerous interactions and overtaking situations.

Walking and cycling

From the qualitative discussions, there was almost no evidence that the 20-mph interventions had affected levels of walking and cycling in either city. In both Edinburgh and Belfast groups, there was a small amount of discussion that the reduced speed limit had created a more pleasant cycling experience through the previously discussed reduced speed differential between cyclists and motorists, and an increased confidence to ride in the primary position on-road:

> *I would like to think I'm more confident, I never liked that really before, that route, I would like to think I'm a bit more, maybe I'm more aggressive now with the 20 mile, I feel I can sit on the road more, but no, I do use that more, I think perhaps, certainly much more than I would have done.*
>
> *Edinburgh, FG3*

> *As a cyclist, it reassures you a wee bit more, because you'll generally be travelling 15–20, max[imum], I'd say, on a bike. It gives you a bit more assurance that you're a bit safer.*
>
> *Belfast, cyclists*

However, there was no evidence from participants that the introduction of the 20-mph speed limits had led to any substantial increase in cycling, through either an increase in journeys in existing cyclists or new cyclists. Only one participant commented that a friend had taken up cycling as a result of the implementation of the 20-mph speed limit. Participants cited continuing concerns over safety, and the need for investment in cycling infrastructure (such as segregated cycle lines), as factors of greater influence around decisions on whether or not to cycle through the cities:

> *Going at 20 miles an hour, that is not going to make me a cyclist, I can tell you, never am I going to get on a bike, because I've seen the buses, I've seen how people drive, I'm not going to put myself at that risk.*
>
> *Edinburgh, FG8*

Participants in Edinburgh reported being aware of, or perceiving, an increase in the level of cyclists during the time period of the implementation of 20-mph speed limits. However, it was viewed that this was likely to be attributable to the range of other cycling promotion initiatives introduced in the city, rather than being solely attributable to the 20-mph intervention. Similarly, there was no evidence from either city that the 20-mph intervention had resulted in an increase in walking, either in terms of participants' own behaviour or a wider perception of the behaviour of others. A minority of participants, mainly from parent groups in Edinburgh, reported that the intervention had led to a safer environment that was more conducive to walking:

> *I guess, feeling a bit better about everyone's safety when we're going somewhere, you know, around Parliament, or anywhere around there you know. You don't have to handgrip everyone extra tight, you know, I do feel that everyone, the kids are a little bit more at ease, yeah. I think in general; I feel a bit better.*
>
> *Edinburgh, FG12*

However, this view was not a dominant one across the groups, with several participants stating that their experience as a pedestrian had not changed.

Overall, there was less discussion of walking and pedestrian behaviour than of cycling, with the purported positive impact of the reduced speed limit not immediately apparent to many. Indeed, in both Edinburgh and Belfast, several participants reported crossing the road at non-designated crossing points, or had observed other pedestrians doing so, because of a perception of a slower driving speed. Although the ability to cross the road in this manner was perceived positively by some pedestrians, this increased risk-taking was viewed negatively by some drivers, acting as a source of frustration and as a safety concern. Drivers expressed the view that pedestrians should have to follow road safety guidelines and laws, just as the driver has to, and they should be penalised for walking in front of cars.

Liveability

In both cities, there was little overall discussion on the various components of liveability (such as pleasantness of the streets, or safety). There was no evidence of any impact of the 20-mph interventions on liveability; indeed, participants discussed only the potential ways in which a reduction in traffic speed could lead to, for example, reduced noise pollution or to a more pleasant environment to live:

> *I think it would improve liveability. As a pedestrian, if you're wanting to go out for dinner or whatever, or out to the shops and walk your dog or whatever, it would probably improve your lifestyle.*
>
> *Belfast, cyclist*

Chapter 6 Economic evaluation

Plans for the economic evaluation comprised three components: a cost-effectiveness/cost–utility analysis using modelled estimates of disability-adjusted life-years or quality-adjusted life-years (QALYs) based on changes in active travel and accidents; a partial cost–benefit analysis (CBA); and a cost–consequences analysis[102] based on information from the range of qualitative and quantitative data being collected in the other WP. In the proposal for the study, we stated that:

> *. . . there are substantial uncertainties over the power of the study to detect changes in casualties and over whether lower speeds will encourage enough of an increase in active travel to have a significant impact on health. Therefore the economic evaluation will only be undertaken if there is evidence from the effectiveness study of a significant effect on either casualties or time spent in active travel.*
>
> *Study protocol; see project web page [www.journalslibrary.nihr.ac.uk/programmes/phr/158212/#/ (accessed 18 May 2022)]*

The SSC meeting in September 2017 discussed the process for making the decision about whether or not to undertake WP4. This decision was taken in September 2018. The SSC identified a number of risks in using significant change in either casualties or time spent in active travel as the decision criterion at that point:

- Short timescales.
  The decision would need to be informed by data on any changes in travel speeds, casualties and active travel available by summer 2018. It was possible that these outcomes may not have changed much by then, but they may change subsequently if attitudes to travel speed, perceptions of safety and levels of active travel change in the longer term.
- Statistical significance.
  The conventional approach would be to conclude there were no significant impacts if effect sizes did not reach the standard level of statistical confidence. However, small risk reductions at an individual level can still yield substantial public health benefits, and if they can be achieved at relatively low cost, they may still be cost-effective.
- Narrow range of outcomes.
  Health economic outcome measures such as disability-adjusted life-years and, in particular, QALYs have the benefit of providing a clear decision criterion (e.g. cost per QALY) that is comparable across a range of interventions affecting different dimensions of health. They are also widely used, enabling comparison across a large and growing body of cost-effectiveness evidence. However, they are still a relatively narrow measure compared with the wide range of benefits often generated by public health measures and typically considered by decision-makers in public health and health policy. Perceptions of increased safety, lower emissions, social connectedness and 'liveability', and other measures are important, but are hard to capture in single measures of outcome, even multidimensional measures such as QALYs. This was the rationale for including a cost–consequences analysis in the study proposal.

The study team therefore suggested using the 'decision-theoretic' approach to inform the progression decision.[103] The approach 'allows formal consideration of many public health interventions designed to deliver small but important effects at relatively low cost, which are infrequently the subject of intervention trials large enough to detect effect sizes at the standard level of statistical confidence'.[5] The approach involves using relevant knowledge, theory and data from empirical studies (observational and, if available, experimental) to form a view on:

- whether or not an intervention is likely to cause harm
- if not, whether or not, in the light of the (low) cost of an intervention, it is likely to be effective enough to be cost-effective, even if effect sizes do not reach conventional levels of statistical confidence.

Information on the potential effect of an intervention can come from a number of sources:

- empirical studies of final or intermediate outcomes from similar interventions implemented elsewhere
- causal understanding of the mechanism driving the outcomes of interest
- plausible theory.

Because, as noted previously, the economic evaluation comprised three components, the progression decision was not only about whether or not it should go ahead, it was also about which elements of the proposed work should be undertaken; for example, the partial CBA and the cost–consequences analysis could still go ahead even if the decision was taken not to go ahead with the cost-effectiveness/cost–utility analysis.

At the time of the progression decision, the SSC felt that there was enough potential for the intervention to be cost-effective to carry on with the economic evaluation, based primarily on:

- the costs of the scheme in Edinburgh
- the changes in speeds that had been observed by the time the decision was taken
- estimates from previous studies of the relationship between changes in traffic speeds and casualties.

The SSC's decision also reflected the potential for the additional data gathered as part of the study, on changes in active travel, liveability (including perceptions of safety) and changes in emissions, to be available to inform the DTA and the cost–consequences analysis, strengthening any conclusion based on the speed and casualty data. The SSC also agreed that the DTA should inform the final conclusions at the end of the study.

Unfortunately, in practice, the analyses planned were not possible because of changes in the role of the health economist co-leading the economic evaluation (NC), and the effect of the COVID-19 pandemic on his role. It was also noted previously in this report that, in the course of the study, it became clear that representative data on active travel were not going to be available. This meant that the cost–utility analysis based on the relationship between changes in active travel and physical activity-related health improvements, with associated changes in length and quality of life, could not be estimated. In addition, emissions data were not available and the data gathered in the study suggested that perceptions of safety had not changed much following the introduction of 20-mph speed limits.

Therefore, in the remainder of this chapter, we state the findings from the analyses carried out to inform the progression decision, update these where we can, reflect briefly on how these updated findings may affect the overall conclusions from the economic evaluation and give pointers to the further work that would be required to complete the planned analysis.

Costs

Cost information for Edinburgh was provided by the City of Edinburgh Council. Three categories of cost were covered:

1. design, supervision and related costs, including project management
2. construction
3. awareness-raising and survey work on perceptions of speed and traffic volumes.

The costs included a value for the staff time spent on the project, estimated on a 'bottom-up' basis using data provided by the council on recorded hours of different personnel working on the programme. No data were available on enforcement or maintenance costs. Discussions with Police Scotland suggested that such costs are likely to be limited. No mechanisms were put in place to record time spent on

enforcement of speed limits specifically in 20-mph zones because it is part of wider speed-monitoring activities. Likewise, the City of Edinburgh Council confirmed that maintenance costs will be subsumed within general road maintenance budgets. However, as there is no reason to expect that maintenance of roads and signage in 20-mph areas will be any greater than they would have been had speed limits not changed, this omission is unlikely to materially affect the estimated costs.

A shown in *Table 23*, the total cost of the scheme in Edinburgh was £2.81M in current prices, or £2.76M in real prices, calculated using the retail price index with 2016 as the base year.

Costs relative to benefits

Preceding chapters have highlighted the methodological challenges in identifying the impacts of 20-mph limits, including the observational study design, absence of a control area and existing trends. In these circumstances, the DTA poses the following questions:

- What level of effectiveness is required for 20-mph speed limits to be cost-effective or cost-beneficial, given the costs of the scheme?
- Do the benefits identified in the programme theory, but not measured in terms that can be incorporated in the cost–benefit or cost–utility analysis, such as changes in liveability, reinforce or weaken these conclusions?

At the time the progression decision was taken in 2018, the data available included data on attitudes to and awareness of 20-mph limits, changes in traffic speed, perceptions of safety and the pleasantness of communities. The data available on casualties were from too short a time series to assess whether or not there had been a significant fall in the number of casualties following the introduction of 20-mph speed limits. Data on changes in active travel and emissions were not available (and, as reported previously, it has not been possible to gather them subsequently).

Therefore, the progression decision was based on the potential for the benefits of 20-mph limits to exceed the costs given the relationship between the changes in speeds observed by that point in the study and the reduction in the numbers of casualties and deaths likely to occur based on existing literature. For 20-mph speed limits to be cost beneficial, the monetary value of the reduced number of injuries and deaths would need to exceed the costs (£2.76M in 2016 prices). *Table 24* gives the values of statistical lives or casualties used by the Department of Transport in calculating the economic value of preventing road traffic casualties (in 2016 prices).

TABLE 23 Costs of Edinburgh 20-mph speed limits

	Cost (£) by year		
Cost category	**2015/16**	**2016/17**	**2017/18**
Internal staff design time	131,767	265,787	281,094
Construction, etc.	585	1,023,086	976,643
Awareness-raising	17,877	55,236	55,000
Total current prices	150,229	1,344,109	1,312,737
Real prices (2016 RPI)	152,902	1,344,109	1,267,454

RPI, retail price index.

Note
Source: City of Edinburgh Council.

TABLE 24 Average value (£, 2016 prices) of prevention per reported casualty and per reported road accident

Accident/casualty type	Cost per casualty	Cost per accident
Fatal	1,841,315	2,053,814
Serious	206,912	237,527
Slight	15,951	24,911
Average for all severities	59,358	83,893
Damage only	–	2211

Notes
Source: Department for Transport statistics, September 2017. (www.gov.uk/government/statistics/reported-road-casualties-great-britain-annual-report-2016). Contains public sector information licensed under the Open Government Licence v3.0.

These monetary values suggest that 1.35 fatal casualties (2.76/2.05) would need to be prevented in Edinburgh (or combinations of other casualty types up to a value of £2.76M) for the benefits of 20-mph limits (in terms of the monetary value of the collisions and casualties prevented) to exceed the costs.

The speed reduction that had been observed in Edinburgh by the time of the progression decision was 1.7 mph (24.3 mph down to 22.7 mph, 95% CI −2.1 to −1.2 mph). (In Belfast there was a small but statistically non-significant fall in speeds, but from an already lower base.) In the absence of empirical data on collisions and casualties at that time, the exploratory analysis to inform the progression decision considered the potential impact of a reduction in speeds of this magnitude on collisions and causalities. The analyses also assumed that part of any reduction in speeds in Edinburgh was likely to have happened anyway, given that, in the Edinburgh pilot, speeds also fell by 0.9 mph in streets where the 30-mph limit was maintained. The analyses therefore considered the potential impact of a 1-mph fall due to the 20-mph speed limits using the work of Taylor *et al.*,[32] which suggested that a 1-mph fall in speeds equates to a 5% fall in casualties, depending on the operational characteristics of the road. Applying this fall to previous years' levels of casualties and valuing these potential reductions using the Department of Transport values in *Table 24* suggested that it was plausible that the number and value of casualties likely to be prevented would exceed the cost of the scheme. On this basis, the decision was taken to progress with the economic evaluation.

In practice, although the reduction in speed observed in the final analysis in Edinburgh was less than at the time of the progression decision (mean reduction of 1.34 mph, compared with 1.7 mph), the fall in casualties appears to have been greater (23% reduction in fatal casualties, 33% reduction in serious casualties and 37% reduction in slight casualties, compared with the 5% figure used in the progression decision). The reduction of 11 casualties observed in the study (see *Table 18*) is well in excess of the 1.35 required for the monetary value of the fatalities prevented to exceed the costs of designing and implementing the 20-mph limits. Adding in the monetary value of the non-fatal casualties prevented would, other things being equal, make it even more likely that the benefits in terms of the value of collisions and casualties prevented would exceed the costs. Even under restrictive assumptions about the extent to which these reductions in fatal and non-fatal casualties were attributable to the 20-mph limits or whether or not they would be sustained over time, it is likely that the monetary value of the benefits would exceed the costs. Likewise, the positive findings regarding liveability increase the likelihood that the overall balance of costs and benefits is favourable.

The likely effect on this conclusion of adding in changes in active travel as part of a more formal economic evaluation is uncertain. Some other schemes have led to increased active travel. As noted in the original proposal, the pilot scheme in Edinburgh and a pilot scheme in Bristol found increases in walking and cycling in the order of 5–10%. NICE[47] underlined the importance of perceived safety in encouraging people to walk and cycle more. However, the Cairns *et al.*[8] review suggested that evidence on physical activity remains uncertain.

The review by Cairns *et al.*[8] suggested that 20-mph zones were cost-effective, although the evidence suggests that cost-effectiveness is context specific. Peters and Anderson,[104] for example, found that, in high-casualty areas, a CBA suggested that mandatory 20-mph zones are cost-effective compared with no intervention. However, the cost–utility analysis results suggested the opposite. Furthermore, cost-effectiveness using either method was dependent on the casualty rate before 20-mph zones were implemented. The study suggested that mandatory 20-mph zones in low-casualty areas are poor value for money. Comparisons of cost-effectiveness estimates from other studies need to consider the comparability of the schemes in terms of the initial investment required (limited investment in a default scheme, signage only in a 20-mph speed limit scheme or investment in street furniture in a 20-mph zone with traffic-calming measures) and the underlying risk of collisions and casualties pre intervention.

Jones and Brunt[105] suggest that the potential cost-effectiveness of 20-mph speed limits would be reinforced if, as has been suggested in Wales, a country-wide default 20-mph limit were implemented and evaluated, rather than town-by-town evaluations. They suggested that a 20-mph default speed limit would potentially be substantially less costly, obviating the need to incur some of the costs of city- or town-specific schemes associated with signage, media work, etc.

These conclusions are therefore cautious at this stage. A full economic evaluation would need to consider the following:

- Duration of benefit. The data on collisions and casualties in this study come from 1 year of follow-up. In practice, the benefits would continue for some years beyond this follow-up period, although they might diminish relative to a scenario of no 20-mph limits if the downwards secular trend in collisions and casualties continues.
- Time profile and discounting of benefits and costs. Investment in the 20-mph limits is likely to produce a stream of benefits in terms of collisions and casualties prevented several years into the future. Even if these diminish over time as noted above, they are likely to keep increasing relative to costs, a very high proportion of which are likely to be front-loaded costs.
- Sensitivity analysis. Previous literature and the comparative results from this study from Edinburgh and Belfast suggest that effectiveness depends on the type of scheme and factors such as existing speeds and casualty rates. Likewise, costs depend on the degree of investment and ongoing maintenance, which depends on the type of scheme. Testing the sensitivity of the conclusions and defining thresholds below which effectiveness would need to fall to render schemes not cost-effective would help to understand the likely cost-effectiveness of other schemes in other contexts. Sensitivity analyses could also test the sensitivity of the conclusions to assumptions made about the proportion of the observed changes in casualties and collisions (and liveability) attributed to the 20-mph limits and the duration of benefit.
- Inclusion of a wider range of benefits in the analysis, for example active travel.

Conclusion

The DTA offers a useful framework for planning and interpreting the results of an economic evaluation when there is substantial uncertainty about the likelihood of finding significant effects (in public health terms) and to ensure a rounded assessment of impacts and cost-effectiveness where valuable interventions might otherwise be rejected on the basis of statistical insignificance. There are risks with the approach, however. In particular, transparency of the DTA process is vital to reduce the risk of publication and other biases that might otherwise lead to ad hoc and partial use of evidence to justify a prior position on dubious grounds.

We have not been able to undertake a full economic evaluation nor a full DTA for the reasons highlighted previously. However, the data suggest that it is likely that the benefits of the 20-mph limits in Edinburgh exceed the costs, and further work is identified that could make these conclusions more robust and more generalisable to other contexts.

Chapter 7 Discussion and conclusions

Introduction

Public health interventions generate particular evaluation challenges. The interventions usually work through complex causal pathways, leading to a range of potential intended and unintended outcomes. Their effects may take a long time to emerge. They may have modest effects in terms of the reduced risks or the likelihood of behaviour change at an individual or population level. These challenges can make it hard to detect statistically significant impacts even when impacts might be significant in public health and well-being terms, and even though they may be cost-effective given their wide reach and low cost per person affected.[103]

Because of the pragmatic nature of the design and data sources, we conducted analyses aiming to elucidate 'what happened' as much as 'was this effective?' These analyses fed into the evaluation of the programme theory. Our approach was one of testing the programme theory and possible mechanisms of change. The diverse outcomes allowed us to test the various proposed pathways. We considered short-term impacts and intermediate- and long-term outcomes with appropriate time frames. We were also guided by the DTA, which is useful to inform recommendations about whether or not interventions are likely to be effective in the absence of trial evidence and/or when the evidence is unlikely to be strong enough to satisfy conventional levels of statistical significance. It has been described as a transparent way of using 'relevant knowledge, theory and data from observational and experimental studies to [assess whether] an intervention is sufficiently unlikely to cause net harm [and if, so to] assess if the benefit relative to its cost is sufficient for the intervention to be recommended'.[5] The approach is particularly useful when 'inappropriate adherence to underpowered randomised controlled trials'[5] might undermine support for safe and cost-effective interventions with strong theoretical and observational support.

Principal findings

The effectiveness of any complex intervention in a complex system is not solely to be judged on the activities and change that are anticipated. Effectiveness is dependent on the systems into which an intervention is implemented, combined with the social, historical, cultural, political and geographical context.[7]

Pre implementation and process of adopting the 20-mph limits

There was evidence that external factors, such as the political context and leadership, influenced decision-making and implementation in the two cities. Although there were similarities in the processes involved in the decision-making and implementation of the 20-mph speed limit interventions in Edinburgh and Belfast, there were also major differences between the two cities. The contrast between the two cities demonstrates that it is possible to implement 20-mph speed limits in varying ways, and that local context is critical for informing how 20-mph speed limits might best be operationalised in a given location. The media analysis shows that there is already relevant narrative in the media long before these speed reduction schemes exist. By understanding what are the arguments and positions in place, local jurisdictions can manage their paths to implementation with clear and coherent media and communication strategies. This would now also include social media.

Implementation

The intervention activities were viewed as being broadly implemented as intended in both cities; for example signage was implemented as intended, probably, in part, because of the rigid parameters afforded by the legislation, with only minor amendments being made. Enforcement activities, specific

to the 20-mph limits, were limited by finite resources and competing priorities in both sites, and over time became 'daily business'. Public experiences of these activities varied, but an important finding was the disjunction between agents (e.g. police services) and the public in terms of how the interventions should be enforced. The processes associated with rolling out such a large scheme in Edinburgh were identified as challenging; a dedicated '20-mph team' was created within the local authority to address this. The creation of a dedicated, official and strong partnership and joined-up working were identified as key facilitators in broad implementation and in the delivery of a tailored education and awareness-raising campaign in Edinburgh. In Belfast, government reticence was seen as a potential barrier to there being no formal awareness-raising activities in Belfast. This latter point may help to explain the difference in levels of awareness of the 20-mph speed limits that was evident between participants from the two cities.

Impact

Outcomes

In Edinburgh, the overall percentage reduction in casualty rates was 39% (a 40% reduction was observed for collision rates). The percentage reduction for each level of severity was 23% for fatal casualties, 33% for serious casualties and 37% for minor casualties. Mean and median speeds were reduced by 1.34 mph and 0.47 mph, respectively, at 12 months. There was an increase in two factors related to perceptions, support for 20-mph speed limits and rule-following after implementation, which were supported by the qualitative data. There were increases in several domains of the MAPS for Edinburgh (assessing liveability).

In Belfast, there was a reduction of 2% in collisions and a small but statistically significant increase in several domains of the MAPS. There was no statistical change in speed. Active travel outcomes could not be assessed because of the lack of robust data. The qualitative data supported the findings of the quantitative data. There was evidence that the intervention had increased people's awareness of both their own driving behaviour and the driving behaviour of others. In relation to perceptions of other drivers' behaviour, there was a consistent, but not conclusive, view from participants that other drivers were adhering to the limits, particularly in certain areas such as residential streets. Again consistently, it was perceived that driving at precisely 20 mph was being done by only a minority, but what the intervention had succeeding in doing was reducing the overall traffic speed in the city by a smaller extent, often from a speed that had been in excess of the previous limit.

There was almost no evidence that the 20-mph interventions had affected levels of walking and cycling in either city.

Comparison with the Department for Transport evaluation

The Department for Transport (DfT) commissioned a large research project to evaluate the effectiveness of 20-mph signed-only speed limits. This was published in 2018.[77] Sometimes known as the 'Atkins Study', this evaluation was based on 12 case study schemes in England, with various comparator areas with 30-mph limits in place. It is helpful to compare our findings with those of this key report:

- Although we observed an important and significant reduction in collision and casualty rates in Edinburgh, the DfT evaluation reported 'no significant change in collisions and casualties in the short term'.[77] Although some individual case studies showed a reduction in the number of collisions/casualties, the results were based on very small sample sizes and the authors concluded that it was 'not possible to attach any confidence to their significance'.[77] Therefore, our results from Edinburgh, based on city-level analysis, are an important step forward in the evidence base, as the findings were based on a large sample, thereby allowing greater confidence in the observed effect.
- Our findings of only minor changes to the numbers of collisions and casualties in Belfast are consistent with the DfT evaluation observation that effects may differ by case study area. In this way, our study adds weight to the notion that a 20-mph signed-only intervention may have differential effects by area.

- The DfT evaluation reported a median reduction in speed of 0.8 mph in residential case study areas, and of 0.6 mph in city-centre case study areas. Our findings for reductions in speed in Edinburgh (mean reduction of 1.34 mph, median reduction of 0.47 mph) are consistent with the direction and order of magnitude of these results. The DfT evaluation reported that faster drivers reduced their speeds more, and our Edinburgh results add city-level evidence to support this. This is a particularly important finding as these are the speeds associated with greater safety risk, so observing this at a city level advances the evidence base. As with collisions and casualties, the DfT report observed a range of effects across the case study areas and our results from Belfast city centre also suggest that effects can be variable by location.
- The DfT evaluation reported general support for 20-mph limits. It found that 'local residents and other road users generally perceive the 20-mph limits as beneficial for local residents, pedestrians and cyclists'.[77] Our findings are consistent with this, while adding some further insight into how local perceptions evolve after implementation.

As an overall reflection, our findings are consistent with those of the DfT evaluation, and so add weight to the developing evidence base on 20-mph speed limits. Our study advances knowledge by (1) being based on a larger, citywide intervention, thereby giving greater confidence in a number of key findings; and (2) being able to conduct more in-depth informative analysis on the various outcomes, thereby developing our level of insight.

Cost-effectiveness

Interim analyses to inform the progression decision suggested that it was plausible that the benefits of the scheme in Edinburgh, associated with the reduction in the numbers of collisions and casualties, would exceed the costs. The observed increases in liveability strengthen this conclusion.

Sustainability and diffusion

One feature that the team did not fully recognise when putting the original proposal together was the 'what next?' question in the two cities, and its connectedness with our programme theory. Our programme theory took us as far as the outcomes, at the points at which we measured them, but the way in which the schemes did or did not become embedded in the future, we now recognise, ought to have been an explicit part of our programme theory. What had happened historically and during implementation was our focus, but clearly what happens next, and the extent to which the gains in terms of casualty reductions might be maintained, is another important question in its own right and one that is closely integrated in the processes and outcomes that had occurred up to the point when our investigation ended.

Since the project finished, three members of the team (RJ, KM and MPK) have leveraged further funds from the Wellcome Trust to carry out a range of diffusion activities. Videos and an interactive logic model are available online.[106]

Strengths and limitations of the study approach

The 20-mph implementation in both Belfast and Edinburgh provided us with a unique opportunity to understand how context influenced the implementation of the 20-mph limits in the two cities. The key strengths are summarised in the following sections.

The breadth of the evaluation

We set out not only to evaluate a range of public health outcomes (including cost-effectiveness), but also to understand the systems (political, cultural, policy) in which the interventions were implemented. To our knowledge, this is one of the most comprehensive studies of a public health policy intervention that has ever been undertaken. In public health, there is a growing consensus that the systems and context in which an intervention is implemented can be as important as the intervention itself, and indeed can be the main factors influencing effectiveness. Through our extensive documentary,

historical, stakeholder and media analysis, we were able to construct a plausible explanation as to the factors that enabled the 20-mph limit policy to move from an idea onto the policy agenda and, finally, into reality. Our qualitative work with stakeholders and the public enabled us to understand more about whether or not the implementation was implemented as intended. This is important because the processes involved in the implementation of 20-mph speed limits have not been a focus of previous evaluations. The outcomes evaluation enabled us to evaluate whether or not it was effective, and, finally, our economic evaluation enabled us to make some judgement as to the cost-effectiveness of the intervention. With all these pieces of the 'jigsaw puzzle', it is likely that other cities and areas will be able to move forward with developing their own policies. An outcomes evaluation alone would have told them only that it worked, not why and how. Although a standard outcomes evaluation with a tranche of numbers, *p*-values and SDs may be viewed by some as more 'scientific', it will undoubtedly be less useful to those who need to implement based on the findings.

The tale of two cities

By choosing two cities with different contexts and different implementation strategies, we were able to develop a much better understanding of the factors that influence decision-making. This enables us understand how the intervention could be transferred to other cities and jurisdictions.

The second key strength was the partnerships we had in both cities with local and national stakeholders. Through working closely with them while developing the evaluation proposal, we were able to gain a good understanding of the questions they wished to have answered and the data that were available. We continued to work closely with them throughout the intervention period, and shared data and results. They were instrumental in providing us with key information for the evaluation, from the documentation we needed to the people we should talk to. Without this strong partnership, we would not have been able to access the data and the key stakeholders. The impact of our work was also greatly enhanced by this partnership. Ruth Jepson (the principal investigator) was asked to present evidence to both local government and national government during the period of evaluation. It was also instrumental as evidence for extending the roll-out of 20-mph speed limits in Edinburgh to more streets in the city.

The Study Steering Committee

Another key strength was the composition of the SSC. As well as academics working in the area, the SSC included representatives from the local bus company, police, advanced car drivers and the local council, and those who had been involved with the development of the 20-mph schemes. Having a range of stakeholders meant that we were able to ask for advice and support, as well as get their feedback on what the results meant to them. They were also instrumental on helping us get access to data and specific participants (such as taxi drivers, police and bus drivers). Without their unique insights we may not have picked up on many of the complexities of the implementation and how it affected the police, the bus drivers and others.

The implementation of 20-mph limits in Edinburgh and Belfast provided a unique opportunity to observe a natural experiment and undertake a comprehensive evaluation. However, policy interventions such as 20-mph speed limits are often associated with a number of challenges and limitations that are outside the control of the researchers. There were two main challenges: (1) timings related to funding and implementation of the policy, and (2) the data that were available to the researchers for analysis.

Timings

The research team had no control over the timetabling of the introduction of the limits. We developed the bid hoping to undertake baseline data collection in all the implementation zones in Edinburgh and in Belfast. However, the funding timeline did not align well with the policy and implementation timeline. Funding was received only after implementation was complete in Belfast and after it had begun in Edinburgh (it been implemented in 50% of the zones). This prevented us from collecting baseline data. Of course, this is a potential issue in any study seeking to investigate real events in real time.

Data

Another challenge related to the data that we had access to on active travel (see *Chapter 4*, *Active travel*). When we initially put together the proposal, we were hopeful that we would have several different measures of active travel. We wanted to limit the number of new data that were collected by the research team to avoid significant additional costs. We were anticipating that the data would be suitable for analysis, but we encountered several problems. This meant that we were not able to undertake analysis of the active travel data as robustly as we had originally planned. This had implications not only for the research objectives relating to active travel, but also for our plans for the economic evaluation. We discussed these issues with the SSC, and provided an alternative plan for the economic evaluation, which was approved.

Methodological strengths and limitations

Each of the substudies in this evaluation had some strengths and limitations, which are described more fully in the relevant chapters. This section provides a short summary of some of the main strengths and limitations of the different methodological approaches we used.

Media analysis

The strength of this analysis is the combination of systematic searching, screening and coding frames, and the use of a theoretical and practical framework to understand processes through the lens of a key social mechanism that shapes opinion and reflects views. Key limitations included the inability to include some important media as they were not available online to our study. Moreover, we are aware that the media are in themselves biased and we cannot be sure if the media presented the real story of what happened. The media may present a simplified public view of what happened, or perhaps from only one perspective, with other local voices being excluded; however, we were able to find examples of different views (e.g. anti-20 mph) being reported. We acknowledge the limitation that we did not examine social media, which may have given us greater insight into new issues or broader views.

Outcomes evaluation

The nature of this study, being a natural experiment evaluation, presents researchers with the need to acknowledge confounding variables and make adjustments in analyses when possible. The main confounder in this natural experiment is related to the citywide efforts to increase active travel during the study period. The attribution of a quantified impact of these efforts on the rates of road traffic collisions and casualties has been a challenge because representative data on active travel for the purposes of this study were not available.

Perceptions

Our survey (the SLiPS) offers a robust method for evaluating relevant public perceptions of speed limit interventions. Repeat data collection before and after (in three implementation areas) the policy change has provided useful insights into the changes in public perceptions, although this was not possible in Belfast. Limitations include the data collection methods and sample size, which limited the extent to which the data could be weighted or considered representative of the city population. We were not able to undertake analyses to explore health inequalities because of the small sample size.

Speed and volume analyses

For Edinburgh, it was not possible to include comparison or control streets in the analysis. If this were possible, it could have helped to identify the independent effects of the intervention. The analysis here cannot rule out that changes in speeds could have happened anyway (secular trends), nor can it determine how much of the observed changes can be attributed to the intervention (rather than other events or interventions within the time frame under analysis). However, this was a study undertaken in real time, when other things were also happening, related directly and indirectly to speed restrictions.

The associational data do not allow precise attribution. However, because of the approach we have used, our study has gone beyond associations to look at detailed mechanisms, and we are confident that we have located plausible mechanisms linking the intervention to the outcomes. The theory-based approach that we used in our evaluation, the pre-stated protocol, and the logical proximal relationship between speed limits changing and traffic speed changing mean that the results presented here add substantial weight to the evidence base for 20-mph limits leading to reduced speeds at 12 months.

Liveability analysis

Strengths include the implementation of MAPS-Liveability, a reliable tool specifically designed to assess liveability at the level of the street and to include information regarding microlevel environmental features. Furthermore, each of the 76 20-mph streets in Belfast and a stratified sample of the 20-mph streets in Edinburgh were assessed for liveability, the nine liveability constructs and the proxy indicators of behaviour. Limitations of the study using GSV include the following: it is not possible to assess variables such as air or noise pollution, or perceived safety; temporality (i.e. an image is one point in time and it is not possible to know time, day or date); and contemporality (i.e. time lapses between GSV images and data collection).

Qualitative work

One of the strengths of the qualitative work is the range of stakeholder and members of the public recruited from both cities, which allowed us to examine, in-depth, how the interventions were implemented and who was involved in this, as well as how the interventions were experienced by those affected (i.e. residents and commuters within the cities). The main limitation was that we found it challenging to recruit groups from socioeconomically deprived areas; thus, it was not possible to qualitatively examine the impact of the interventions on health inequalities, as originally intended. A further limitation was that, as noted, funding for this evaluation was received post implementation in Belfast and during implementation in Edinburgh; therefore, this may have led to an element of recall bias.

Economic analysis

The key strength is the DTA that we adopted. It offers a useful framework for planning and interpreting the results of an economic evaluation where there is substantial uncertainty about the likelihood of finding significant effects (in public health terms) and to ensure a rounded assessment of impacts and cost-effectiveness when valuable interventions might otherwise be rejected on the basis of statistical insignificance. There are risks with the approach, however. In particular, transparency of the DTA process is vital to reduce the risk of publication and other biases that might otherwise lead to ad hoc and partial use of evidence to justify a prior position on dubious grounds. In addition, we were not able to undertake a full economic evaluation nor a full DTA for the reasons discussed in *Chapter 6*. The health economist was unable to complete the work within the project timelines as a result of being a member of the Scottish Government response team working on COVID-19.

The programme theory

As detailed in *Chapter 1*, prior to the evaluation we had several iterations of the programme theory that we used as the framework for our evaluation. We added and refined it all the way through the evaluation as new data became available, and other data were lacking. The programme theory allows for clear identification of certain processes, thought to be integral to implementation, to be examined, acknowledging that it may not be possible to investigate all plausible causal assumptions or uncertainties around a complex intervention. Thus, we adapted much of our qualitative work, for example in an iterative manner, focusing on specific areas of the programme theory and allowing us to consider different implementer roles and population subgroups and contexts. The final iteration of the programme theory (*Figure 18*) shows the areas for which we were not able to find data to support or refute the link to 20-mph interventions, plus some additional data that resulted from the qualitative studies.

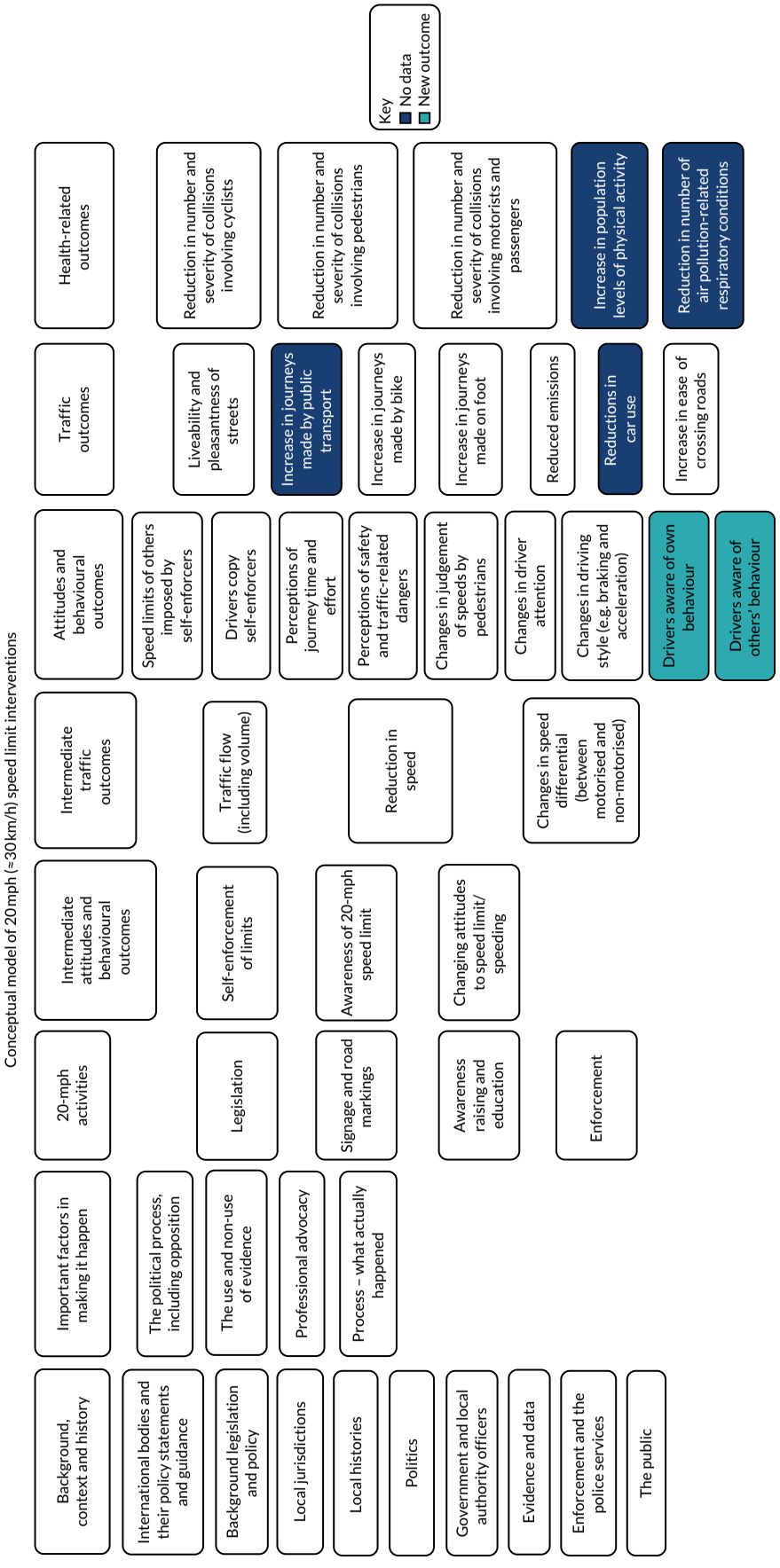

FIGURE 18 Final iteration of the programme theory.

Maximising the impact of the findings: dissemination

We have published a number of research papers from this study; see *Acknowledgements*, *Publications*.

To support dissemination of the findings and transferability to other parts of the UK, we planned to hold a series of workshops. The COVID-19 pandemic meant that it was not possible to undertake these workshops. As an alternative approach to face-to-face dissemination, we have created online resources. These summarise the evidence from the Edinburgh and Belfast schemes, and provide practical guidance on adopting this public health policy in other towns and cities, including how to navigate and work with the political and bureaucratic processes and how to determine the most appropriate approach to implementation given the local context.

The interactive online model can be accessed at https://html5.is.ed.ac.uk/20mph/20mph-model/version-2/ (accessed 1 November 2021). Videos can be viewed at https://html5.is.ed.ac.uk/20mph/ (accessed 16 May 2022).

Implications for policy and practice

Speed reduction interventions, such as 20-mph limits, can be implemented at various scales, from around schools to cities, and even countries. Although small-scale changes that have a direct impact on vulnerable road users are generally welcomed, any large-scale change, such as a citywide implementation of 20-mph speed limits, needs careful planning and consultation. Evidence of effectiveness is an important first step to getting the key stakeholders, such as the police, public transport authorities and local councillors, on board. This needs to be followed by addressing local concerns and potentially undertaking pilot studies. Linking in with other policy agendas (such as climate considerations, health and tourism) can increase traction. Once implemented, education and promotion are key to getting the public to respond positively. The value of enforcement is complex: although the proportion of the public in favour of the intervention want more visible enforcement, it may be considered heavy-handed by others. In addition, police resources are scarce and need to be considered pre implementation. The impact of these interventions can be primarily demonstrated through the reduction in the number and severity of collisions. It was not possible to demonstrate the effectiveness of the 20-mph speed limits on other outcomes such as active travel (walking and cycling). However, although changes in the rate of casualties can be achieved through altering the speed limit, changes in active travel depend on changes in perceptions of safety potential related to speed. This consideration needs to be factored into any roll-out of this intervention seeking to increase active travel. Interim analyses for the economic analysis suggested that it was plausible that the benefits of the scheme in Edinburgh, associated with the reduction in collisions and casualties, would exceed the costs. Costs were incurred at the beginning of the implementation and require little further investment, whereas the benefits (reduction in casualties, increases in liveability) will continue to accrue over the longer term. However, some of these benefits that can be attributed to the 20-mph intervention may be diminished by other similar interventions being implemented (such as cycle paths and greening of cities). In addition, the rate of road casualties has been falling over time, so the benefits of any intervention may be reduced.

It was initially envisaged that we would hold workshops to support the roll-out of 20-mph speed limits in other cities. These workshops did not take place because of COVID-19. However, we did secure external funding (from the Wellcome Trust) to develop interactive online resources to support dissemination.[106]

Implications for decision-makers

The evidence generated by this project suggests that, when decision-makers are considering introducing speed restrictions at local level, a number of considerations should be taken account of.

- First, it will be worth investing in a gradual and sometimes lengthy process. It is important to build support for the idea among the general public, vested interests and stakeholders. This will take time. It may involve the official publications by the local authority, but also the press – social, print and broadcast media. When possible, such efforts should draw on evidence about accident reduction, but also focus on the wider benefits of an environment with slower traffic. The idea of working for the common good was a particularly effective narrative that emerged in Edinburgh.
- Second, leadership locally is very important. Leadership should articulate a clear vision that can be shared by officials, and more generally with the public.
- Third, one of the most noticeable things about both Edinburgh and Belfast was that the idea of reducing speed never became a party-political issue. This allowed divergence of opinion within political parties and it meant that groups who were unconvinced of the merits of the scheme did not become aligned with one political party.
- It is worth noting too that barriers to successfully getting the decision agreed in the first place will always arise. However, on the basis of what we observed, such barriers are more likely to gain traction where the three preceding points are not followed.

Recommendations for future research

- Develop a statistical approach to public health interventions that incorporates variables from multiple outcomes. In our study we analysed each outcome independently. Further research could incorporate prior knowledge, such as estimates from Elvik's[89] models and from relevant systematic reviews, within a Bayesian framework, which will allow for a broader modelling approach to the evaluation of the impact of 20-mph speed limits on the rate of road traffic collisions.
- Develop population measures of active travel that can be administered simply, inexpensively and at scale. The audit of the active travel data sources has raised some important points about the difference between routinely and non-routinely collected data in terms of timing, frequency and location, and how these can affect evaluation of natural experiments. Of course, such monitoring has to be low burden and low cost for all stakeholders. The required quality of these data, combined with the more distal pathway from the intervention (compared with, for example, proximal outcomes such as speed or collisions), raises crucial methodological challenges for future evaluation work.
- Undertake further work on perceptions to establish (1) whether or not there are sustained changes in support for the intervention over time and (2) the relationship between perceptions around safety, support and change in speed and other outcomes.
- Further research is needed to assess the differential effectiveness of changes to speed on different socioeconomic groups and communities, and the effects of this change on these groups. There are many suggestions in the extant literature of differential risk, but it remains an important question as to what happens in different groups following the introduction of speed restrictions.
- Further research is needed on the effects on noise and air pollution following the introduction of lower speed restrictions. This should be linked to the differential effects in different communities mentioned previously.
- Further research using direct observation of walking and cycling following the introduction of speed restrictions is needed. Direct observation, rather than relying on reported behaviour, will provide much more objective evidence to inform future planning and decision-making.
- Some important broader methodological questions were raised by this project. The guidance on complex interventions was helpful up to a point, but we encountered a situation in which the intervention was not a single thing, but rather multiple things going on in different places at different times, in ways over which the researchers had no control. This was truly a complex intervention in a complex environment, occurring in real time. We learnt a great deal, but we think there is future scope for the complexity guidelines to be revisited to elaborate on some of the problems we encountered.
- Undertake a full economic evaluation of 20-mph speed limit interventions.

Conclusions

- In Edinburgh, the overall percentage reduction in collision rates was 40% and in casualty rates was 39%.
- The percentage reduction for each level of severity was 23% for fatal casualties, 33% for serious casualties and 37% for slight casualties.
- Average speeds reduced by 1.34 mph at 12 months.
- At 12 months after implementation, the number of people who were supportive of the speed limits increased, as did their willingness to obey the limits.
- The pleasantness of the streets also increased slightly.
- In Belfast only minor changes were seen for all outcomes.
- We were not able to measure the effect on walking and cycling.

The citywide approach in Edinburgh was effective at reducing speed, leading to reductions in collisions and casualties. Public perceptions and compliance with the speed limits also increased post implementation. These findings suggest that 20-mph limits can lead to similar public health outcomes to 20-mph zones, and have the advantage of being less costly and less intrusive. The city-centre approach was less effective; this may be because speeds were already low in the city centre, or may be a result of other factors.

Speed limit interventions that use signs and lines (plus education and promotions) instead of street architecture can reduce casualties and have significant public support and compliance once implemented. To be most effective, they may need to be implemented at a citywide level, or in areas where speeds are high, and be combined with significant education and awareness-raising. Large-scale implementation may mean there is a differential effect depending on factors such as time of day and volume of traffic (e.g. a driver would still be restricted to driving at 20 mph at 02.00 on an empty street and the impact on casualties and other health outcomes would be negligible). The main alternative, speed reduction interventions that include street architecture such as speed humps, are always likely to be more effective in reducing casualties, but are more expensive to implement and maintain over a large area. In addition, it is not known if this would be more acceptable than signs and lines only. In Edinburgh, it works, it is less intrusive and it is less costly, and the benefits keep on accruing without any additional costs. We have not been able to undertake a full economic evaluation for the reasons highlighted previously. However, the data suggest that it is likely that the benefits of the 20-mph limits in Edinburgh exceed the costs and further work has been identified that could make these conclusions more robust and more generalisable to other contexts.

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Contributions of authors

Ruth Jepson (https://orcid.org/0000-0002-9446-445X) (Professor of Public Health in Social Science) was the principal investigator leading on the design and execution of the study, oversaw the research governance and led the preparation of the final report.

Graham Baker (https://orcid.org/0000-0002-9547-6778) (Lecturer in Physical Activity for Health) was a co-investigator on the study, leading the design and execution of the qualitative components of work, as described in *Chapters 3* and *5*.

Claire Cleland (https://orcid.org/0000-0002-2738-8274) (Public Health Research Fellow) was the Post-Doctoral Research Fellow at Queen's University Belfast who implemented the Belfast perceptions survey and analysed the data; designed, implemented and analysed the Belfast focus groups; led the design, execution and analysis of the liveability studies in both Belfast and Edinburgh; and was involved in the preparation of the final report.

Andy Cope (https://orcid.org/0000-0001-8506-5054) (Director of Evidence and Insight at Sustrans) was involved in research design and data gathering, policy alignment and contextualisation, and provided policy practitioner insights to papers and the final report.

Neil Craig (https://orcid.org/0000-0002-7370-5541) (Acting Team Head Evaluation, Public Health Scotland) was responsible for the economic analyses presented in *Chapter 6*.

Charlie Foster (https://orcid.org/0000-0002-5041-0601) (Professor of Physical Activity and Public Health) was a co-investigator in the design of the study. He supported the research across WP3 (see *Chapter 2*) and led the media analysis.

Ruth Hunter (https://orcid.org/0000-0001-7315-0382) (Reader of Public Health) was the lead investigator for the Belfast site, leading on the design and execution of the study elements in Belfast, and was involved in the preparation of the final report.

Frank Kee (https://orcid.org/0000-0002-0606-8167) (Professor Director, School of Medicine, Dentistry and Biomedical Sciences Centre for Public Health) was a Belfast co-investigator, contributing local public health expertise and critiques on relevant WPs and the final report.

Michael P Kelly (https://orcid.org/0000-0002-2029-5841) (Senior Visiting Fellow, University of Cambridge) undertook the qualitative analysis of policy documents and interviews, and contributed to the sections of the final report related to WP3 (see *Chapter 2*).

Paul Kelly (https://orcid.org/0000-0003-1946-9848) (Reader in Physical Activity for Health) was a co-investigator contributing to study conception and to the design and execution of the outcomes evaluation. He contributed to the preparation of the final report.

Karen Milton (https://orcid.org/0000-0002-0506-2214) (Associate Professor in Public Health) was co-lead for WP3. In this role, she undertook (with Michael P Kelly) the qualitative analysis of policy documents and interviews, and led the sections of the final report related to WP3 (see *Chapter 2*).

Glenna Nightingale (https://orcid.org/0000-0002-0110-3939) (Statistician) conducted statistical analyses for the outcome measures and was the overall project manager. She contributed to the writing of the final report and other publications.

Kieran Turner (https://orcid.org/0000-0002-7708-5781) (Research Assistant) was a research assistant primarily assisting with the collection and analysis of qualitative data for WP2. He undertook all the interviews with stakeholders and the focus groups in Edinburgh.

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Data-sharing statement

All available data can be obtained from the corresponding author.

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Appendix 1 Explanation of each factor on the programme model

Background, context and history

International bodies and their policy statements and guidance

- A number of high-level policies on transport and health have been produced by international agencies such as the WHO and the European Union.
- These policies provide a general policy direction for national governments to follow.

Background legislation and policy

- The national government typically sets the policy framework for road safety.
- It is usually the responsibility of local authorities to implement measures locally.
- A key early step is to ensure that a 20-mph speed limit complies with the national framework.
- When a 20-mph speed limit does not fit within the national framework, lobbying for change at the national level may be required.

Local jurisdictions

- In Edinburgh, the scheme was initially led by the Lothian Regional Council, and then the City of Edinburgh Council (following a shift in governance structures). The formal legal mechanism for implementing speed restrictions in Scotland is via traffic regulation orders, which follow a statutory process including a robust consultation.
- Local jurisdictions did not play a role in Belfast, as the scheme there was led and managed by the government of Northern Ireland – the Department for Regional Development/Department for Infrastructure (the department changed its name in May 2016).

Local histories

- Local history is important for understanding traffic issues, previously tested interventions, and public perceptions and attitudes. We found a 20-year timeline to be helpful, although this is likely to vary from place to place.
- There may be particular historical factors that remain important, for example medieval and Victorian street design, and railway developments and closures, but these will be specific to localities.
- Local traffic data (e.g. on volume, speed and collisions) can be used to 'make the case' for speed reduction interventions around schools or in other 'accident hotspots'.
- If small-scale interventions are shown to be effective, then this provides local data that a 20-mph speed limit is an appropriate solution to address road safety.
- Implementing small-scale interventions in different locations (e.g. around schools) can help to create a societal 'norm'.

Politics

- Strong political leadership is required to push the agenda forward.
- Securing support across political parties helps to prevent the issue from becoming party political.

Government and local authority officers

Officers within the City of Edinburgh Council and civil servants in Belfast were central to making the schemes happen. These officers supported the politicians and political decisions, and implemented the relevant processes to take 20-mph speed limits from an idea to a reality.

Evidence and data

- The evidence discussed mostly related to vehicle speed and the related risks, as opposed to the effectiveness of 20-mph restrictions specifically.
- The limited available evidence on the effectiveness of 20-mph restrictions on slowing traffic and reducing the number of collisions and casualties was important in persuading different stakeholder groups that the speed limit policy may be worth pursuing. This evidence came mostly from evaluations of 20-mph 'zones' with traffic-calming infrastructure, as opposed to 'limits', which do not use physical traffic-calming measures.
- Without this evidence, it is likely that the idea would never have 'taken off'.

Enforcement and the police services

- Speed limits of 20 mph have no physical traffic-calming measures.
- A concern around 20-mph sign-only schemes is the perception that enforcement is required to ensure compliance, which puts additional strain on the police service.
- Policy enforcement was implemented in both Edinburgh and Belfast, although some stakeholders felt that more visible enforcement would be beneficial.
- A combination of awareness, enforcement, education, driver training, and community and statutory involvement was recommended for future interventions.

The public

- Engaging the public in a democratic decision-making process can help to ensure buy-in and support.
- Public support can add weight to political debates.
- Running 'pilot' schemes can allow the public to experience a 20-mph speed limit on a small scale.
- Evidence from Edinburgh and Belfast indicates that some of those who are opposed to 20-mph limits can be 'won over' when they see the intervention in practice.

Proximal factors

The political process including opposition

Interestingly, in both Edinburgh and Belfast, there were no clear political divides in opinion on 20-mph speed limits; instead, there were individuals who were for and individuals who were against the idea across all parties.

The use and non-use of evidence

- Once 20 mph made it onto the political agenda, evidence played only a small role in decision-making, although, from time to time, evidence was used to defend political arguments, for example when challenged in the public consultation.
- As the 20-mph speed limit moved closer to becoming a reality, little reference was made to the existence of evidence on whether or not the intervention 'works' (i.e. reduces speed and improves road safety). Other types of data became of interest to specific stakeholder groups, for example the impact that lower speed limits would have on bus timetabling, taxi drivers, carbon emissions and even pizza delivery times.

- A key concern in Belfast was that the speed limit would deter people driving to the shopping centre, and thus would have a detrimental impact on local businesses.
- Over time, the narrative shifted from road safety to a broader ideological vision of better communities and supporting wider economic and environmental agendas.

Professional advocacy

- Advocacy groups play an important role in bringing topics such as road safety and 20-mph speed limits to the attention of policy-makers.
- Such groups included 20's Plenty for Us, Sustrans, Living Streets and cycling organisations.
- These groups can make a compelling case for the need to act, based on evidence and statistics, but also on case studies.

Process: what actually happened

- In Edinburgh and Belfast the approach was gradualist.
- Small schemes were implemented around schools as a first step: child safety was an 'easy win'.
- There was a range of steps in the build-up to implementation, including consultations with the public, pilot schemes, and discussions around the design and implementation of the schemes.
- A large pilot scheme in the south of Edinburgh was particularly critical in gaining widespread public support for the wider roll-out in Edinburgh.

Activities for the implementation of 20-mph speed limits

Legislation

Both cities had to issue legislative traffic regulation orders to implement 20-mph limits.

Signage and road markings

- Signage was implemented in both Edinburgh and Belfast, including advanced warning signs (i.e. new limit in force), terminal signs (on entering the 20-mph area) and repeater signs (throughout the area).
- Road markings were implemented in Edinburgh, and to a lesser extent in Belfast.
- In Edinburgh, 'buffer zones' were introduced between areas that had national speed limits and those that had 20-mph limits. These involved the installation of speed limits of 30 mph on sections of road to ease the transition from 60 mph to 20 mph, and vice versa.
- In Belfast there were some changes to signage once implementation had begun. Approximately 8 months into implementation, the original signs with a white background were replaced with signs with a yellow background to increase conspicuousness.

Awareness-raising and education

- In Edinburgh, an education and awareness-raising campaign was integral to the intervention and was implemented from the outset, with dedicated staffing and funding. This included physical adverts (e.g. bus backs/shelters, billboards) and press, media and social media releases delivered prior to signage being constructed, at the 'go-live' stage and throughout implementation. These activities were often tailored to a specific geographical area and informed by public feedback about preferences.
- In contrast, this component of implementation was delivered on a smaller scale with few delivery partners in Belfast. In retrospect, stakeholders and members of the public felt that a larger campaign in Belfast would have helped to raise awareness and build support for the intervention.

Enforcement

- A general view from police stakeholders was that 20-mph limits should be self-enforcing, requiring limited (if any) additional police resourcing.
- In Edinburgh, additional officers were trained in speed detection in advance of the speed limit, speed checks were carried out and community officers had 'responding to 20 mph issues' added to their remit. In addition, Police Scotland supported the city council's media releases.

Intermediate attitudinal and behavioural outcomes

Self-enforcement of limits

- Some members of the public perceived that the 20-mph limit was not being enforced, and therefore there was no reason to stick to the new limit.
- The public expressed that a stronger police presence, with strict and visible enforcement (e.g. through the installation of speed cameras and the issuing of penalty points and fines), would improve compliance with the new speed limit, but acknowledged that greater enforcement may lead to negative public attitudes towards the police.

Awareness of 20-mph speed limits

- The scheme in Edinburgh was perceived by the general public as being highly visible, attributable in part to the education and awareness-raising activities that took place.
- In contrast, lower levels of awareness of the 20-mph speed limit initiative in Belfast are likely to stem from the relatively low-key public education and awareness-raising activities.

Changing attitudes to speed limit/speeding

- In Edinburgh, using the SLiPS, an increase in support and decrease in resistance to the 20-mph speed limit intervention was identified 6 and 12 months after the implementation. This was also supported by qualitative focus group data obtained from members of the general public.

Intermediate traffic outcomes

Traffic flow (including volume)

- The volume of traffic on the roads decreased slightly in both cities.
- The average 7-day volume of traffic decreased by 87 vehicles (95% CI −112 to 286 vehicles) in Edinburgh.
- The average 7-day volume of traffic in Belfast city centre decreased by 133 vehicles (95% CI −252 to −15 vehicles).

Reduction in speed

- One year after the policy change, average speeds on monitored roads in Edinburgh had reduced by 1.34 mph (95% CI 0.95 to 1.72 mph).
- In Belfast, the average speed reduced by 0.91 mph (95% CI −3.01 to 1.18 mph).
- The observed speed reductions in Edinburgh and Belfast are consistent with other signage-only schemes, which have also shown an approximate 1-mph reduction in speed.

Changes in speed differential (between motorised and non-motorised)

- In both the Edinburgh and Belfast focus groups, there was a small amount of discussion that the reduced speed limit had created a more pleasant cycling experience through a reduced speed differential between cyclists and motorists.
- However, some members of the general public also discussed how this reduced speed differential could lead to potentially dangerous interactions and overtaking situations.

Attitudinal and behavioural outcomes

Speed limit of others imposed by self-enforcers

Feelings of frustration when caught behind a slow driver did not change markedly on the perceptions survey in Edinburgh, although in the focus groups it was reported that drivers were becoming frustrated with slower drivers, leading to increased overtaking.

Drivers copy self-enforcers

- In Edinburgh, using the SLiPS, members of the public reported an increase in following the behaviour of others on the road (rule-following) 6 and 12 months after implementation.
- In Belfast, drivers reported not changing their driving speed and not self-enforcing a 20-mph driving speed, which was attributed to a lack of awareness of the 20-mph speed limits, the perception that there was no need for the 20-mph speed limits within the city centre and a lack of enforcement of the 20-mph speed limits.

Perceptions of journey time and effort

- In Edinburgh, using the SLiPS, members of the public reported a reduction in perceptions that 20-mph speed limits would lengthen their journey times, worsen traffic flow and increase congestion. These findings were supported by the qualitative data gathered via focus groups with the general public.
- In Belfast, those who participated in the focus groups perceived that traffic congestion had increased as a result of a reduction in driving speed; however, they also reported that congestion was an ongoing issue in the city centre prior to the implementation of the 20-mph speed limits.

Perceptions of safety and traffic-related dangers

- The SLiPS in Edinburgh did not identify marked changes in the perceptions of safety on the city's roads. In Edinburgh, the general public did not report any enhanced feelings of safety as a driver of a motor vehicle, as a cyclist or as a pedestrian.
- Stakeholders in Belfast perceived that the 20-mph speed limits would improve cyclist safety; however, if the limits were not being enforced or drivers were not adhering to the new limits, they felt that the 20-mph speed limit would be ineffective and that there would be no improvements in road safety.
- In Belfast, it was perceived that the reduced driving speeds could result in drivers becoming irate/frustrated, which may cause an increase in the rate of collisions and casualties, although a reduced driving speed could reduce the severity of collisions and casualties.

Changes in judgement of speeds by pedestrians

- The SLiPS in Edinburgh did not identify marked changes in the perceptions of walking safety near the city's roads or when crossing the road.

- In Belfast and Edinburgh, the general public perceived that reduced driving speeds caused pedestrians to walk in front of moving cars. It was discussed that pedestrians walking in front of moving cars could cause drivers to become irate/frustrated, potentially leading to an increase in the rate of collisions and casualties. Consequently, this was viewed as an unintended consequence of the 20-mph speed limits.

Changes in driver attention

The public perceived that 20-mph limits may lead to reductions in driver attention, as a result of concentrating on the speedometer and drivers checking their phone when travelling at slower speeds. This was perceived to have the potential to result in an increased rate of collisions and casualties. This was not substantiated by the collision and casualty data, highlighting a discrepancy between the effectiveness of the intervention and its perceived effectiveness among the public.

Changes in driving style (e.g. braking and acceleration)

- The general public in both cities perceived that driver behaviour had worsened to some extent as a result of the 20-mph speed limits. For example, they perceived that there had been an increase in overtaking due to driver frustration with slower moving traffic.
- In Belfast it was also perceived that an increase in breaking/accelerating could lead to increased noise and air pollution.

Traffic outcomes

Liveability and pleasantness of streets

- Using the MAPS-Liveability tool, liveability significantly increased in both Edinburgh and Belfast.
- In Edinburgh, the liveability constructs of traffic/transport, places and pavements were found to have significantly increased.
- In Belfast, the liveability constructs of traffic/transport and places were found to have significantly increased.

Increase in journeys made by public transport

- Insufficient data were available to determine the impact of the intervention on the number of journeys made by public transport. There was very little change in the volume of vehicles on the roads, which may suggest that the 20-mph speed limits did not lead to a change in travel mode from the car to public transport.
- The general public in Belfast and Edinburgh did not report changes in their selected mode of transport as a result of the 20-mph speed limit intervention.

Increase in journeys made by bike

- Insufficient data were available to determine the impact of the intervention on the number of journeys made by bike.
- The general public in Belfast and Edinburgh did not report a change in the number of journeys they made by bike; however, they did perceive that the 20-mph speed limits may improve cyclist safety.

Increase in journeys made on foot

- Insufficient data were available to determine the impact of the intervention on the number of journeys made by foot.

- The general public in Belfast and Edinburgh did not report a change in the number of journeys they made on foot as a result of the 20-mph speed limit intervention.

Reduced emissions

- Insufficient data were available to determine the impact of the intervention on emissions.
- In Belfast, the general public perceived that the reduced speed limits could lead to an increase in air pollution through reduced car efficiency and increased breaking/accelerating.

Reductions in car use

- No data were available to determine the impact of the intervention on overall car use.
- Vehicle volume did not decrease as a result of the new limit, which may suggest that people continued to use their cars in their usual way.
- The general public in Belfast and Edinburgh did not report a change in car use as a result of the 20-mph speed limit intervention.

Increase in ease of crossing roads

Data from focus groups with the general public in Belfast and Edinburgh suggested that the intervention was perceived to lead to pedestrians more freely crossing the road, and less frequently utilising formal crossing points. It was suggested that this could have the unintended consequence of more pedestrians being hit by cars.

Health-related outcomes

Reduction in number and severity of collisions involving cyclists

No data were available on the number and severity of collisions involving cyclists.

Reduction in number and severity of collisions involving pedestrians

No data were available on the number of collisions involving pedestrians; however, the number of pedestrian casualties decreased by 53% (–591 casualties).

Reduction in number and severity of collisions involving motorists and passengers

- In Edinburgh, the number of collisions in a year reduced by 367 (40% reduction), with 409 fewer casualties (39% reduction). The number of road traffic fatalities in Edinburgh decreased by 11 (23% reduction).
- There was a 2% reduction in collisions and a 6% reduction in casualties in Belfast city centre up to 3 years following the introduction of the 20-mph speed limits. Road traffic fatality rates decreased by 44.3%.

Increase in population levels of physical activity

No data were available to determine the impact of the intervention on overall physical activity levels, which we proposed would change as a result of increases in walking and cycling.

Reduction in the number of air pollution-related respiratory conditions

- No data were available to determine the impact of the intervention on the number of air pollution-related respiratory conditions.
- The general public in Belfast perceived that the 20-mph speed limits could lead to an increase in air pollution through reduced car efficiency and increased breaking/accelerating.

Appendix 2 Examples of print media

Media search: numbers of hits by study area and source media (including years of searches)

Sources	Included articles (*n*)	News (*n*)	Opinion (*n*)
Belfast			
Belfast Telegraph (April 1999–May 2018)	5	2	3
Belfast News Letter (January 1997–September 2006)	0	0	0
The Irish Times (Belfast) (January 2013 to date)	7	7	0
Edinburgh			
The Scotsman (January 1993 to date)	19	14	5
The Herald (January 1992 to date)	20	11	9
Daily Record and *Sunday Mail* (January 1994 to date)	5	1	4
Evening Express (March 1998 to date)	15	11	4
The Press and Journal (March 1998 to date)	9	9	0
The Sunday Herald (February 1999 to September 2018) and *Herald on Sunday* (September 2018 to date)	4	4	0

Additional quotations

Problem stream

Evidence sources from professional advocacy groups outside Scotland were also cited, to support the call for safer streets:

> *The first, full independent survey into the effect of school traffic on road safety and traffic congestion is to be carried out by the AA Foundation for Road Safety Research over the next nine months.*
>
> *Dangers of congestion highlighted, The Scotsman, 7 May 1999*

These combinations of both professional advocacy and public advocacy merged into a universal advocacy call for improvements to the problem:

> *Demonstrators lay in the street yesterday bearing 103 crosses to symbolise the projected death toll on Britain's roads before the Government launches its safety review in 11 days' time. Around 200 families affected by road accidents gathered at Whitehall, in London, to draw the Government's attention to the fact that half the 3400 people killed or seriously injured on Britain's roads every year would be saved by 20 mph speed limits in built-up areas.*
>
> *Protest over road deaths, The Herald (Glasgow), 21 February 2000. Reproduced with permission from Newsquest Media Group*

As 20-mph schemes were being more wildly reported, opposition to such ideas was also reported. Nearly all of these anti-20-mph views were expressed as editorial or opinion articles stressing a political positioning of anti-speed and depersonalised positions or non-enforcement:

> *The Green Party have been advocating this, but do any of these people actually drive a car? Or could they be cyclists? And have they tried to drive at 20 mph?*
>
> *Efforts to get drivers on go-slow must have been dreamed up by cyclists, Evening Express, 12 May 2018. Reproduced with permission from Aberdeen Journals Archive*

Policy stream

The problem stream pro-20-mph speed limit evidence of impacts had focused on speed and child fatalities, pre 2000. Now new types of evidence appeared in the policy stream that had more breadth in terms of the range of issues reported, across health, economic, environmental and social benefits for individuals and communities. The problem of traffic was now expressed in policy language, in terms of economic cost:

> *The GCPH [Glasgow Centre for Population Health] found that imposing a similar limit in Scotland could cut road casualties by more than 10%, and up to £39.9m per year in costs to emergency services . . . Under the higher estimate, there could be 755 fewer casualties, including saving save [sic] five lives per year and £39.9m.*
>
> *Cutting the speed limit to 20 mph 'would save lives and £40m a year', The Herald (Glasgow), 20 September 2018. Reproduced with permission from Newsquest Media Group*

This broadening of benefits was coded as a theme of remessaging of evidence, as it was reported as being trumpeted by advocacy groups and, for the first time, political individuals and parties:

> *Mark Lazarowicz [Scottish Labour] said . . . 'Improving the pedestrian environment will be good for business, good for local people and good for visitors and tourists. What we are bringing forward will create a city centre to rival those of the great cities in Europe'.*
>
> *Drivers face total Princes St ban, The Scotsman, 15 February 2000*

Despite 20-mph schemes being sought as a solution to the problem, there were few calls for a political and policy solution pre 2000; however, articles post 2000 introduced examples of 'successful' implementation of 20-mph schemes in Scotland, reporting additional and potential benefits, proposing 20-mph speed limits as a solution and calling for political support:

> *Edinburgh could become one of the first cities . . . to introduce a 20 mph limit across its city centre to reduce accidents and improve the pedestrian environment . . .*
>
> *The main reason behind the scheme is to reduce accident figures. Over the last three years there have been 550 accidents in the city centre.*
>
> *20 mph – and that's the limit, The Scotsman, 16 November 2000*

The impact of 20-mph schemes from other parts of the UK and within Scotland become more frequently reported post 2000, and connected with solving similar problems elsewhere. This powerful connection was expressed in terms that a solution already exists and is being used by others like us. For example, redevelopment plans in Aviemore included 20-mph speed limits as part of the traffic safety measures:

> *Two roundabouts at either end of Grampian Road will take traffic at 20 mph up to a new system of streets organised around the green, designed as the heart of the village, its commercial as well as its community life.*
>
> *Blueprint unveiled for new face of Aviemore, The Herald (Glasgow), 9 September 1997. Reproduced with permission from Newsquest Media Group*

The pilot of the 20-mph Edinburgh scheme was reported as successful and as the principal reason for the expansion of the scheme across the whole city in 2014, with the endorsement of a local pressure group:

> *Edinburgh is to become the first city in Scotland to impose a 20 mph speed limit across its streets . . . The plan follows a successful pilot in the Marchmont, Grange and Prestonfield areas of the city last year.*
>
> *Edinburgh to have 20 mph speed limit, The Herald (Glasgow), 14 January 2014. Reproduced with permission from Newsquest Media Group*

> *This is not a particularly poor or problem area, nor is Edinburgh a city where traffic problems are as ghastly as in many . . . Poorer areas in general have worse roads: the poorest children in Britain are four times likelier to be killed in a traffic accident than children from social class one . . ..*
>
> *Pollution and danger on the walk to school, Scotland on Sunday, 30 October 1994. Reproduced with permission from Newsquest Media Group*

> *[Person 4] said he faced problems trying to stick [to] the limit, writing: 'Driving through Portobello the other day, doing 20 mph with the driver behind practically in the boot! I agree 20 zones should only be near schools, residential areas etc but not on main roads'.*
>
> *Facebook responses – Evening News readers have their say on 20 mph limits, The Scotsman, 4 July 2017*

Politics stream

Political parties began to connect the problems of traffic and 20-mph schemes as a policy option to champion:

> *Robin Harper, Green Party, Lothian, expressed sympathy with the petition, but added: 'I hope that every council in Scotland will introduce home-zones and 20 mph areas.'.*
>
> *Speed freeze, The Scotsman, 24 May 2000*

The impact of political support for 20-mph schemes was reported within the policy stream, as were the critical efforts of one Green Party MSP to champion 20-mph schemes. The reporting quoted 'the postcode lottery' and inequality in that some areas had these schemes already whereas others did not. This political advocacy and offering of a policy solution shows the interaction of both the problem and policy streams, preceding the political stream in which legislation was agreed:

> *Mark Ruskell . . . said at present there is a . . . 'Children and the elderly are being put at uneccessary [sic] risk of injury and death by our failure . . .' Mr Ruskell plans to introduce a member's bill at Holyrood to make 20 mph the default speed limit for residential area . . .*
>
> *Green MSP bids to roll out 20 mph limit in all residential areas, The Scotsman, 12 February 2017*

> *Green MSP Mark Ruskell is putting forward legislation. 'By making 20 the norm in built-up areas we can end this frustration and provide the clarity that residents and motorists deserve' . . .*
>
> *Cyclist Mark Beaumont says 20 is plenty for motorists in urban areas, The Scotsman, 24 September 2018*

Appendix 3 Characteristics of focus group participants

Characteristic	Belfast, *n* (%)	Edinburgh, *n* (%)
Total number of participants	60	99
Focus group classification		
Older adults	3 (5.0)	8 (8.1)
Older adults (males)	–	11 (11.1)
Parents with young children (socioeconomically disadvantaged)	8 (13.3)	7 (7.1)
Parents of schoolchildren	–	6 (6.1)
Regular road cyclists	4 (6.7)	7 (7.1)
	–	6 (6.1)[a]
Commuters	7 (11.7)	–
	5 (8.3)[b]	–
Multimodal transport users	13 (21.7)	–
City-centre workers	7 (11.7)	–
Middle-aged adults	7 (11.7)	–
Students/young drivers	6 (10.0)	–
Advanced motorcyclists	–	11 (11.1)
Semi-rural residents/community councillors (Edinburgh West)	–	9 (9.1)
	–	5 (5.1)[c]
Semi-rural residents/community councillors (Edinburgh South)	–	6 (6.1)
Public transport users	–	6 (6.1)
Active transport (general)	–	3 (3.0)
Car/private motorised transport users	–	7 (7.1)
Taxi drivers	–	4 (4.0)
Bus drivers and management representatives	–	3 (3.0)
Gender		
Male	16 (26.7)	59 (59.6)
Female	44 (73.3)	39 (39.4)
Prefer not to say	–	1 (1.0)
Ethnicity		
White	57 (95.0)	92 (93.0)
Mixed/multiple ethnic groups	1 (1.7)	–
Asian/Asian British/Asian Irish	1 (1.7)	4 (4.0)
Other	1 (1.7)	1 (1.0)
Missing	–	2 (2.0)

Characteristic	Belfast, *n* (%)	Edinburgh, *n* (%)
Disability		
No	55 (91.7)	97 (98.0)
Yes	4 (6.7)	2 (2.0)
Missing	1 (1.7)	–
Age range (years)		
17–20	1 (1.7)	0 (0)
21–30	19 (31.7)	8 (8.1)
31–40	14 (23.3)	11 (11.1)
41–50	4 (6.7)	19 (19.2)
51–60	7 (11.7)	20 (20.2)
61–70	11 (18.3)	18 (18.2)
≥ 71	3 (5.0)	23 (23.2)
Missing	1 (1.7)	0 (0)

a This was a second focus group that took place in Edinburgh under the characteristic of 'regular road cyclist'.
b This was a second focus group that took place in Belfast under the characteristic of 'commuters'.
c This was a second focus group that took place in Edinburgh under the characteristic of 'semi-rural residents/community councillors (Edinburgh West)'.

Appendix 4 Topic guide for stakeholder interviews: Edinburgh

Awareness of scheme

When did you first become aware that the City of Edinburgh Council were introducing a citywide 20-mph speed limit?

- Prompt: pre, during or post implementation?

How did you find out that the city was introducing this speed limit?

- Prompts: media, social media, word of mouth, workplace.
- City council scheme: bus backs, bus stops, street signage?

Did you realise it would impact your area directly at this time? How did you find out it would impact you directly?

Opinions of the 20-mph speed limit

What were your thoughts when you first heard about the 20-mph speed limit being introduced? Have these views changed now that the scheme has been completed?

How did you feel when you found out it would impact you directly? Have your views changed?

- Prompt: encourage to be honest with their initial views/compared with now.

What are your opinions on the signage that is used for the 20-mph speed limit?

- Prompts: adequate? Size, frequency?

What are your opinions of the 20-mph limit? Do you think that it is a positive thing for vulnerable members of society?

- Impacted the local area where you live? Commuting? Safety?

Do you think it has made people drive slower?

Do you think that it has, or it will, change the number of collisions? Car, bicycle, pedestrian?

Do you think safety has improved?

Do you feel safer on the roads? Either as a pedestrian, cyclist or driver?

- What about crossing roads?
- Do you feel your family and friends are as safe doing these activities at 20 mph?

Do you think that the 20-mph speed limit will have any negative impacts?

- Prompts: noise, congestion, pollution, inconvenience, fuel efficiency?

Rationale for the scheme

What do you think were the reasons for the city council introducing the citywide 20-mph speed limit?

Prompts:

- reduce speed/traffic calming
- casualties/casualty severity
- safety/perceived safety
- pedestrian safety
- cyclists
- public health
- pleasant environments.

Enforcement

Do you have any opinions regarding enforcement of the 20-mph speed limit? Do you believe that enforcement activity has been sufficient?

- Prompts: how do you feel it should be enforced?
- Who do you feel is responsible for enforcement?

Behaviour change

Has the introduction of the new 20-mph speed limit caused you to change your behaviour?
If so, how? Why?

- Prompts: changed the way that you travel? . . . for daily travel to work, city centre, commonly travelled routes, etc.
- Changed the speed that you drive it? Other aspects of driving behaviour?
- Other reasons for change?

Has the 20-mph speed limit caused anyone you know to change their behaviour?

Do you believe that the 20-mph speed limit has changed anything in practice?/Are you seeing evidence of people changing their behaviour?

- Prompts: driving behaviour, modal shift?
- Car use, walking, cycling, commuting.

Liveability

Do you think that the 20-mph speed limit has improved the liveability of areas in Edinburgh? i.e. has it increased how pleasant environments are/improved the environment quality?

Prompts:

- noise
- aesthetics
- making environment more pleasant

- ability to socialise
- protecting the environment
- use of/access to/provision of services
- pollution/air quality
- safety
- public transport.

Appendix 5 Topic guide for stakeholder interviews: Belfast

Introduction

Would you first be able to confirm what your professional role is, and how this relates to the 20-mph speed limit scheme here in Belfast?

What has your involvement in the scheme consisted of to date?

What is your involvement in the scheme likely to consist of in the future?

Background

Who have been the key organisations/departments in developing this policy, and in rolling it out to date?

- What have each of their roles been in this?

What has the scheme consisted of in Belfast? (Signage, education, enforcement?)

How was the decision made to make this a 3-year pilot, and on the city-centre scale that it has been implemented?

Legislation process/speed limit order process

What was the rationale behind choosing to introduce the scheme in such a way (so signage only)?

- Was this decision influenced by any legislation change?
- Is it a 20-mph zone or a 20-mph speed limit?

Would you be able to discuss what the legislative process consisted of?

- What legislative guidelines/procedures were followed?
- Key dates/milestones, consultations.
- Committee voting? What did this process consist of?

Who were the key parties involved in passing the legislative process?

To what extent was this process carried out as intended?

- Any setbacks/anything unexpected?
- Any adaptations made?

Were there any unexpected activities that occurred as a part of the legislative process?

Were there any facilitators that helped this process?

Were there any challenges/barriers that hindered this process?

Signage and road markings/infrastructure

What has the signage/road markings element of implementation consisted of?

- Who designed the signage/markings?
    - Any legislation/guidance used here?
- Who was responsible for creating the signage?
- Who was responsible for installing the signage?

Have there been any changes to any of the signage or road markings since the scheme was introduced?

- Why?
- Based on learning/mistakes?

Have there been any changes to streets within the 20-mph speed limit area since implementation?

- Are these all documented in reports?

Were there any difficult decisions on streets prior to the scheme being rolled out?

To what extent has the 20-mph speed limit signage and road markings been implemented as intended?

- If not, how, and why not?
- Do you believe it is sufficient?

Challenges and unexpected actions

Have there been any challenges with regard to the road signage element of the intervention?

- Cost? Time issues?
- Expected/unexpected?

Have there been any unexpected activities during the implementation of the road signage for the 20-mph speed limit?

Barriers to/facilitators of implementation

Can you identify factors that have acted as a facilitator of the successful implementation of road signage?

- Community group support, media coverage, national/local campaigns, backing from support groups?

Have there been any barriers or challenges to the successful implementation of the road signage component?

- Policies/commercial bodies that have influenced implementation.
- Pressure groups against/backlash/media coverage.

What has the public response been to the change in road signage?

Awareness-raising and education

To what extent has there been an awareness-raising/education campaign regarding the 20-mph speed limit in Belfast?

- If none, why not?

What have awareness-raising/education activities consisted of in this scheme?

Prompts:

- Bus backs, bus stops, bin lorries, etc.; media, social media, engagement with schools and workplaces, engagement with community councils?
- When did each of these activities start/timelines of these activities?
- Magnitude of these activities?
- Document listing all of these activities?
- What informed decision-making on these materials? Surveys?

Who has been responsible for this element of the scheme?

- Who has been responsible for creating the educational and awareness-raising materials?
- Who was responsible for installing/delivering these resources?

Have any other bodies carried out educational/awareness-raising programmes?

- Prompt: thinking along lines of external road safety/sustainable transport charities, etc.

Has the awareness-raising element of the scheme been delivered as was intended?

- If not, what has been changed? Why? And when? Has this been based on key learning?
- Would you have done anything differently?

Are there plans for any further education activities?

Challenges and unexpected actions

Have there been any challenges with regard to the awareness-raising/education component of the intervention?

- Cost? Time issues?
- Expected/unexpected?

Have there been any unexpected activities during the implementation of the awareness-raising/education?

Barriers to/facilitators of implementation

Can you identify factors that have acted as a facilitator to the successful implementation of the awareness-raising scheme?

- Community group support, media coverage, national/local campaigns, backing from support groups?

Have there been any barriers or challenges to the successful implementation of the awareness-raising/education component?

- Policies/commercial bodies that have influenced implementation.
- Pressure groups against/backlash/media coverage.

What has the feedback from the public been on any educational activities?

Enforcement

What has enforcement consisted of for this scheme?

- What enforcement activities have taken place during the scheme?

Who has responsibility for the enforcement activities involved?

Do the enforcement activities on the ground match what was intended by the enforcement agency? If not, why not?

Have there been any changes to enforcement throughout? Either in quantity or type? If so, why have these changes been made?

Could enforcement activities for the scheme change? What would inform these changes?

Unexpected activities/barriers and facilitators

Have there been any unexpected activities during the enforcement of the scheme?

- Prompts: any unintended consequences?

Have there been any challenges or barriers to the enforcement of the 20-mph speed limits?

Prompts:

- Funding?
- Time issues?
- Politics?
- Policies/commercial bodies/that have influenced implementation?
- Pressure groups against/backlash/media coverage?

Can you identify any factors that have facilitated the enforcement activities of the 20-mph speed limit in Belfast?

Prompts:

- Additional funding from city council, other external? Support from other groups?
- Community group support, media coverage, national/local campaigns, backing from support groups?

Monitoring

What is the extent of the monitoring activity of the scheme?

What is being monitored? Speeds, casualties, walking and cycling?

What do you think are the important elements to monitor surrounding the scheme?

Who are the relevant partners involved in the monitoring of the scheme, and what are their respective responsibilities?

Are there key dates that you are looking at regarding monitoring?

Broader implementation

Apart from the element of the scheme with which you are involved, what activities has the 20-mph speed limit scheme in Belfast consisted of?

- Legislative processes, signage, awareness-raising and education, enforcement? Others?

To what extent have these activities been implemented as planned?

To your knowledge, have any of these activities been altered or adapted at all?

- What, and why?
- Has this been based on any learning?

Barriers and facilitators/unintentional activities

Can you identify factors that have acted as a facilitator to the implementation of the scheme overall or to any specific implementation activities?

- Prompts: community group support, media coverage, national/local campaigns, backing from support groups?

Have there been any barriers or challenges to implementation overall or other specific implementation activities?

Prompts:

- Pressure groups/public backlash/media coverage/political/commercial interests influencing extent of implementation?
- Costs/cut-backs?
- Time-related issues/pushed back.
- Politics?

Have there been any unintentional implementation activities throughout to your knowledge?

To what extent have factors such as setting or context impacted on other activities within the 20-mph speed limit implementation, or overall?

- Roles/relationships/external partners?
- Other concurrent interventions, demographics, geography, physical location?
- Generalisable?

Are there streets where you think the scheme has worked differently to any of the others?

Prompts:

- Why?
- Other concurrent interventions, demographics, geography, road characteristics?

Success of scheme

What do you believe would constitute success for the scheme?

- Based on this, do you believe it has been successful so far?
- What do you think are the implications for success going forwards?

Stakeholder identification

We are keen to identify all key stakeholders involved in the 20-mph speed limit in Belfast, including those involved in the planning and policy-making early in the process (prior to this being implemented), and those involved in different areas of the intervention (such as signage installation, education and enforcement if applicable). Are there any stakeholders who would fall under these categories who you believe would be of use to discuss the scheme with?

Final remarks

Is there anything that you would like to comment on that has not been discussed so far?

Appendix 6 Topic guide for focus group interviews

Theme	Question	Points for further investigations by the facilitator
Awareness	When did you first become aware that the City of Edinburgh Council was implementing a citywide 20-mph speed limit?	Encourage participants to think about pre, during or post implementation of the 20-mph limit
	How did you find out that the city was implementing this limit?	Encourage participants to recall how they heard about the limit: media, social media, word of mouth, workplace, etc.; CEC awareness-raising (bus backs, bus stops, on-street signs)
	What were your thoughts when you first heard about the 20-mph limit?	Encourage participants to be honest about their initial views of the 20-mph limit/their views now
	Now that the 20-mph scheme has been implemented, have your thoughts changed?	
	When did you become aware that the particular area you live/work/socialise in or that you travel through was about to have or it was having a 20-mph speed limit implemented?	Was it at the same time that they first heard about the city wide limit or was it at a different time?
	How did you find out that the 20-mph limit would impact you directly?	Encourage participants to recall how they heard about the limit: media, social media, word of mouth, workplace, etc.; CEC 20-mph awareness materials/signage
	How did you feel when you realised that the 20-mph limit would impact you directly?	Encourage participants to be honest about their views of the 20-mph limit directly impacting them: does this differ from their feelings when they heard about it being a citywide scheme? Have views changed as result of experiencing limit?
	Now that the 20-mph scheme has been implemented, have your thoughts changed?	
Engagement	Do you recall seeing any campaigns or press releases about the 20-mph scheme in Edinburgh?	Encourage participants to provide details
	What were they? What did you think about them?	Consultation, council events, education/awareness-raising campaign, media, social media
	Have you ever attended any event that aimed to deliver awareness or education of the 20-mph scheme?	
Rationale	What do you think the reason/s were behind the introduction of this scheme?	Talking points: traffic calming, reduced speed, reduction in accidents, reductions in accident severity, safety, pedestrian safety, cyclists, public health, pleasant environments
Perceptions	What are your opinions of the 20-mph limit? • Impacted the local area where you live? Commuting? Safety? Additional probing questions: • Do you think that the 20-mph speed limit will make people drive slower?/has it made people drive slower in your opinion? • Do you think the 20-mph limit will reduce the number of collisions? (car vs. car, motorcycle vs. car, car vs. bicycle) • Do you think the 20-mph limit will reduce the number of pedestrian accidents?	Good, bad, worthwhile, causes problems, congestion, reduction in accidents

Theme	Question	Points for further investigations by the facilitator
	• Would you or do you feel safer walking/cycling on a 20-mph limit road? If so, why? If not, why? • Do you think safety has improved? • Regarding other members of your family (e.g. children, adolescents, older adults, those with a disability), do you feel they are safe walking/cycling in a 20-mph speed limit zone? If so, why? If not, why? • Do you think there should be certain areas for implementation? • Do you think they should be implemented 24 hours per day, 7 days per week? • Would you or do you feel safer driving on a 20-mph limit road? If so, why? • Regarding other members of your family (e.g. adolescents, older adults, those with a disability), do you feel they are safe driving in a 20-mph speed limit zone? If so, why? If not, why?	
Enforcement	Do you have any opinions regarding enforcement of the 20-mph scheme?	Fines, penalty points, speed cameras, policing, traffic wardens, etc.
	Or how you feel it should be enforced? Who do you feel is/are responsible for this enforcement?	
	Do you believe the enforcement activity has been sufficient?	
Behaviour change	Has the introduction of the new 20-mph speed limit caused you to change your behaviour? If so, how? Why? (i.e. for daily travel to work, city centre, commonly travelled routes, etc. Other reasons for change?)	Car use, walking, cycling, commuting, motorcycling (i.e. mode change?)
		Driving efficiency/behaviour/consciously reducing speed in 20-mph areas?
	Driving behaviour?	Have you noticed speeds drop in 20-mph areas since introduced? (Others copy lower speeds?)
	Do you believe that the 20-mph speed limit has changed anything in practice?/Are you seeing evidence of people changing their behaviour? (i.e. driving behaviour, modal shift?)	Avoiding driving through certain streets/areas to avoid 20 mph?
	Problem with speeding before?	
	How do you travel to/out of Belfast/Edinburgh?	Walk, cycle, drive, taxi, bus, run, motorcycle, etc.
	How do you travel within Belfast/Edinburgh?	Have you always travelled this way?
		If not how did you travel before?
	Why did your behaviour change?	Traffic, 20 mph, congestion, petrol prices, health, car-sharing, bicycle scheme – explore reasons
	Is this 20-mph scheme where you live, work, travel to or travel through?	Explore which aspect of their life the limit may have changed
	If no, why do you feel your behaviour has not changed or the scheme has not impacted you?	
	Has the 20-mph speed limit changed anyone's behaviour that you know and in what way?	Car use, walking, cycling, commuting, driving efficiency/behaviour
	Has the scheme impacted you in any way? If so, how?	Positively, negatively? Encourage participants to provide examples
	What behaviours do you think 20-mph limits have the potential to change/impact? And how/why?	Car use, walking, cycling, commuting, driving efficiency/behaviour
	Do you think it has impacted any of these?	

Theme	Question	Points for further investigations by the facilitator
Other	Do you think there are any negative aspects of 20-mph limits?	Congestion, pollution, noise, inconvenience, decrease fuel efficiency
Liveability	Regarding liveability (e.g. elements of environmental quality), do you think the 20-mph scheme will have implications such as creating more pleasant environments/improved environmental quality? Prompt components: • noise • aesthetics • making a more pleasant environment • ability to socialise • protect the environment • services – use of, access to, provision of • pollution/air quality • well-being • safety • public transport	

CEC, City of Edinburgh Council.

Appendix 7 Speed Limits Perceptions Survey

Speed Limits Perception Survey (SLIPS)

Adapt the survey to the specific study, location and intervention, items for adaptation enclosed in <>.

Speed Limits Perception Survey (SLIPS)

Study Information

<Insert study information, e.g. *This short survey is investigating Edinburgh residents, living, working or travelling in **Zone 6** (see map), and their perceptions of the new 20mph speed limits being implemented throughout the city. It is independent research led by the University of Edinburgh and funded by the National Institute of Health Research.>*

The survey consists of **17 questions** and should take around **10 minutes** to complete.

The survey will not be assessed or marked, so please be as honest as you can.

Please complete all questions on your own as best you can, but ask the researchers if there is anything you do not understand. You can decide to stop taking the survey at any time.

All responses will be treated confidentially and all reporting will be anonymous.

We hope to use the results to better understand how the <20mph> speed limit influences driver perceptions and behaviors. We will report the findings in scientific journals, at conferences, and on social media. We may also produce short reports to <The City of Edinburgh Council>.

Participant consent

For ethical reasons, we need to ask for your consent before you complete the survey.

By ticking this box, you agree to take the survey and give your consent for your anonymous responses to be used in the study.

☐ **I understand what I am being asked to do and agree to take part**

---

1. What is the postcode of the area of <Edinburgh> you LIVE in? ☐☐☐☐☐☐☐

Area/suburb _____

2. What is the postcode of the area of <Edinburgh> you WORK in? ☐☐☐☐☐☐☐

Area/suburb _____

Tick here if you are not working ☐

3. Which of the following statements applies to the street or road you live on / work on / drive through?

☐	The street/road where I live/work has <20mph> limits on all or some of it
☐	The street/road where I live/work does not have any <20mph> limits
☐	I do not drive through roads with <20mph> speed limits
☐	I am not sure/don't know

4. Are you aware of any (more) plans for <20mph> limits in the area where you live?

☐	Yes
☐	No
☐	I am not sure/don't know

5. How strongly do you agree or disagree with the following statements?

Please remember there are no right or wrong answers

Please place a tick in the appropriate columns	Strongly agree	Tend to agree	Neither agree nor disagree	Tend to disagree	Strongly disagree
<20mph> speed limits <will make/have made> people drive slower					
I understand why <Edinburgh City Council> introduced <20mph> speed limits					
<20mph> speed limits are a bad idea					
We only need <20mph> limits where safety is an issue (e.g. schools, dangerous junctions)					
We do not need <20mph> limits at night when roads are quieter					
<20mph> speed limits will take time to get used to, but eventually <20mph> will be accepted as the normal speed					

6. How much do you agree or disagree with the following statements?
'<20mph> SPEED LIMITS <WILL/HAVE> LED TO…...'

Please place a tick in the appropriate columns	Strongly agree	Tend to agree	Neither agree nor disagree	Tend to disagree	Strongly disagree
An increase in people cycling					
A decrease in the number of *severe* collisions					
An increase in people walking on the streets					
Better traffic flow (less stopping and starting)					
Decreases in the number of collisions					
More congestion					
More air pollution					
Longer journey times					
Less noise from vehicles					
Decrease in fuel efficiency					
An increase in how pleasant the area is to live or work in					
Safer streets					
More opportunities to socialise					

7. How often do you use the following transport to travel around <Edinburgh>?

Please place a tick in the appropriate columns	Every day	Several times a week	About once a week	About once a fortnight	About once a month	Less than once a month	Never
Bus, train or tram							
Motorcycle/ scooter/ moped							
Car or van							
Taxi/Uber							
Bicycle							
Walking or running							

8a. Which of the following apply to you in terms of CYCLING in Edinburgh? Tick all that apply.

- ☐ I don't cycle and never will
- ☐ I feel safe cycling on roads with a speed limit of 20mph
- ☐ I feel safe cycling on roads with a speed limit of 30mph
- ☐ I would cycle more if there were more roads with <20mph> speed limits
- ☐ I feel unsafe cycling in <Edinburgh>
- ☐ Other road safety policies (e.g. cycle lanes) would make me cycle more

8b. If other road safety policies would make you cycle more, please indicate which ones below:

_____

9. Which of the following apply to you in terms of WALKING in Edinburgh? Tick all that apply.

- ☐ I don't walk around <Edinburgh> and never will
- ☐ I feel safe crossing roads with a speed limit of 20mph
- ☐ I feel safe crossing roads with a speed limit of 30mph
- ☐ I feel safe walking near roads with a speed limit of 20mph
- ☐ I feel safe walking near roads with a speed limit of 30mph
- ☐ I would walk more if there were more roads with <20mph> speed limits
- ☐ I feel unsafe walking in <Edinburgh>

10. Which of the following apply to you in terms of CHILDREN in Edinburgh? Tick all that apply.

- ☐ I don't have children
- ☐ I feel children are safe near roads with a speed limit of 20mph
- ☐ I feel children are safe near roads with a speed limit of 30mph
- ☐ I feel children are safe crossing roads with a speed limit of 20mph
- ☐ I feel children are safe crossing roads with a speed limit of 30mph
- ☐ I would let children walk more if there were more roads with <20mph> speed limits
- ☐ I feel children are unsafe walking in Edinburgh due to the traffic and speed

11. Which of the following best describes your driving status and experience?

- ☐ I hold a <UK> driving license *Please state years held:* _____
- ☐ I hold a non-<UK> driving license and I drive in the UK *Please state years held:* _____
- ☐ I am a learner driver
- ☐ I have a provisional license
- ☐ I do not hold any driving license (**PLEASE GO TO Q13**)

12. How strongly do you agree or disagree with the following statements?
There are no right or wrong answers

Please place a tick in the appropriate columns	Strongly agree	Tend to agree	Neither agree nor disagree	Tend to Disagree	Strongly disagree
I use my own judgment, not speed limits, to decide on my speed on the road					
I am careful to drive at <20mph> wherever limits are					
If I think a road with <20mph> limit has no traffic I may drive faster than <20mph>					
It is just too difficult to stay at <20mph>					
I will ignore the <20mph> limits if I think I will not get caught by the police					
I get frustrated when I have to reduce my speed because someone in front of me is driving at <20mph>					
I feel pressured when I drive at <20mph> in a <20mph> zone when the driver behind me seems annoyed					
There is a high rate of road collisions caused by speeding in Edinburgh					
I tend to drive at the speed of other people on the road					
People will ignore <20mph> limits because they don't see themselves getting caught by the police					
Slowly but surely <20mph> limits are making me drive slower					
I think <20mph> speed limits will make my journeys longer					
As long as I understand the reasons for the <20mph> speed limit I will drive within the limit					

13. What is your year of birth? __ __ __ __

14. What is your gender? Male / Female / Other / Prefer not to say

15. Do you find it difficult to get around because of a permanent disability or a medical condition? Yes / No

If yes, feel free to tell us more _____

16. Which of the following below best describes your ethnic group?
Please place a tick next to the appropriate category.

Ethnic group	Selection
White	
Mixed/Multiple ethnic groups	
Asian/Asian Scottish/Asian British	
African	
Caribbean or Black	
Other ethnic group (please specify)	

17. Please write down any comments you may have on the <20mph> zones/limits:

_____

_____

<FINALLY
We would like to contact you in the future to invite you to take part in a short group discussion exploring your views on the <20mph> scheme. You do not have to take part in this group if you do not wish. If you are happy to be contacted to be given more information, please tick the box below and provide us with your name and address. You can decide not to take part at any time.
I am interested in finding out more about the short group discussions, and agree to be contacted in the future ☐

Name: _____
Telephone Number: _____
And/or Email Address: _____

If you wish to find out more about the study, please take one of our postcards.>

THANK YOU FOR TAKING PART IN THIS SURVEY!

Appendix 8 Perception survey data collection dates and location type

Zone and time point	Date	Location(s) type
Implementation zones 4 and 5 (16 August 2017)		
Baseline	10 August 2017 (Thursday)	Shopping centre
	11 August 2017 (Friday)	Shopping centre
	12 August 2017 (Saturday)	Shopping centre
	13 August 2017 (Sunday)	Shopping centre
6 months	9 February 2018 (Friday)	Shopping centre
	10 February 2018 (Saturday)	Shopping centres (× 2)
	23 February 2018 (Saturday)	Shopping centre
12 months	9 August 2018 (Thursday)	Shopping centres (× 2)
	11 August 2018 (Saturday)	Shopping centres (× 2)
Implementation zone 6 (5 March 2018)		
Baseline	9 February 2018 (Friday)	Shopping centre and sports centre
	10 February 2018 (Saturday)	Shopping centre and sports centre
6 months	9 August 2018 (Thursday)	Shopping centre and sports centre
	11 August 2018 (Saturday)	Shopping centre
	30 August 2018 (Thursday)	Hospital
	1 September 2018 (Saturday)	Hospital
	6 September 2018 (Thursday)	Hospital
12 months	15 January 2019 (Tuesday)	Hospital
	17 January 2019 (Thursday)	Hospital
	19 January 2019 (Saturday)	Hospital
	22 January 2019 (Tuesday)	Hospital
	24 January 2019 (Thursday)	Hospital

Appendix 9 Participant perceptions at each time point and changes

Survey question	Survey responses	Baseline (A), % (*n*)	6 months (B), % (*n*)	1 year (C), % (*n*)	6-month change (B – A)	1-year change (C – A)
General attitudes to the road						
I use my own judgement, not speed limits, to decide on my speed on the road	Strongly agree	14.34 (146)	13.52 (81)	8.96 (57)	−0.82	−5.38
	Tend to agree	18.66 (190)	20.37 (122)	21.23 (135)	1.71	2.57
	Neither agree nor disagree	15.82 (161)	11.85 (71)	11.48 (73)	−3.97	−4.34
	Tend to disagree	26.03 (265)	25.88 (155)	26.57 (169)	−0.15	0.54
	Strongly disagree	25.15 (256)	28.38 (170)	31.76 (202)	3.23	6.61
I tend to drive at the speed of other people on the road	Strongly agree	6.39 (65)	8.51 (51)	6.45 (41)	2.12	0.06
	Tend to agree	35.66 (363)	34.56 (207)	34.91 (222)	−1.10	−0.75
	Neither agree nor disagree	19.35 (197)	18.36 (110)	21.07 (134)	−0.99	1.72
	Tend to disagree	25.44 (259)	23.37 (140)	26.1 (166)	−2.07	0.66
	Strongly disagree	13.16 (134)	15.19 (91)	11.48 (73)	2.03	−1.68
There is a high rate of road collisions caused by speeding in Edinburgh	Strongly agree	7.66 (78)	6.68 (40)	8.02 (51)	−0.98	0.36
	Tend to agree	14.44 (147)	13.36 (80)	15.57 (99)	−1.08	1.13
	Neither agree nor disagree	43.91 (447)	48.91 (293)	50.16 (319)	5.00	6.25
	Tend to disagree	23.18 (236)	21.7 (130)	19.03 (121)	−1.48	−4.15
	Strongly disagree	10.81 (110)	9.35 (56)	7.23 (46)	−1.46	−3.58
I feel safe walking near roads with a speed limit of . . .	Always unsafe	2.16 (22)	2.17 (13)	2.52 (16)	0.01	0.36
	< 20 mph	24.95 (254)	22.54 (135)	18.71 (119)	−2.41	−6.24
	20 mph	7.66 (78)	10.52 (63)	12.58 (80)	2.86	4.92
	30 mph	65.23 (664)	64.77 (388)	66.19 (421)	−0.46	0.96
I feel safe crossing roads with a speed limit of . . .	< 20 mph	15.91 (162)	15.53 (93)	14.15 (90)	−0.38	−1.76
	20 mph	12.38 (126)	14.86 (89)	15.41 (98)	2.48	3.03
	30 mph	71.71 (730)	69.62 (417)	70.44 (448)	−2.09	−1.27
I feel safe cycling on roads with a speed limit of . . .	Always unsafe	23.08 (235)	18.53 (111)	19.97 (127)	−4.55	−3.11
	< 20 mph	54.42 (554)	57.43 (344)	55.66 (354)	3.01	1.24
	20 mph	6.78 (69)	7.68 (46)	10.69 (68)	0.90	3.91
	30 mph	15.72 (160)	16.36 (98)	13.68 (87)	0.64	−2.04
I feel children are safe near roads with a speed limit of . . .	Always unsafe	3.63 (37)	5.01 (30)	7.86 (50)	1.38	4.23
	< 20 mph	57.07 (581)	47.25 (283)	45.28 (288)	−9.82	−11.79
	20 mph	15.82 (161)	23.71 (142)	25 (159)	7.89	9.18
	30 mph	23.48 (239)	24.04 (144)	21.86 (139)	0.56	−1.62

Survey question	Survey responses	Baseline (A), % (*n*)	6 months (B), % (*n*)	1 year (C), % (*n*)	6-month change (B – A)	1-year change (C – A)
I feel children are safe crossing roads with a speed limit of . . .	< 20 mph	66.31 (675)	61.27 (367)	61.95 (394)	−5.04	−4.36
	20 mph	11.39 (116)	17.53 (105)	18.87 (120)	6.14	7.48
	30 mph	22.3 (227)	21.2 (127)	19.18 (122)	−1.10	−3.12
Attitudes to 20-mph limits						
I am careful to drive at 20 mph wherever limits are	Strongly agree	25.64 (261)	31.55 (189)	28.77 (183)	5.91	3.13
	Tend to agree	34.77 (354)	33.72 (202)	38.21 (243)	−1.05	3.44
	Neither agree nor disagree	15.23 (155)	10.52 (63)	12.89 (82)	−4.71	−2.34
	Tend to disagree	18.86 (192)	16.53 (99)	15.88 (101)	−2.33	−2.98
	Strongly disagree	5.5 (56)	7.68 (46)	4.25 (27)	2.18	−1.25
I understand why City of Edinburgh Council introduced 20-mph speed limits	Strongly agree	20.83 (212)	28.71 (172)	27.83 (177)	7.88	7.00
	Tend to agree	31.14 (317)	32.55 (195)	38.52 (245)	1.41	7.38
	Neither agree nor disagree	11.59 (118)	9.52 (57)	10.22 (65)	−2.07	−1.37
	Tend to disagree	16.7 (170)	13.69 (82)	13.68 (87)	−3.01	−3.02
	Strongly disagree	19.74 (201)	15.53 (93)	9.75 (62)	−4.21	−9.99
As long as I understand the reasons for the 20-mph speed limit, I will drive within the limit	Strongly agree	22.79 (232)	26.54 (159)	21.38 (136)	3.75	−1.41
	Tend to agree	29.76 (303)	31.05 (186)	31.13 (198)	1.29	1.37
	Neither agree nor disagree	28.49 (290)	23.21 (139)	30.35 (193)	−5.28	1.86
	Tend to disagree	11.79 (120)	11.85 (71)	10.38 (66)	0.06	−1.41
	Strongly disagree	7.17 (73)	7.35 (44)	6.76 (43)	0.18	−0.41
20-mph speed limits will take time to get used to, but eventually 20 mph will be accepted as the normal speed	Strongly agree	10.12 (103)	12.02 (72)	11.95 (76)	1.90	1.83
	Tend to agree	23.58 (240)	28.05 (168)	28.30 (180)	4.47	4.72
	Neither agree nor disagree	12.97 (132)	12.19 (73)	14.47 (92)	−0.78	1.50
	Tend to disagree	28.98 (295)	25.71 (154)	27.36 (174)	−3.27	−1.62
	Strongly disagree	24.36 (248)	22.04 (132)	17.92 (114)	−2.32	−6.44
I think 20-mph speed limits will make my journeys longer	Strongly agree	45.48 (463)	37.56 (225)	35.06 (223)	−7.92	−10.42
	Tend to agree	28.88 (294)	32.55 (195)	30.66 (195)	3.67	1.78
	Neither agree nor disagree	12.08 (123)	14.02 (84)	16.35 (104)	1.94	4.27
	Tend to disagree	10.22 (104)	11.35 (68)	12.89 (82)	1.13	2.67
	Strongly disagree	3.34 (34)	4.51 (27)	5.03 (32)	1.17	1.69
It is just too difficult to stay at 20 mph	Strongly agree	30.45 (310)	25.71 (154)	24.06 (153)	−4.74	−6.39
	Tend to agree	34.18 (348)	32.05 (192)	33.81 (215)	−2.13	−0.37
	Neither agree nor disagree	15.03 (153)	15.36 (92)	14.62 (93)	0.33	−0.41
	Tend to disagree	11.2 (114)	14.36 (86)	14.94 (95)	3.16	3.74
	Strongly disagree	9.14 (93)	12.52 (75)	12.58 (80)	3.38	3.44

Survey question	Survey responses	Baseline (A), % (*n*)	6 months (B), % (*n*)	1 year (C), % (*n*)	6-month change (B – A)	1-year change (C – A)
20-mph speed limits are a bad idea	Strongly agree	27.5 (280)	23.04 (138)	18.4 (117)	−4.46	−9.10
	Tend to agree	16.4 (167)	14.19 (85)	15.88 (101)	−2.21	−0.52
	Neither agree nor disagree	15.91 (162)	15.36 (92)	18.71 (119)	−0.55	2.80
	Tend to disagree	20.24 (206)	23.54 (141)	20.91 (133)	3.30	0.67
	Strongly disagree	19.94 (203)	23.87 (143)	26.1 (166)	3.93	6.16
We do not need 20-mph limits at night when roads are quieter[a]	Strongly agree	33.33 (106)	39.23 (235)	31.13 (198)	5.90	−2.20
	Tend to agree	21.07 (67)	19.03 (114)	23.74 (151)	−2.04	2.67
	Neither agree nor disagree	11.32 (36)	10.68 (64)	13.05 (83)	−0.64	1.73
	Tend to disagree	18.87 (60)	15.86 (95)	17.3 (110)	−3.01	−1.57
	Strongly disagree	15.41 (49)	15.19 (91)	14.78 (94)	−0.22	−0.63
We need 20-mph limits only where safety is an issue (e.g. schools, dangerous junctions)[a]	Strongly agree	43.4 (138)	46.41 (278)	44.03 (280)	3.01	0.63
	Tend to agree	23.58 (75)	22.37 (134)	23.58 (150)	−1.21	0.00
	Neither agree nor disagree	8.49 (27)	7.35 (44)	5.19 (33)	−1.14	−3.30
	Tend to disagree	15.09 (48)	12.35 (74)	15.57 (99)	−2.74	0.48
	Strongly disagree	9.43 (30)	11.52 (69)	11.64 (74)	2.09	2.21
People will ignore 20-mph limits because they do not see themselves getting caught by the police	Strongly agree	28.98 (295)	25.04 (150)	28.46 (181)	−3.94	−0.52
	Tend to agree	44.3 (451)	47.58 (285)	44.81 (285)	3.28	0.51
	Neither agree nor disagree	15.42 (157)	17.03 (102)	16.19 (103)	1.61	0.77
	Tend to disagree	8.74 (89)	6.68 (40)	7.86 (50)	−2.06	−0.88
	Strongly disagree	2.55 (26)	3.67 (22)	2.67 (17)	1.12	0.12
I will ignore the 20-mph limits if I think I will not get caught by the police	Strongly agree	8.84 (90)	9.68 (58)	7.23 (46)	0.84	−1.61
	Tend to agree	17.68 (180)	15.19 (91)	15.72 (100)	−2.49	−1.96
	Neither agree nor disagree	18.07 (184)	16.36 (98)	16.35 (104)	−1.71	−1.72
	Tend to disagree	22.69 (231)	24.54 (147)	25 (159)	1.85	2.31
	Strongly disagree	32.71 (333)	34.22 (205)	35.69 (227)	1.51	2.98
If I think a road with a 20-mph limit has no traffic, I may drive faster than 20 mph	Strongly agree	14.34 (146)	15.69 (94)	13.84 (88)	1.35	−0.50
	Tend to agree	37.82 (385)	34.72 (208)	33.65 (214)	−3.10	−4.17
	Neither agree nor disagree	12.67 (129)	11.52 (69)	15.25 (97)	−1.15	2.58
	Tend to disagree	19.55 (199)	17.03 (102)	19.97 (127)	−2.52	0.42
	Strongly disagree	15.62 (159)	21.04 (126)	17.3 (110)	5.42	1.68
I get frustrated when I have to reduce my speed because someone in front of me is driving at 20 mph	Strongly agree	15.03 (153)	16.03 (96)	14.15 (90)	1.00	−0.88
	Tend to agree	22.69 (231)	19.37 (116)	18.24 (116)	−3.32	−4.45
	Neither agree nor disagree	16.6 (169)	15.36 (92)	17.77 (113)	−1.24	1.17
	Tend to disagree	21.12 (215)	23.21 (139)	22.64 (144)	2.09	1.52
	Strongly disagree	24.56 (250)	26.04 (156)	27.2 (173)	1.48	2.64

Survey question	Survey responses	Baseline (A), % (*n*)	6 months (B), % (*n*)	1 year (C), % (*n*)	6-month change (B – A)	1-year change (C – A)
I feel pressured when I drive at 20 mph in a 20-mph zone when the driver behind me seems annoyed	Strongly agree	32.81 (334)	29.55 (177)	31.6 (201)	−3.26	−1.21
	Tend to agree	32.12 (327)	28.55 (171)	33.02 (210)	−3.57	0.90
	Neither agree nor disagree	12.18 (124)	15.03 (90)	10.85 (69)	2.85	−1.33
	Tend to disagree	11 (112)	11.85 (71)	11.48 (73)	0.85	0.48
	Strongly disagree	11.89 (121)	15.03 (90)	13.05 (83)	3.14	1.16
I would walk more if there were more roads with 20-mph speed limits	No	93.71 (954)	92.65 (555)	91.67 (583)	−1.06	−2.04
	Yes	6.29 (64)	7.35 (44)	8.33 (53)	1.06	2.04
I would cycle more if there were more roads with 20-mph speed limits	No	92.73 (944)	92.99 (557)	91.67 (583)	0.26	−1.06
	Yes	7.27 (74)	7.01 (42)	8.33 (53)	−0.26	1.06
Perceived impacts of 20-mph limits						
20-mph speed limits will make/ have made people drive slower	Strongly agree	13.26 (135)	16.53 (99)	12.11 (77)	3.27	−1.15
	Tend to agree	33.01 (336)	36.23 (217)	42.3 (269)	3.22	9.29
	Neither agree nor disagree	9.92 (101)	12.35 (74)	10.53 (67)	2.43	0.61
	Tend to disagree	26.82 (273)	21.87 (131)	22.8 (145)	−4.95	−4.02
	Strongly disagree	16.99 (173)	13.02 (78)	12.26 (78)	−3.97	−4.73
Slowly but surely, 20-mph limits are making me drive slower	Strongly agree	8.45 (86)	10.35 (62)	9.59 (61)	1.90	1.14
	Tend to agree	27.6 (281)	30.22 (181)	31.76 (202)	2.62	4.16
	Neither agree nor disagree	28.88 (294)	23.54 (141)	28.77 (183)	−5.34	−0.11
	Tend to disagree	22.3 (227)	22.37 (134)	19.34 (123)	0.07	−2.96
	Strongly disagree	12.77 (130)	13.52 (81)	10.53 (67)	0.75	−2.24
20-mph speed limits will lead/have led to longer journey times	Strongly agree	47.35 (482)	40.23 (241)	35.85 (228)	−7.12	−11.50
	Tend to agree	31.63 (322)	32.55 (195)	34.59 (220)	0.92	2.96
	Neither agree nor disagree	9.43 (96)	13.52 (81)	14.15 (90)	4.09	4.72
	Tend to disagree	7.27 (74)	9.68 (58)	11.32 (72)	2.41	4.05
	Strongly disagree	4.32 (44)	4.01 (24)	4.09 (26)	−0.31	−0.23
20-mph speed limits will lead/have led to better traffic flow (less stopping and starting)	Strongly agree	4.91 (50)	3.51 (21)	3.14 (20)	−1.40	−1.77
	Tend to agree	11 (112)	9.02 (54)	13.52 (86)	−1.98	2.52
	Neither agree nor disagree	12.57 (128)	21.2 (127)	19.03 (121)	8.63	6.46
	Tend to disagree	29.27 (298)	29.55 (177)	32.55 (207)	0.28	3.28
	Strongly disagree	42.24 (430)	36.73 (220)	31.76 (202)	−5.51	−10.48
20-mph speed limits will lead/have led to more congestion	Strongly agree	35.27 (359)	30.38 (182)	25.63 (163)	−4.89	−9.64
	Tend to agree	28.88 (294)	26.21 (157)	29.25 (186)	−2.67	0.37
	Neither agree nor disagree	17.49 (178)	24.21 (145)	23.58 (150)	6.72	6.09
	Tend to disagree	11.69 (119)	13.19 (79)	16.67 (106)	1.50	4.98
	Strongly disagree	6.68 (68)	6.01 (36)	4.87 (31)	−0.67	−1.81

Survey question	Survey responses	Baseline (A), % (*n*)	6 months (B), % (*n*)	1 year (C), % (*n*)	6-month change (B – A)	1-year change (C – A)
20-mph speed limits will lead/have led to more air pollution	Strongly agree	38.41 (391)	31.55 (189)	22.48 (143)	−6.86	−15.93
	Tend to agree	25.25 (257)	22.37 (134)	25.79 (164)	−2.88	0.54
	Neither agree nor disagree	18.66 (190)	31.22 (187)	31.13 (198)	12.56	12.47
	Tend to disagree	11.39 (116)	9.02 (54)	15.25 (97)	−2.37	3.86
	Strongly disagree	6.29 (64)	5.84 (35)	5.35 (34)	−0.45	−0.94
20-mph speed limits will lead /have led to less noise from vehicles[a]	Strongly agree	6.29 (20)	3.51 (21)	4.56 (29)	−2.78	−1.73
	Tend to agree	23.27 (74)	12.69 (76)	17.3 (110)	−10.58	−5.97
	Neither agree nor disagree	31.76 (101)	39.9 (239)	38.84 (247)	8.14	7.08
	Tend to disagree	23.9 (76)	25.04 (150)	26.42 (168)	1.14	2.52
	Strongly disagree	14.78 (47)	18.86 (113)	12.89 (82)	4.08	−1.89
20-mph speed limits will lead/have led to decrease in fuel efficiency	Strongly agree	31.93 (325)	26.21 (157)	20.75 (132)	−5.72	−11.18
	Tend to agree	21.91 (223)	19.03 (114)	20.75 (132)	−2.88	−1.16
	Neither agree nor disagree	26.42 (269)	36.23 (217)	36.64 (233)	9.81	10.22
	Tend to disagree	11 (112)	10.18 (61)	13.05 (83)	−0.82	2.05
	Strongly disagree	8.74 (89)	8.35 (50)	8.81 (56)	−0.39	0.07
20-mph speed limits will lead/have led to decreases in the number of collisions	Strongly agree	9.04 (92)	5.34 (32)	3.77 (24)	−3.70	−5.27
	Tend to agree	25.83 (263)	19.2 (115)	20.28 (129)	−6.63	−5.55
	Neither agree nor disagree	18.86 (192)	41.24 (247)	46.54 (296)	22.38	27.68
	Tend to disagree	27.31 (278)	19.87 (119)	20.28 (129)	−7.44	−7.03
	Strongly disagree	18.96 (193)	14.36 (86)	9.12 (58)	−4.60	−9.84
20-mph speed limits will lead/have led to a decrease in the number of severe collisions	Strongly agree	13.95 (142)	7.85 (47)	6.29 (40)	−6.10	−7.66
	Tend to agree	33.3 (339)	21.87 (131)	25.31 (161)	−11.43	−7.99
	Neither agree nor disagree	16.9 (172)	40.4 (242)	42.77 (272)	23.50	25.87
	Tend to disagree	23.77 (242)	17.36 (104)	16.98 (108)	−6.41	−6.79
	Strongly disagree	12.08 (123)	12.52 (75)	8.65 (55)	0.44	−3.43
20-mph speed limits will lead/have led to safer streets[a]	Strongly agree	20.13 (64)	13.36 (80)	14.47 (92)	−6.77	−5.66
	Tend to agree	32.08 (102)	26.88 (161)	29.87 (190)	−5.20	−2.21
	Neither agree nor disagree	20.75 (66)	26.71 (160)	26.89 (171)	5.96	6.14
	Tend to disagree	18.87 (60)	19.03 (114)	19.65 (125)	0.16	0.78
	Strongly disagree	8.18 (26)	14.02 (84)	9.12 (58)	5.84	0.94
20-mph speed limits will lead/have led to an increase in how pleasant the area is to live or work in[a]	Strongly agree	15.72 (50)	8.35 (50)	10.38 (66)	−7.37	−5.34
	Tend to agree	16.98 (54)	17.03 (102)	17.45 (111)	0.05	0.47
	Neither agree nor disagree	39.31 (125)	39.73 (238)	36.64 (233)	0.42	−2.67
	Tend to disagree	17.61 (56)	16.53 (99)	21.23 (135)	−1.08	3.62
	Strongly disagree	10.38 (33)	18.36 (110)	14.31 (91)	7.98	3.93

Survey question	Survey responses	Baseline (A), % (*n*)	6 months (B), % (*n*)	1 year (C), % (*n*)	6-month change (B – A)	1-year change (C – A)
20-mph speed limits will lead/have led to more opportunities to socialise[a]	Strongly agree	3.46 (11)	2.67 (16)	2.99 (19)	–0.79	–0.47
	Tend to agree	5.03 (16)	4.01 (24)	3.3 (21)	–1.02	–1.73
	Neither agree nor disagree	34.59 (110)	38.73 (232)	38.68 (246)	4.14	4.09
	Tend to disagree	27.36 (87)	21.54 (129)	21.7 (138)	–5.82	–5.66
	Strongly disagree	29.56 (94)	33.06 (198)	33.33 (212)	3.50	3.77
20-mph speed limits will lead/have led to an increase in people walking on the streets	Strongly agree	5.99 (61)	4.01 (24)	2.83 (18)	–1.98	–3.16
	Tend to agree	14.73 (150)	11.19 (67)	11.01 (70)	–3.54	–3.72
	Neither agree nor disagree	26.62 (271)	41.24 (247)	42.92 (273)	14.62	16.30
	Tend to disagree	34.28 (349)	26.04 (156)	29.87 (190)	–8.24	–4.41
	Strongly disagree	18.37 (187)	17.53 (105)	13.36 (85)	–0.84	–5.01
20-mph speed limits will lead/have led to an increase in people cycling	Strongly agree	6.68 (68)	5.51 (33)	5.03 (32)	–1.17	–1.65
	Tend to agree	14.54 (148)	12.52 (75)	13.68 (87)	–2.02	–0.86
	Neither agree nor disagree	30.65 (312)	47.41 (284)	44.65 (284)	16.76	14.00
	Tend to disagree	28.09 (286)	21.54 (129)	24.69 (157)	–6.55	–3.40
	Strongly disagree	20.04 (204)	13.02 (78)	11.95 (76)	–7.02	–8.09

a These questions were not asked until after baseline data had been collected in zones 5 and 6, so there are 700 fewer observations at baseline.

Note
Variables in bold vary statistically significantly across time points.

Appendix 10 Polychoric correlation matrix

APPENDIX 10

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
General attitudes to the road														
A. I use my own judgement, not speed limits, to decide on my speed on the road	1													
B. I tend to drive at the speed of other people on the road	0.390	1												
C. There is a high rate of road collisions caused by speeding in Edinburgh	−0.119	−0.138	1											
D. I feel safe walking near roads with a speed limit of …	0.025	−0.087	0.206	1										
E. I feel safe crossing roads with a speed limit of …	−0.076	−0.094	0.213	0.671	1									
F. I feel safe cycling on roads with a speed limit of …	−0.035	−0.078	0.107	0.014	0.147	1								
G. I feel children are safe near roads with a speed limit of …	−0.033	−0.022	0.206	0.243	0.213	0.140	1							
H. I feel children are safe crossing roads with a speed limit of …	−0.014	−0.021	0.252	0.362	0.207	0.076	0.872	1						
Attitudes to 20-mph limits														
I. I am careful to drive at 20 mph wherever limits are	−0.286	−0.435	0.359	0.049	0.122	0.059	0.112	0.144	1					
J. I understand why City of Edinburgh Council introduced 20-mph speed limits	−0.228	−0.207	0.442	0.066	0.100	−0.038	0.069	0.111	0.373	1				
K. As long as I understand the reasons for the 20-mph speed limit I will drive within the limit	−0.196	−0.259	0.417	0.067	0.103	0.044	0.091	0.089	0.530	0.408	1			
L. 20-mph speed limits will take time to get used to, but eventually 20 mph will be accepted as the normal speed	−0.221	−0.183	0.465	0.081	0.147	−0.007	0.055	0.091	0.407	0.605	0.484	1		
M. I think 20-mph speed limits will make my journeys longer	0.187	0.173	−0.325	−0.082	−0.100	0.047	−0.134	−0.112	−0.255	−0.482	−0.297	−0.451	1	
N. It is just too difficult to stay at 20 mph	0.283	0.322	−0.352	−0.056	−0.126	0.012	−0.101	−0.089	−0.382	−0.514	−0.386	−0.495	0.547	1
O. 20-mph speed limits are a bad idea	0.196	0.189	−0.335	−0.011	−0.094	−0.004	−0.056	−0.085	−0.313	−0.533	−0.359	−0.519	0.489	0.497
P. People will ignore 20-mph limits because they do not see themselves getting caught by the police	−0.011	0.050	0.150	0.029	−0.045	0.051	0.069	0.090	0.019	−0.004	0.048	−0.031	0.092	0.127
Q. I will ignore the 20-mph limits if I think I will not get caught by the police	0.415	0.485	−0.279	−0.055	−0.146	−0.083	−0.060	−0.034	−0.587	−0.313	−0.423	−0.358	0.306	0.510
R. If I think a road with 20-mph limit has no traffic, I may drive faster than 20 mph	0.377	0.478	−0.292	−0.074	−0.135	−0.051	−0.070	−0.046	−0.525	−0.280	−0.358	−0.329	0.285	0.532
S. I get frustrated when I have to reduce my speed because someone in front of me is driving at 20 mph	0.387	0.443	−0.365	−0.045	−0.095	−0.033	−0.055	−0.062	−0.527	−0.417	−0.465	−0.436	0.457	0.616
T. I feel pressured when I drive at 20 mph in a 20 mph zone when the driver behind me seems annoyed	0.035	0.138	−0.148	−0.125	−0.112	0.088	−0.042	−0.022	−0.089	−0.215	−0.144	−0.221	0.308	0.411
U. I would walk more if there were more roads with 20-mph speed limits	0.141	0.145	−0.464	−0.176	−0.302	0.073	0.002	−0.061	−0.334	−0.397	−0.315	−0.489	0.363	0.307
V. I would cycle more if there were more roads with 20-mph speed limits	0.096	0.089	−0.257	0.029	−0.098	0.311	−0.006	−0.100	−0.273	−0.556	−0.224	−0.488	0.383	0.458

O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG
1																		
0.029	1																	
0.315	0.152	1																
0.247	0.045	0.695	1															
0.417	0.060	0.661	0.598	1														
0.192	0.202	0.149	0.164	0.344	1													
0.445	–0.018	0.181	0.237	0.315	0.242	1												
0.517	0.057	0.236	0.204	0.312	0.178	0.590	1											

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Perceived impacts of 20-mph limits														
W. 20-mph speed limits will/have made people drive slower	−0.146	−0.085	0.377	0.008	0.073	−0.069	−0.034	0.039	0.335	0.500	0.383	0.595	−0.328	−0.388
X. Slowly but surely 20-mph limits are making me drive slower	−0.204	−0.227	0.448	0.076	0.121	−0.002	0.024	0.075	0.452	0.406	0.572	0.599	−0.264	−0.319
Y. 20-mph speed limits will lead/have led to longer journey times	0.204	0.170	−0.269	−0.052	−0.064	0.053	−0.077	−0.115	−0.245	−0.428	−0.264	−0.442	0.686	0.458
Z. 20-mph speed limits will lead/have led to better traffic flow (less stopping and starting)	−0.135	−0.129	0.448	0.100	0.179	−0.101	0.114	0.161	0.295	0.610	0.395	0.611	−0.571	−0.533
AA. 20-mph speed limits will lead/have led to more congestion	0.172	0.104	−0.239	0.022	−0.030	0.076	−0.084	−0.079	−0.206	−0.417	−0.235	−0.419	0.581	0.396
BB. 20-mph speed limits will lead/have led to more air pollution	0.186	0.139	−0.226	−0.009	−0.054	0.095	−0.047	−0.066	−0.218	−0.413	−0.246	−0.423	0.536	0.431
CC. 20-mph speed limits will lead/have led to decrease in fuel efficiency	0.149	0.145	−0.286	−0.107	−0.125	0.013	−0.070	−0.080	−0.225	−0.296	−0.177	−0.313	0.373	0.321
DD. 20-mph speed limits will lead/have led to decreases in the number of collisions	−0.199	−0.135	0.474	0.072	0.130	−0.035	0.059	0.102	0.283	0.589	0.427	0.662	−0.449	−0.481
EE. 20-mph speed limits will lead/have led a decrease in the number of severe collisions	−0.167	−0.158	0.419	−0.005	0.077	−0.048	0.040	0.088	0.326	0.577	0.410	0.624	−0.428	−0.431
FF. 20-mph speed limits will lead/have led to a *n* increase in people walking on the streets	−0.021	−0.019	0.240	0.115	0.196	−0.068	0.056	0.115	0.120	0.290	0.250	0.393	−0.215	−0.257
GG. 20-mph speed limits will lead/have led to an increase in people cycling	−0.073	−0.081	0.331	0.023	0.132	−0.119	0.040	0.096	0.216	0.371	0.293	0.464	−0.313	−0.313

O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG
−0.367	−0.079	−0.266	−0.215	−0.312	−0.238	−0.409	−0.519	1										
−0.356	0.008	−0.360	−0.306	−0.413	−0.101	−0.374	−0.408	0.514	1									
0.543	0.045	0.237	0.235	0.363	0.254	0.323	0.362	−0.321	−0.275	1								
−0.542	−0.059	−0.275	−0.255	−0.391	−0.251	−0.476	−0.532	0.506	0.457	−0.551	1							
0.470	0.036	0.170	0.176	0.278	0.193	0.359	0.434	−0.375	−0.282	0.806	−0.563	1						
0.500	0.041	0.168	0.192	0.299	0.204	0.369	0.427	−0.341	−0.262	0.769	−0.499	0.792	1					
0.397	0.026	0.138	0.201	0.226	0.115	0.264	0.365	−0.146	−0.239	0.534	−0.325	0.459	0.558	1				
−0.495	−0.063	−0.286	−0.240	−0.393	−0.217	−0.486	−0.555	0.575	0.492	−0.430	0.732	−0.431	−0.418	−0.283	1			
−0.472	−0.050	−0.309	−0.240	−0.383	−0.216	−0.440	−0.595	0.565	0.483	−0.376	0.649	−0.378	−0.358	−0.226	0.767	1		
−0.247	0.011	−0.126	−0.125	−0.169	−0.162	−0.344	−0.295	0.327	0.291	−0.216	0.451	−0.187	−0.193	−0.042	0.379	0.432	1	
−0.313	−0.032	−0.160	−0.169	−0.225	−0.136	−0.403	−0.545	0.476	0.398	−0.323	0.507	−0.319	−0.294	−0.167	0.440	0.479	0.580	1

Appendix 11 Demographic characteristics of the study sample

Demographic characteristic	*n* (%)
Age category (years)	
< 21	51 (10.4)
21–30	145 (29.6)
31–40	77 (15.7)
41–50	48 (9.8)
51–60	42 (8.6)
≥ 60	58 (11.8)
Missing	69 (14.1)
Gender	
Male	206 (42.0)
Female	212 (43.3)
Other	2 (0.4)
Prefer not to say	3 (0.6)
Missing	67 (13.7)
Permanent disability or a medical condition	
Yes	22 (4.5)
No	381 (77.8)
Missing	87 (17.8)
Ethnicity	
White	402 (82.0)
Mixed/multiple ethnic groups	7 (1.4)
Asian/Asian British/Asian Irish	3 (0.6)
African	3 (0.6)
Other ethnic group	1 (0.2)
Missing	74 (15.1)

Appendix 12 Perception factors for 20-mph speed limit: characteristics and description

Survey question	Factor					Uniqueness
	1. Detraction and resistance	2. Support	3. Rule-following	4. Child safety	5. Walking safety	
General attitudes to the road						
I use my own judgement, not speed limits, to decide on my speed on the road			0.5103			0.7464
I tend to drive at the speed of other people on the road			0.6565			0.6238
There is a high rate of road collisions caused by speeding in Edinburgh	0.4907					0.5830
I feel safe walking near roads with a speed limit of …					0.7732	0.3638
I feel safe crossing roads with a speed limit of …					0.7733	0.3860
I feel safe cycling on roads with a speed limit of …						0.9143
I feel children are safe near roads with a speed limit of …				0.9007		0.1839
I feel children are safe crossing roads with a speed limit of …				0.8925		0.1609
Attitudes to 20-mph limits						
I am careful to drive at 20 mph wherever limits are			–0.6384			0.4812
I understand why City of Edinburgh Council introduced 20-mph speed limits	0.5445					0.4702
As long as I understand the reasons for the 20-mph speed limit, I will drive within the limit	0.4281		–0.4019			0.5623
20-mph speed limits will take time to get used to, but eventually 20 mph will be accepted as the normal speed	0.6854					0.3655
I think 20-mph speed limits will make my journeys longer		0.6141				0.4457
It is just too difficult to stay at 20 mph		0.3237	0.4407			0.4367
20-mph speed limits are a bad idea	–0.3206	0.3950				0.5210
People will ignore 20-mph limits because they do not see themselves getting caught by the police						0.9593
I will ignore the 20-mph limits if I think I will not get caught by the police			0.8498			0.3114
If I think a road with 20-mph limit has no traffic, I may drive faster than 20 mph			0.7816			0.4105
I get frustrated when I have to reduce my speed because someone in front of me is driving at 20 mph			0.7080			0.3562

Survey question	Factor					Uniqueness
	1. Detraction and resistance	2. Support	3. Rule-following	4. Child safety	5. Walking safety	
I feel pressured when I drive at 20 mph in a 20-mph zone when the driver behind me seems annoyed						0.8433
I would walk more if there were more roads with 20-mph speed limits	−0.5738					0.5127
I would cycle more if there were more roads with 20-mph speed limits	−0.6946					0.4229
Perceived impacts of 20-mph limits						
20-mph speed limits will make/have made people drive slower	0.7331					0.4896
Slowly but surely, 20-mph limits are making me drive slower	0.6266					0.5166
20-mph speed limits will lead/have led to longer journey times		0.9078				0.2015
20-mph speed limits will lead/have led to better traffic flow (less stopping and starting)	0.6411					0.3198
20-mph speed limits will lead/have led to more congestion		0.8526				0.2612
20-mph speed limits will lead/have led to more air pollution		0.8585				0.2810
20-mph speed limits will lead/have led to decrease in fuel efficiency		0.6080				0.6321
20-mph speed limits will lead/have led to decreases in the number of collisions	0.7753					0.3323
20-mph speed limits will lead/have led to a decrease in the number of severe collisions	0.8147					0.3471
20-mph speed limits will lead/have led to an increase in people walking on the streets	0.6621					0.6565
20-mph speed limits will lead/have led to an increase in people cycling	0.7426					0.5436

Note
Factor loadings of < 0.3 have been left blank.

EME
HSDR
HTA
PGfAR
PHR

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