Active Travel England

Active Travel Evidence Review

Safety, Journey Quality and Urban Realm Impacts In Active Travel Appraisal:

International Literature Review

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Contents

List of figures

List of tables

* See Appendix C for additional information.

Executive Summary

This paper sets out the results of an international evidence review of the safety, journey quality and place quality/urban realm impacts of active travel infrastructure schemes and applied valuation methods. The purpose of the study is to understand how appraisal guidance might be updated to account for enhanced infrastructure standards since the inception of Active Travel England, and the areas for further research that might be required.

The findings are split into four sections focused on three different aspects of active mobility – safety, place quality and urban realm, and journey quality – and the methods used to value them. Each of these sections – research areas – are divided into a range of themes derived from the literature. The following paragraphs outline the key findings, recommendations and areas for future research:

For the section on **safety**, three key themes were identified around infrastructure and collision risk; perceived safety and actual safety; and perceived safety and travel behaviour. The main findings across these sections were as follows:

- **Segregated infrastructure reduces collision risks:** Physically separated cycle tracks significantly decrease collisions compared to painted cycle lanes or shared bus lanes. Several Dutch and British case studies report that implementing cycle tracks have reduced collisions by up to 89% (Hull and O'Holleran, 2014). Reynolds *et al.* (2009) also report a 50% reduction in collisions on on-road cycle lanes in several North American studies. However, the overall findings on cycle lanes are mixed, largely due to potential conflicts with motorised vehicles. Facilities mixing cycle and pedestrian users introduce risk if very low speed limits (<10km/h) are not enforced (Chong *et al.*, 2010). Junctions and roundabouts pose higher risks for cyclists, but Dutch case studies find that purpose-built segregated facilities like Dutch roundabouts may reduce collisions by up to 90% (Reynolds *et al.*, 2009).
- **Road types and speed limits impact safety:** Cycling on residential and one-way roads is generally safer than on busier arterial roads. Studies in New Hampshire (USA) indicate that collisions on two-way roads increase the probability of severe cycle injury by 4% compared to one-way roads (Chen *et al.*, 2017). Implementing lower speed limits, such as 20mph zones, typically reduces injury odds for cyclists: 20mph limits in London reduce injury odds by 21% in comparison to 30mph in London (Aldred *et al.*, 2018). However, interventions like speed reductions for vehicles can have counter-intuitive effects, as these have been shown to increase the level of risk taking adopted by cyclists, potentially increasing risks for pedestrians instead (Ye *et al.*, 2024).
- **Design features influence safety:** Proper lighting, smooth paved surfaces, gentle gradients, and reducing street clutter (e.g., bollards, excessive signage) contribute to cyclist safety. Conversely, greenery, while enhancing aesthetics, may encourage faster cycling, increasing risk. Maintenance is crucial for safety perceptions and can lead to increased active travel.
- **Perceived safety affects travel behaviour:** Perceived safety often dictates travel behaviour more than actual risk data. Negative perceptions of cycling safety can deter people from using active modes, especially among groups like women and older adults.
- **Safety-in-numbers phenomenon:** Higher volumes of active travel users can enhance visibility and reduce collision likelihood ("safety-in-numbers"). As the number of cyclists and pedestrians increases, the safer the experience of travelling is.

For the discussion of place quality and urban realm, a wider range of themes covering urban/street environments, competition with other modes, access to amenities and traffic-calming/pedestrianisation were introduced in the context of driving uptake of active modes – with the following key takeaways:

- **Urban realm enhancements promote active travel:** Rérat and Schmassmann's (2024) note a 20% weekday increase in active travel following cycleway developments in Swiss towns. Additionally, improvements like planting, benches, and lighting in public spaces enhance comfort, safety, and attractiveness, directly encouraging walking, wheeling and cycling. Evidence thus suggests that such enhancements can lead to significant increases in active travel uptake, supporting the "build it, and they will come" approach.
- **Tailoring infrastructure to user needs:** Walking, wheeling and cycling require different infrastructure standards. While high-quality cycling infrastructure boosts cycling rates, changes can impact other users, such as creating severance for pedestrians. Interventions must balance the needs of different demographics, including older adults and women, who may react differently to urban realm improvements (Dill *et al.*, 2014).
- **Connectivity and proximity to services:** Access to amenities, well-connected street networks, and enhancements around transport hubs significantly affect the uptake of active travel. Proximity to services like schools and workplaces, along with well-designed routes, encourages walking, wheeling and cycling, particularly for mandatory trips.
- **Street design and environment quality:** Streetscape quality, including greenery, diverse street features, and well-maintained surfaces, positively impacts active travel patterns. Lighting and direct routes support navigability and safety, which are key to fostering a positive perception of active travel. Uttley and Fotios (2017) find for instance that the volumes of pedestrians and cyclists double during daylight hours; while fewer people generally travel during the night, these findings suggest that lighting as a design feature has the potential to encourage active travel. Greenery also has the potential to increase the likelihood and duration of walking, wheeling and cycling (Yu *et al.*, 2024).
- **Traffic-calming and road space reallocation:** Implementing speed restrictions, cycle boulevards, and pedestrianisation can reduce car use and create safer, more appealing environments for active travel. Following pedestrianisation schemes in Madrid, 32.8% of all participants stated that they intended to reduce car use; 91.6% of all participants people indicated that they would cycle the same amount or more after the pedestrianisation scheme, and 94.9% stated that they intended to walk the same amount of more following the scheme (Brownrigg *et al.*, 2023). However, these interventions must be carefully designed to avoid conflicts between different road users and to maximise their effectiveness in promoting walking, wheeling and cycling.

On **journey quality** for active modes, the following observations have been made – many of these also touching on elements of safety and place quality:

- **High-quality infrastructure and maintenance:** Well-designed and maintained infrastructure, such as smooth cycle lanes, traffic calming, and greenery, significantly enhances the comfort and safety of walking, wheeling and cycling, encouraging greater uptake. Poor road conditions (e.g. with potholes) hinder cycling comfort levels (Hull and O'Holleran, 2014).
- Core components of journey quality: Key factors like directness, coherence, safety and aesthetics (e.g., greenery) directly influence journey satisfaction and the likelihood of choosing active travel modes. The implementation of a cycle lane in Fribourg (Switzerland) significantly enhanced participants' view on comfort with a 22% increase in the number of people finding it more "enjoyable" and "faster" than before (Rérat and Schmassmann, 2024).

- **Tailored interventions:** Designing interventions that consider road networks, street elements, and user demographics improves journey quality, supporting different travel patterns and aligning with specific user needs.

Overall, research into the first three topics leads to the following key recommendations in terms of interventions that have positive impacts and benefits:

- **Prioritise safe and comfortable infrastructure:**
  - Infrastructure that addresses perceptions of safety influences travel behaviour positively. Segregated cycle tracks and Dutch-style roundabouts are shown to reduce collisions, as do lower speed limits (e.g., 20mph) and traffic-calming measures.
  - Well-lit, maintained surfaces with gentle gradients generate benefits in terms of comfort and safety.
  - Reducing street clutter and addressing potential hazards on footways and cycleways have positive impacts.
- **Enhance urban realm for accessibility and connectivity lead to the following benefits:**
  - Enhanced accessibility, connectivity and user experience with routes/amenities.
  - Tailored interventions to context, considering factors like traffic controls, greenery, noise and pollution.
  - Dense, connected active travel networks rather than isolated infrastructure.
  - Enhancing cycling, wheeling and walking facilities near key destinations – for example transport hubs, schools, and commercial centres – for improved connectivity.
- **Expand research and appraisal tools:**
  - Update appraisal tools (e.g. AMAT) to include time savings, greenery benefits, maintenance quality, and journey continuity, amongst others.
  - Conduct further research on long-term behavioural shifts and differential impacts on walking, wheeling and cycling.

The review into valuation methods followed a slightly different approach to that of other topics in this report. This research area looked at the economic valuation methods used for active travel infrastructure individual attributes, packages of improvements or new infrastructure in the UK and international evidence. This assessed the range of methods available, their advantages and limitations, and the contexts in which they may be appropriate and proportionate to use.

Various authors have developed valuations of active travel attributes or interventions. What is valued varies substantially, as does the unit of valuation. Several studies estimate the impact on house prices of delivering improved active travel infrastructure close by. Nordstrom (2022), for example, estimated that houses located near to 'complete streets' which include raised or protected cycleways, widened pavements for pedestrians, traffic-calming elements and 'right of way' for public transport can have house prices 10.5% higher than otherwise. For journey quality, examples include Shore et al (2012) who estimated cyclists were willing to pay 7.09 pence per journey to travel on an even payment with no cracks or 4 pence per journey to have advanced stop boxes for cyclists before traffic lights. Place-based valuations are available per unit of time, for example, Atkins (2011) found that pedestrians would be willing to pay £64 per year for the full pedestrianisation of an urban area.

The strength and relevance of valuations is an important consideration for determining what may be appropriate to include in appraisal guidance in England. Studies such as Flügel et al (2019), for example, provide relatively strong evidence on the value to existing cyclists of enhancing journey quality by improving road surfaces. Using their combination of methods (which enhanced robustness) and a sample of 815 participants (recruited from a nation-wide panel in the Netherlands and on-street to reduce bias) they estimated a value of £2.37/ hour (equivalent) to cycle on a cycle lane instead of a basic road. However, further work would be needed to consider whether values (such as this) generated in other countries, could be used in appraisal guidance for England given the differences in context and cycling behaviour.

The valuation methods in the active travel literature can be split into three broad approaches:

- **Stated preference:** This is a group of valuation techniques based on questionnaires given to elicit respondents' willingness-to-pay (WTP) for active travel. These are flexible techniques that can value a variety of journey or place quality attributes; however, care is needed in the research design to minimise bias, as these techniques use information on hypothetical decisions which may not always reflect the decisions participants would make in real life. These techniques require primary research, which generally comes from on-the-street or panel recruitment.
- **Revealed preference:** This is a group of valuation techniques that seek out markets in which the value of a good or service to an individual might be revealed. These techniques use primary or secondary data on actual decisions that individuals have made, meaning this data is generally robust. However, using real-life decisions means that there may be difficulties with data availability, it may only be possible to value a smaller range of attributes, and it can be hard to distinguish between journey quality and place quality impacts.
- A **combination** of stated and revealed preference can be used to minimise the weaknesses of each method in isolation. However, it increases the data collection required and may cause issues for researchers if results differ for the different methods.

Each method has its pros and cons. The choice of suitable method depends on the attributes being valued, existing data, and the time and budget available to researchers. Of the active travel literature reviewed, several gaps emerge that further work could explore. Evidence was generally limited for valuations of:

- Place quality.
- Attributes on short journeys.
- Attributes relevant to wheeling.
- Benefits of active travel interventions for new users.
- Package effects.

1. Introduction

1.1 Background and context

1.1.1 Active Travel England (ATE) was launched in 2022. It is an executive agency of the government, sponsored by the Department for Transport (DfT). ATE is responsible for making walking, wheeling and cycling the preferred choice for everyone to get around in England.

1.1.2 Since its inception, any cycle scheme funded by ATE is to meet the standards set out in Local Transport Note (LTN) 1/20, the DfT guidance for cycle infrastructure design. LTN 1/20 demands high standards of cycle infrastructure, ensuring new cycle networks are coherent, direct, safe, comfortable and attractive. Manual for Streets is the established infrastructure guidance for walking networks, providing similar benefits for pedestrians in terms of improved design standards.

1.1.3 Guidance for the appraisal of the costs and benefits of active travel schemes is set out in Transport Analysis Guidance (TAG) Unit A5.1 Active Mode Appraisal, and generally relies on the use of the Active Mode Appraisal Toolkit (AMAT). AMAT is a DfT-developed spreadsheet model that allows the user to appraise the economic benefits and costs of different types of cycle and pedestrian schemes based on a range of inputs.

1.1.4 AMAT was originally developed prior to the inception of ATE. Infrastructure standards for new schemes have since improved without the increased benefits of these standards being taken into account in active mode appraisal. However, the (often increased) cost of implementing these standards are incorporated, potentially reducing the value for money of active travel schemes. Furthermore, there are a number of different types of schemes that are not suitable to be appraised in AMAT, such as junction schemes, crossings, and schemes featuring significant urban realm or road space reallocation measures. Therefore, current appraisal guidance and tools are potentially underestimating the benefits of new active mode schemes, or (for some schemes) are not suitable for undertaking a robust transport economic appraisal.

1.1.5 To address this, the DfT and ATE have commissioned Frontier Economics (Frontier) and SYSTRA Ltd (SYSTRA) to undertake a review of the available evidence on the safety, journey quality and place quality/urban realm impacts and valuation methods of active mode infrastructure schemes.

1.2 Purpose and scope of the study

1.2.1 This study reviews the available evidence on the safety, journey quality and place quality/urban realm impacts of active mode infrastructure schemes. The review encompasses both quantification (such as the reduction in collision rates or increase in demand) and valuation (such as the willingness to pay for improved infrastructure).

1.2.2 As part of this evidence review, an assessment is also made on the strength of evidence and whether any of the findings can be applied in DfT appraisal guidance, as well as whether and in which areas further research is required.

1.2.3 The study is split into four core research areas, with the scope of these summarised below.

Safety

1.2.4 The safety benefits of new and improved infrastructure for active mode users are not specifically quantified in AMAT, with only benefits associated with mode shift and subsequent reduced vehicle kilometres quantified. Therefore, current guidance is potentially not accounting for the safety benefits that enhanced segregation, priority and visibility generated by LTN 1/20 standards provide for users. Furthermore, as well as the direct impacts on collision rates, safety perceptions and how these impact demand levels are potentially not currently accounted for.

1.2.5 Therefore, the evidence review will focus on the impacts on active travel demand of the safety and safety perceptions of users, and how different types of infrastructure may influence this. The review will also seek to understand if there are safety impacts not currently accounted for in appraisal guidance that could or should be.

Place quality and urban realm

1.2.6 There is a potential overlap between this research area and that of journey quality (introduced below) in terms of the type of schemes, the benefits generated and the evidence available in the literature. Therefore, it is important for the distinction between these research areas to be made at the outset.

1.2.7 Place quality and urban realm benefits can relate to non-users (through indirect impacts such as land values) and to users who 'dwell' and spend time in a space as well as those who 'move through' the space as part of a journey.

1.2.8 Place quality and urban realm benefits are relevant to schemes that have this 'place' function in mind, as opposed to solely about movement and 'A to B' journeys, including public squares, event spaces, public transport interchanges, station environments, street environments and neighbourhood schemes that include a place function.

1.2.9 While there are existing valuations within TAG and AMAT that could relate to place quality, there is no existing evidence in current appraisal guidance about the impact of place quality on active travel demand. This is of particular relevance given the general trend in transport investment towards schemes that create low traffic or traffic-free environments and invest in facilities, aesthetics and materials that encourage people to spend time in, enjoy and engage with public spaces, particularly in town and city centres. There is an existing gap in the guidance and supporting evidence on the impacts of these schemes.

1.2.10 Therefore, this research area assesses the impacts of different aspects of place quality and urban realm infrastructure on the demand for active travel, and how any findings might be incorporated into appraisal guidance in the future.

Journey quality

1.2.11 Journey quality is defined in TAG Unit A4.1 Social Impact Appraisal as:

"real and perceived physical and social environment experienced while travelling"[1]

1 Transport Analysis Guidance Unit A4.1 Social Impact Appraisal, Department for Transport (November 2022).

1.2.12 Journey quality impacts can be divided into the following three groups:

- **Traveller care** – including aspects such as cleanliness, information provision, and the standard of facilities.
- **Travellers' views** – including aspects such as the view and external surroundings of the traveller and how pleasant these are to experience.
- **Traveller stress** – including aspects such as frustration, perception of safety, and uncertainty over route.

1.2.13 The concept of journey quality benefits derives from the generally accepted tenet that travel is a derived demand that arises from travellers wishing to access services and engage in activities. Notable exceptions include tourism and sightseeing journeys where the journey itself is the attraction. If the quality of a journey is improved, the negative impact of the journey on the traveller is reduced and they derive a benefit from this.

1.2.14 Journey quality is relevant for all modes and is reasonably well developed for active mode appraisal. AMAT currently generates economic benefits in terms of journey quality (benefits to new and existing users as a result of improvements to infrastructure, related to safety perception and/or environmental conditions) for walking, wheeling and cycling schemes, determined by the infrastructure type selected in the tool, although the tool does not generate impacts on the number of walking, wheeling and cycling journeys. Furthermore, the valuations currently used are several years old and require updating. Existing values for pedestrian environment and cycle facilities are nearly 20 and 30 years old respectively.

1.2.15 Additionally, and as noted previously, enhanced infrastructure standards are now creating improved conditions for users which the existing guidance is potentially not quantifying or valuing the impacts of.

1.2.16 This research area will therefore review the existing evidence behind journey quality impacts on active travel demand, if this is being sufficiently captured in the existing appraisal guidance, and what improvements to the guidance or further research might be required.

Valuation methods

1.2.17 This study considers both quantification and valuation of the impacts of active travel infrastructure improvement. The fourth research area reviews current valuations from the literature, the methods used to estimate those valuations, and their relative strengths and weaknesses in the context of active travel infrastructure improvements. It is important to note that valuing safety benefits is not included within this study as it is well covered in other research, so this study focuses on the valuation of journey and place quality impacts. The perception of safety is included in this as an important part of journey quality.

1.3 Structure of this report

1.3.1 The remainder of this report is structured as follows:

- Chapter 2 describes the methodology undertaken for this research, including the steps taken to collate, review and sift papers that have been identified as relevant.
- Chapter 3 sets out the findings from the evidence review, split by research area with some key themes identified under each.
- Chapter 4 summarises the key findings, evidence gaps and areas for future research identified.

2. Methodology

2.1 Overview

2.1.1 This chapter sets out the approach taken for this evidence review, including how papers were identified, initial assessments and scoring, and the shortlist of papers for more detailed analysis.

2.1.2 A four-step process was used to collate and sift the literature and target the review to the most relevant papers. Table 1 summarises this process and the following sections describe each stage in more detail.

Table 1. Literature review process overview

No.	Stage	Description
1	Long list	Develop long list of relevant papers based on key search criteria.
2	Initial sift	Sift long list papers based on agreed inclusion/exclusion criteria.
3	Quality assessment	Assess sifted papers against agreed quality scoring to prioritise inclusion.
4	Thematic analysis	Summarise findings and categorise by theme.

2.2 Long list

2.2.1 The first stage of the process was to develop a long list of papers relevant to the study for further review. This was undertaken using a list of search terms combined with a set of inclusion and exclusion criteria, split by research area, both of which were agreed with ATE and DfT.

2.2.2 Evidence was collated from a range of sources, including Google Scholar, JSTOR and papers provided by the DfT and ATE at the start of the study.

2.2.3 Key search terms for each research areas and were developed to encompass aspects such as:

- Intervention and infrastructure type.
- Location of intervention.
- Published guidance and standards.
- Existing tools.
- Types of impacts.
- Study and analysis methodologies, particularly in terms of valuation methods.

2.2.4 A full list of key search terms, alongside the other inclusion and exclusion criteria, is provided at Appendix A.

2.2.5 The long list process produced the results summarised in Table 2.

Table 2. Long list summary

Number of papers	Literature types	key characteristics
RA1 – 28	Academic: 74 Grey: 20 Other: 1 guidance document	Date range 2009-2024 Locations: UK/England, Europe, America/Canada, Australia/New Zealand
RA2 – 31		
RA3 – 29		
RA4 – 30		
Total – 95		

2.2.6 The long list process produced 95 papers across the four research areas, which were relatively evenly distributed across the four (noting that some papers were relevant to more than one research area). Of the 95 papers, the majority were academic papers, with 20 examples of 'grey' literature and one guidance document. The publication dates of the papers spanned from 2009 to 2024 with the various locations of the studies including the UK, Europe, North America, Australia and New Zealand.

2.3 Initial sift

2.3.1 The second stage of the evidence review process was the initial sift of the long list of papers against a further set of inclusion and exclusion criteria.

2.3.2 The full list and details of the criteria are provided in Appendix A, and can be summarised as follows:

- **Scope** – papers were sifted according to their date of publication, geographic location of the study and study design.
- **Quality** – an assessment of publication bias by considering the type of publication and details of sampling.
- **Relevance** – an assessment of the papers' relevance based on the professional judgement of the study team.

2.3.3 The initial sift process produced the results summarised in Table 3.

Table 3. Initial sift summary

Number of papers	Literature types	Key characteristics
RA1 – 25	Academic: 38 Grey: 7 Other: 1 guidance documents	Out of scope due to: • Date range (n=6) • Geographical region (n=5) • Beyond core research areas (n=19) Duplication (n=7) Low relevance scoring (n=26)
RA2 – 29		
RA3 – 13		
RA4 – 14		
Total – 46		

2.3.4 The initial sift process reduced the number of papers by approximately half, to 46 across the research areas. The scope of papers was slightly skewed towards research areas 1 and 2. Of the 46 papers, 39 were academic papers, four examples of grey literature and three guidance documents. Most papers were excluded for either low relevance scoring or their areas of coverage being beyond the four research areas.

2.4 Quality assessment

2.4.1 The third stage of the evidence review process was a more detailed quality assessment of the remaining papers. The quality assessment aimed to prioritise papers that remained following the initial sift and arrive at a shortlist of papers for detailed analysis of their findings.

2.4.2 The quality assessment criteria are split into the following areas:

- Methodology.
- Analysis.
- Ethics.
- Peer reviewed.

2.4.3 This step in the process ensured that the shortlisted papers were the strongest in terms of methodological rigour, analytical depth and evidential support, as well as any consideration around evidence sensitivity that is of note. The key considerations in each of these areas are set out in Appendix B. The quality assessment process reduced the number of papers down to a final short list of 40 across the research areas, which were taken forward into the thematic analysis.

*Table 4. Final short list summary**

Number of papers	Literature types
RA1 – 25	Academic: 35 Grey: 4 Other: 1 guidance document
RA2 – 28	
RA3 – 12	
RA4 – 14	
Total – 40	

** See Appendix C for additional information.*

2.5 Thematic analysis

2.5.1 The final stage of the evidence review process was the analysis of each shortlisted paper against a set of themes, set out below.

Table 5. Key themes in each research area

Research area	Key themes
Research Area 1 – Safety	• Reduced active mode collisions and casualties • Increased confidence and safety perception of active mode users • Impact of improvements in safety on demand • Impact of infrastructure types on safety • Applying the existing evidence and areas for further research
Research Area 2 – Place quality and urban realm	• Impacts of place quality and urban realm improvements • Impacts of improvements at public transport hubs and interchanges • Impacts of improvements to street environments • Impacts of improving access to local facilities • Impacts of low traffic or traffic-free environments • Applying the existing evidence and areas for further research
Research Area – Journey quality	• Impacts of journey quality improvements • Applying the existing evidence and areas for further research
Research Area – Valuation methods	• Attributes that have been valued in the literature and results • Methodologies for valuation and accompanying data collection • Advantages and disadvantages of different methods • Gaps in the literature

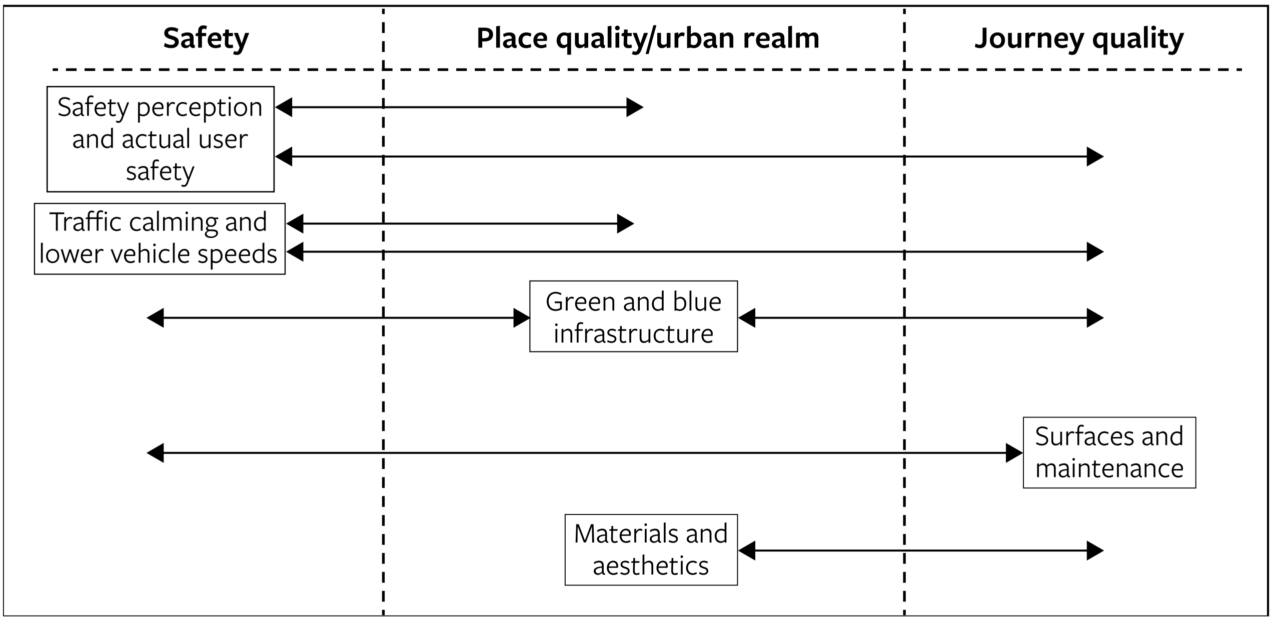
3. Findings

3.1 Introduction

3.1.1 It is important to note that in the first three research areas – safety, place quality and urban realm, and journey quality – there are inherent overlaps present in both the evidence and in existing appraisal guidance in terms of how impacts are categorised and which area a particular intervention is impacting.

3.1.2 Figure 1 demonstrates the areas of overlap and cross-cutting themes between research areas 1-3. For these topics, evidence is discussed across the research areas, with the research area where the evidence is most prominent indicated by its column placing in the diagram.

Figure 1. Cross-cutting themes



3.1.3 It is also important to acknowledge that, while ATE's remit encompasses wheeling as well as walking and cycling, 'wheeling' is relatively new in terms of active travel terminology. Therefore, much of the evidence reviewed does not specifically reference wheeling as a mode that has been studied, nor quantifies the impacts of infrastructure on wheeling trips or the safety of wheeling users. However, where the evidence notes benefits for walking and cycling users, it should be assumed that these benefits would also apply, at least to some extent, for wheeling as well.

3.2 Safety

3.2.1 This section explores how physical infrastructure in the road environment contributes to user safety and perceptions of safety for pedestrians and cyclists, thus impacting propensity to use these modes. Recommendations are then made, as well as an outline of areas for further research. The section is organised around three key themes, as follows:

- **Theme 1:** Infrastructure and collision risk
- **Theme 2:** Perceived safety and actual safety
- **Theme 3:** Perceived safety and travel behaviour

Theme 1: Infrastructure and collision risk

Introduction

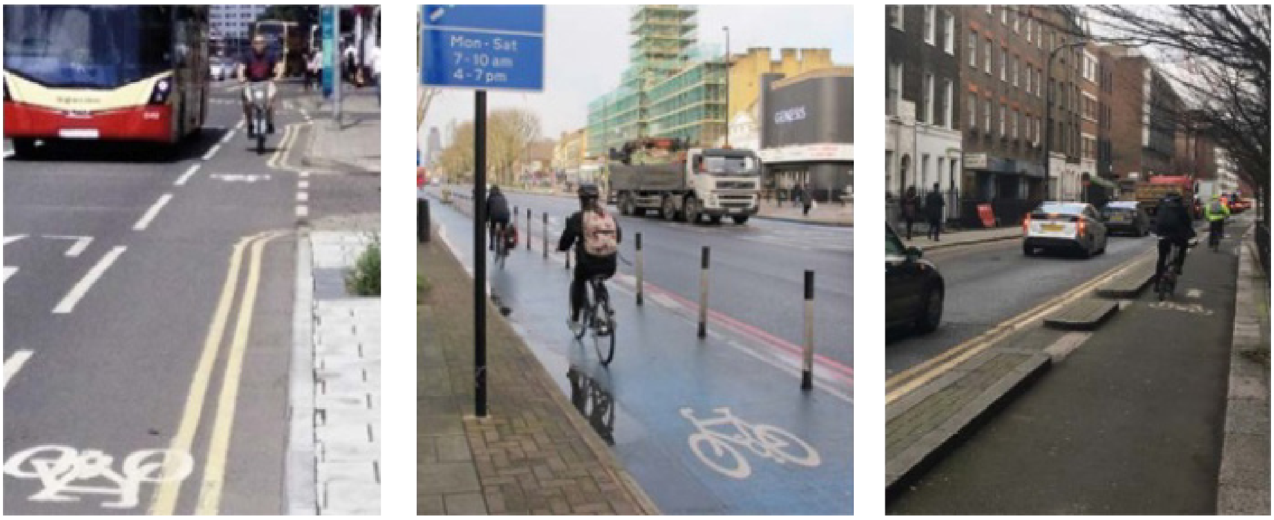
3.2.2 This subsection examines various types of cycling infrastructure, road design, and design factors that influence the safety and uptake of walking, wheeling and cycling. It explores the following:

- Benefits and limitations of different cycle lane designs.
- Risks associated with junctions and roundabouts.
- Impact of road types and speed limits.
- Key design considerations such as lighting and greenery.
- The "safety-in-numbers" phenomenon.

Cycle lanes and cycle tracks

3.2.3 The two main types of on-street cycling infrastructure are painted "cycle lanes" and physically segregated "cycle tracks" (noting that hybrid "stepped" or "wanded" infrastructure providing light, but incomplete segregation also exist) – illustrations are shown in Figure 2.

Figure 2. Cycling infrastructure types (*LTN 1/20*)



Cycle lane | *"Wanded" cycle lane* | *Cycle track*

3.2.4 For such infrastructures, studies undertaken in the USA and Canada suggest that segregation of cycling infrastructure from vehicular lanes may significantly collisions between all users (Hull and O'Holleran, 2014; Reynolds *et al.*, 2009; Chen, 2015). Hull and O'Holleran (2014) highlight various studies in the UK and the Netherlands which found that the odds of incidents on cycle tracks were 89% lower than on a road with parked cars and no cycling infrastructure. These findings make a strong case for the benefits of physical segregation infrastructure such as cycle tracks.

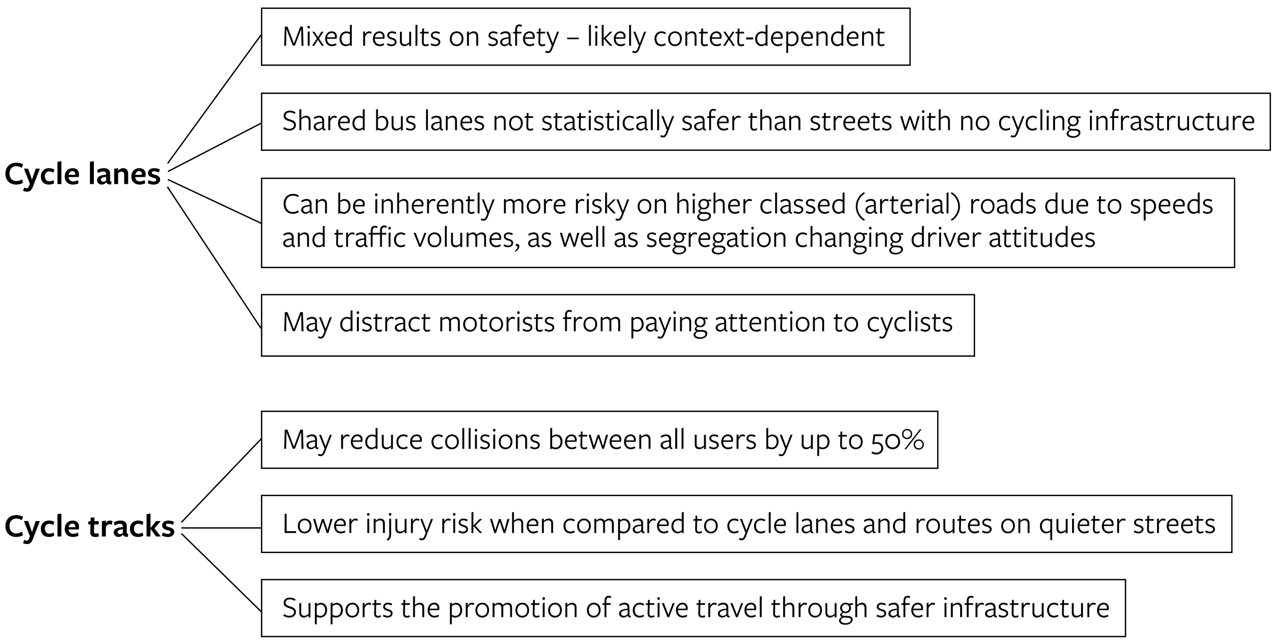
3.2.5 Findings specifically for on-road, painted cycle lanes provide mixed results, as some studies note that they may attract cyclists while also "putting them in the proximity of dangerous conditions" (Chen *et al.*, 2017). Reynolds *et al.* (2009) reports numerous North American studies which show that cycle lanes have reduced collision rates by up to 50%. However, other studies demonstrate that no causal relationship between cycle lanes and the reduction of collisions can be found (Mulvaney *et al.*, 2015). Still others find that shared bus lanes (cycles and buses only, with no hard segregation) are not statistically safer than streets with no infrastructure (Aldred *et al.*, 2018).

3.2.6 Collisions are more likely to be reported in areas with higher traffic speeds and volumes. Cycle lanes are generally implemented on busier (arterial roads) which are inherently more dangerous for cyclists (Chen, 2015; Chen *et al.*, 2017). Consequently, the presence of cycle lanes on these roads is correlated with an increased likelihood of sustaining severe injuries. Additionally, motorists may pay less attention to cyclists as they are no longer "sharing" a lane, which may encourage faster driving speeds. This demonstrates that it is important to consider the road type to analyse the root of collision data, rather than merely acknowledging the presence of cycling infrastructure.

3.2.7 Further studies demonstrate that whilst cycle lanes can protect cyclists from motorised traffic (McCartney *et al.*, 2012; Hull and O'Holleran, 2014), the risks are still much higher than with dedicated cycle tracks and routes on quieter streets. Indeed, cycle tracks have the lowest injury risk, followed by lanes on major streets with no parked cars (Hull and O'Holleran, 2014). Parked cars present a danger to cyclists: they can force cyclists onto the carriageway, as opening car doors or cars pulling out of a bay may obstruct a cyclist and lead to collisions. Hull and O'Holleran (2014) highlight studies in the UK and the Netherlands that find that major streets with parked cars are associated with a 37% increase in the risk of incidents.

3.2.8 Overall, these findings potentially support the opportunity for AMAT to value the safety benefits of segregated infrastructure vs. non-segregated infrastructure.

Figure 3. Cycle lanes vs. cycle tracks



Shared-Use Facilities

3.2.9 Research agrees that collisions between cyclists and motorists must be addressed, and off-road shared-use facilities often seem to be the solution to shield cyclists from motorised traffic. However, increasing the opportunity for conflict between cyclists and pedestrians may "shift the burden of injury from cyclists to pedestrians", and therefore may dampen overall safety benefits for those travelling on foot (Chong *et al.*, 2010). Chong *et al.* (2010) highlight this with findings from other studies which state that the "kinetic energy differential between a car travelling at 60 km/h and a bicycle travelling in the same direction at 30 km/h is not much different to that between a person walking at 5 km/h and a bicycle travelling at 30 km/h". Research therefore indicates that segregation from both motorists and cyclists enhances pedestrian safety (*ibid*).

Junctions and roundabouts

3.2.10 Junctions and roundabouts occur at the intersections of roads and streets, and are associated with substantially higher injury odds than mid-block locations (Aldred *et al.*, 2018; Reynolds *et al.*, 2009). Aldred *et al.* (2018) note for instance that "junctions [are] associated with over three times the odds ratio of injury, compared to non-junction sites". Junctions and roundabouts have been noted as the "main hazard" for cyclists (Hull and O'Holleran, 2014).

3.2.11 Crossing points, and severance forcing cyclists to merge with traffic, are "the weak spot(s) in any cycle network" (Hull and O'Holleran, 2014). In their own literature review, Mulvaney *et al.* (2015) find that designs where cycle lanes continue across the mouth of a side road with a give-way line onto the main road for cyclists increase collision risks between motorists and cyclists. However, they nuance these findings, stating that there is generally a lack of evidence that advanced stop lines reduce or increase injury collisions in cyclists.

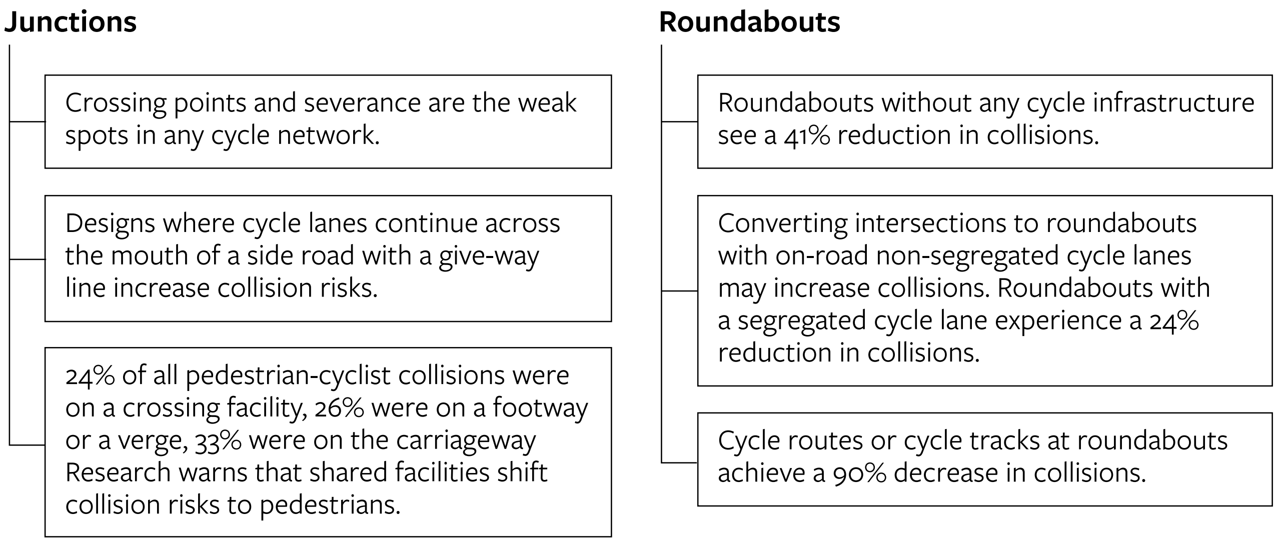
3.2.12 Roundabouts with marked cycle lanes that are marked as part of the circulation carriageway are subject to the same dangers as discussed in the previous section (Mulvaney *et al.*, 2015); however, purpose-built segregated facilities – such as cycle tracks at roundabouts – reduce the risk of collisions and injuries in comparison to on-road cycling or shared-off road routes (ibid; Reynolds *et al.*, 2009). To reduce collision rates between motorists and cyclists, single-lane roundabouts with a central island radius exceeding 10m (which is easier for all to manoeuvre around and navigate safely), and Dutch roundabouts (which have dedicated, setback cycle lanes, shown in Figure 4 below) are particularly successful (Reynolds *et al.*, 2009) as they "increase visibility of the cyclist [and] move conflict with other users away from the junction without impeding queueing traffic" (Hull and O'Holleran, 2014). When evaluating a study that reviews 181 intersections before and after the implementation of roundabouts in the Netherlands, Reynolds *et al.* (2009) highlight that there was an overall 8% reduction in collision rates following the installation of roundabouts in the Netherlands, and specified the following:

- Roundabouts with a cycle lane experience a 24% reduction in collisions.
- Roundabouts without any cycle infrastructure see a 41% reduction in collisions. (presumably as motorists are more cautious in the absence of infrastructure).
- Roundabouts featuring cycle tracks achieve a 90% decrease in cyclist injuries.

Figure 4. Dutch roundabout in Cambridge (BBC)

3.2.13 When considering the conflict between pedestrians and cycles, from 2005 to 2015 (in England), 24% of all reported pedestrian collisions with one or more pedal cycles were on a crossing facility, 26% were on a footway or a verge, and 33% were on the carriageway (Ram *et al.*, 2022). This data demonstrates that, while shared-use facilities may shield cyclists from motorised traffic, pedestrians are more exposed to collision risks (Chong *et al.*, 2010).

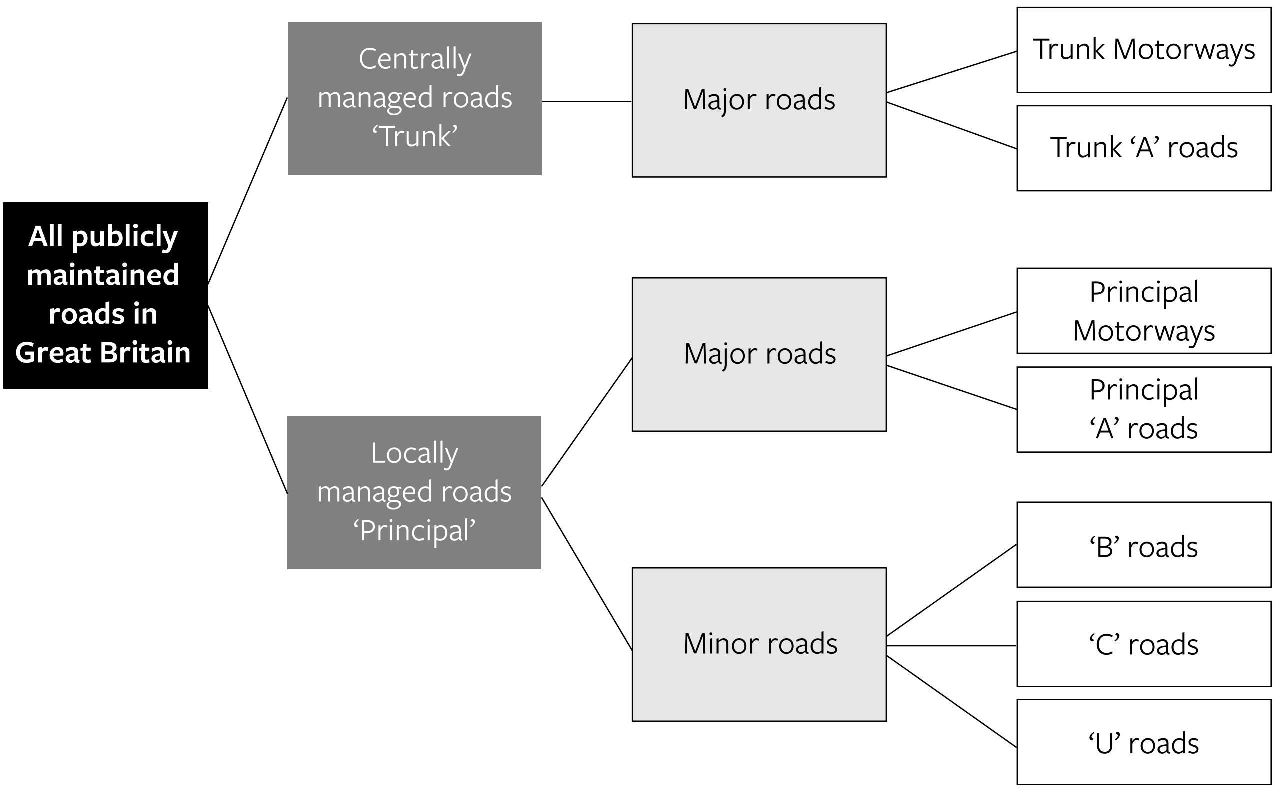
Figure 5. Key considerations for safety at junctions and roundabouts



Road types and speed limits

3.2.14 Road types (A, B, C etc., as well as one- vs. two-direction) differ from each other in a few key aspects – namely their size and number of lanes, vehicular flows and design speeds. The hierarchy of these roads is outlined below:

Figure 6. UK road hierarchy (source: Gov.uk)



3.2.15 The evidence collated and reviewed suggests that road layouts influence the severity of cycling collisions. Studies in the State of New Hampshire (USA) indicate that collisions on two-way roads increase the probability of severe cycle injury by 4% compared to one-way roads (Chen *et al.*, 2017). Practitioners may therefore consider prioritising cycling infrastructure on one-way roadways (ibid) if segregation is not feasible. Furthermore, it was found that "roadways with narrow lane widths cause more severe injuries" (ibid), likely because passing distances are smaller in such cases. A minimum width for cycle infrastructure of five feet, and eight feet for new cycleway sections, may prevent obstruction from parked cars, opening doors, and enable safe overtaking (Hull and O'Holleran, 2014).

3.2.16 Road types and speed limits also affect injury risk (Aldred *et al.*, 2018), but the relationship is not always linear. Whilst residential and other "U"-type roads typically are safer than other roads, secondary (B) roads tend to be more dangerous than primary (A) roads (ibid), typically because secondary roads tend to lack cycling provision. However, both A and B roads significantly increase the likelihood of collision risks compared to residential roads given the faster travel speeds on these roads (Ye at al., 2024).

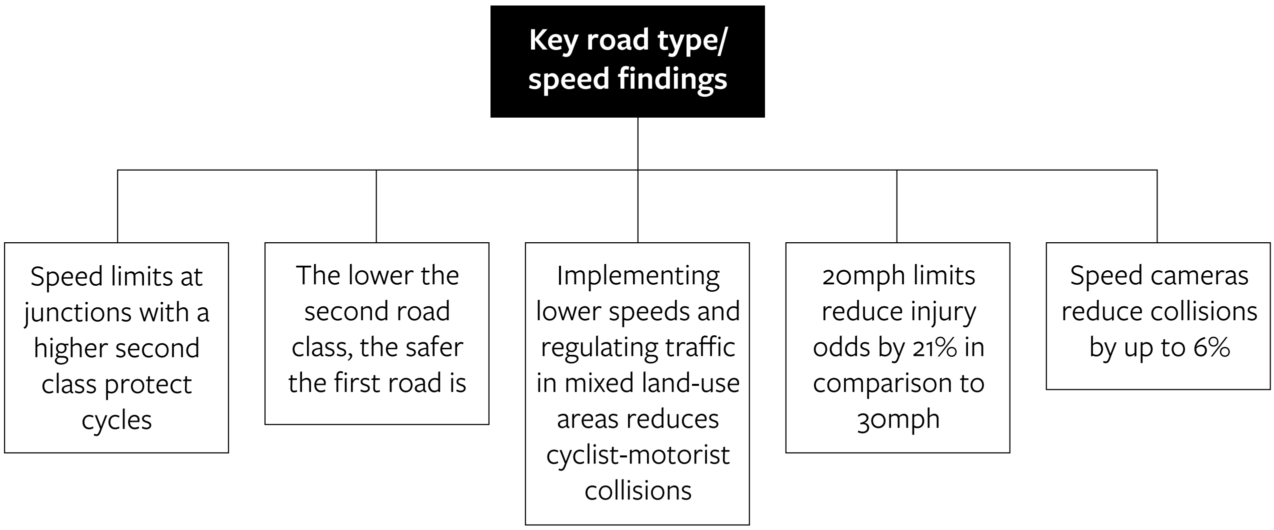
3.2.17 "Second road effects" indicate that the lower the class of the adjoining "second" road at a junction, the safer the first road is (Ye *et al.*, 2024). The paper therefore recommends implementing speed limits at junctions where the adjoining second road is a higher speed/class than the "first" road, to isolate cyclists from these environments; installing segregated cycleways in such locations can also work. If a junction is between two roads of the same functional class, the one with the higher speed limit has been found more likely to lead to injuries (ibid), probably because vehicles are approaching the junction at higher speeds and are less able to react in time to stop collisions. Reducing the driving speed is a recurring recommendation in international literature and supports the introduction of a speed reduction safety benefit for cycles into appraisal guidance.

3.2.18 Implementing lower speeds and regulating traffic in areas with multiple land uses are measures that reduce collisions risks between cyclists and motorists (Chen, 2015). The implementation of speed restrictions in urban areas in recent years have also reduced cyclist casualties (Mulvaney ***et al.***, 2015). In terms of the data on injury reduction in London, 20mph limits reduce injury odds by 21% in comparison to 30mph, but 30mph roads appear more dangerous than 40mph roads in the data, presumably because there is often existing segregated infrastructure on roads with higher speed limits (Aldred *et al.*, 2018).

3.2.19 However, there are other counter-intuitive effects to consider. While reducing motorised speeds have improved pedestrian and cycling safety overall, lower motorised traffic speeds may facilitate faster cycling speeds. Ye *et al.* (2024) find that the lower the speed limit for cars, the more tempting it is for cyclists and pedestrians to engage in risky behaviour such as crossing a street mid-block or changing lanes without signalling (for cyclists). This is especially the case when the speed limit is 20mph. Moreover, facilitating cycle flows may disproportionately increase collision risks for pedestrians, as cyclists could be encouraged to ride faster or be less cautious, potentially compromising pedestrian safety (Ram *et al.*, 2022).

3.2.20 Engineering interventions, such as speed cameras or road modifications such as speed bumps/pillows, reduce cycle collisions by up to 34% in Great Britain, with speed cameras alone resulting in a 6% reduction (Mulvaney *et al.*, 2015). Features such as quiet streets or no parking on major streets are associated with overall lower levels of injury risks (Hull and O'Holleran, 2014). This is partly because having many parked cars leads to hazards such as opening vehicle doors, vehicles pulling out and vehicles parking in the cycle lane.

Figure 7. Key findings for road types and speeds



Design factors

3.2.21 Outside of the road carriageway and of the footway specifically, a variety of design factors such as paving, signage and gradient can impact walking, wheeling and cycling safety. For walking appraisal for instance, AMAT already considers:

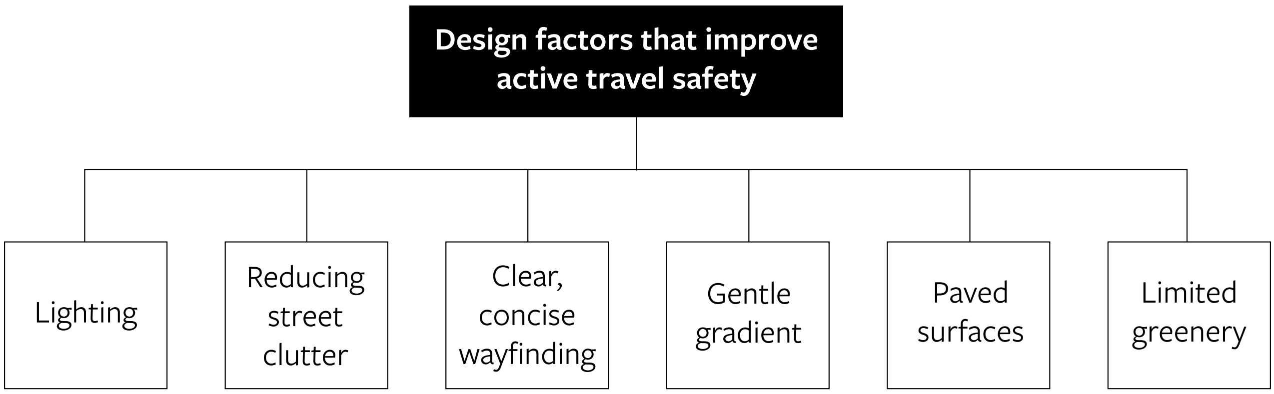
- Whether the new infrastructure introduces lighting to previously unlit routes.
- If schemes provide a continuous surface at one level (but includes no specific mention of gradient).
- The percentage of pedestrian infrastructure that is uneven (to assess its evenness and quality).

3.2.22 Features that improve pedestrian and cyclist safety include street lighting, paved surfaces, and gentle gradients (Reynolds *et al.*, 2009). Adequate lighting conditions encourage walking, wheeling and cycling by allowing obstacles to be seen and avoided, enhancing safety perceptions, and improving visibility to reduce the risk of collisions (Uttley and Fotios, 2017). Additionally, research indicates that a darker environment tends to generate higher uncertainties towards safety (Ye *et al.*, 2024). As a result of these factors, researchers advocate for more consideration of lighting as an essential design element to ensure that the layout of lighting equipment provides for the safety of all users (ibid). Recommendations include ensuring that all urban roads are lit at night, especially in areas with high pedestrian and cyclist frequency (*ibid*).

3.2.23 While important for wayfinding, the density of road signals and parking signs is positively correlated with cycle collisions (Chen, 2015). Similarly, potential consequential hazards arise from obstacles such as bollards, road signs, or parked objects on footways and cycleways (Hess *et al.*, 2023), suggesting that measures to reduce street clutter can have positive safety benefits.

3.2.24 Greenery, which refers to plants, foliage, and vegetation, is generally present in areas with fewer vehicle and pedestrian flows. Such areas may encourage cyclists to ride at excessive speeds or be less vigilant due to the less threatening and quieter environment (Ye *et al.*, 2024). For the same reason (cyclists being less cautious), exposure risk is higher in areas with lower vehicle flows. However, a higher density of cycle lanes, a higher normalised difference vegetation index,[2] and lower building density generally display lower collision rates on average, likely because there are fewer motorists (Branion-Calles *et al.*, 2020).

Figure 8. Key findings related to streetscape design



"Safety-in-numbers" phenomenon

3.2.25 Safety of active travel users is also affected by their visibility. This is the safety-in-numbers phenomenon, defined as the "tendency for the number of collisions to grow less than in proportion to traffic volume" (Elvik and Goel, 2019). This phenomenon affects users differently and is stronger for active travel users than for motorists (ibid). Aldred *et al.* (2018) find that, in London, "for every increase in cycling traffic by a factor of approximately 2.72 (the base of the natural logarithm), the likelihood of cycling injuries decreases by 18%". This suggests that a higher adoption of active transportation modes, such as cycling, may inherently reduce the number of collisions involving these users.

3.2.26 The research identifies another interesting finding: the strongest safety-in-numbers effects, particularly for pedestrians, occur in the worst safety environments – those with more lanes to cross, signalised junctions and traffic entering from multiple directions at crossing locations (Elvik and Goel, 2019) – and this effect is diluted as environments become better. So, despite poor infrastructure generally contributing to more collisions, a higher number of cyclists and pedestrians can lead to increased safety. Therefore, the presence of users may in itself foster safety in such environments, as motorists are generally more aware of their surroundings and especially likely to notice larger groups of pedestrians and cyclists.

2 The Normalised Difference Vegetation Index (NDVI) is a widely used metric for assessing the health and density of vegetation. NDVI values range from -1 to 1. A value of -1 typically indicates water bodies, a value of 0 suggests urban areas, barren land, or areas with little to no vegetation, and a value of 1 refers to areas with dense, healthy vegetation.

Theme 2: Perceived safety and actual safety

Introduction

3.2.27 The design and characteristics of walking, wheeling and cycling infrastructure play a critical role in shaping users' perceptions of safety. Various factors, including the type and quality of infrastructure, vehicle speeds, and crossing facilities, influence confidence levels among different user groups. This subsection explores the relationship between infrastructure standards and perceived safety, emphasising how these perceptions differ across sociodemographic groups.

The impacts of infrastructure on perceived safety

3.2.28 Overall, there is a disproportionately negative perception of cycling safety in comparison to driving safety. Indeed, cycling is widely perceived to be dangerous for all users; however, this view is more moderate for leisure trips on segregated infrastructure (Ogilvie *et al.*, 2010). Junctions and crossing facilities are a key location for perceived danger (as well as previously noted for actual danger). Hess *et al.* (2023) state that that 81% of cycling respondents in their German study regularly feel fear interacting with turning vehicles and 68% feel this way during overtaking manoeuvres.

3.2.29 While there are conflicting views on the benefits of cycle lanes, perceptions of segregated cycle lanes are overwhelmingly positive (Hull and O'Holleran, 2014). In Switzerland, following the development of cycle lane schemes, cyclists' feeling of safety increased from 51% to 82% (feeling "safe") in response to more separation from motorised vehicles (Rérat and Schmassmann, 2024). Conversely, lanes that are shared between cycles and buses can be off-putting for new cyclists and the most vulnerable users (Hull and O'Holleran, 2014), which is somewhat supported by previously mentioned findings that such lanes do not provide any additional safety benefits.

The impacts of perceived safety on actual safety

3.2.30 There may also be a link between perceptions of safety and cyclists' actual safety. Women and older people have lower collision risks relative to men. Some of this may relate to findings that women tend to be more cautious regarding directness, safety, and cohabitation with motorised traffic (Rérat and Schmassmann, 2024).

3.2.31 Lower collisions rates may also be due to the choice of infrastructure, lower cycle speeds (Branion-Calles *et al.*, 2020), or because cyclists using safer streets may be "more cautious or skilled than average" (Aldred *et al.*, 2018). Research notes a safety-in-exposure effect, whereby participants who cycle more often display lower collision levels (Branion-Calles *et al.*, 2020), suggesting safety benefits for existing users if those groups can be encouraged to cycle more. This may be because the more frequent exposure to cycling allows users to maintain the skills and sensibilities necessary for cycle safely, as well as to plan and follow safer routes. People who cycle frequently may also do so in a presumably more supportive environment for cycling.

3.2.32 Additionally, those who disagreed that cycling was a well-regarded mode of transport in their neighbourhood have a 1.28 times higher collision risk than those with a positive view, while a neutral view increases the risk by 1.16 (Branion-Calles *et al.*, 2020). So, it may be self-fulfilling – that the safer one perceives an environment to be for cycling, the safer that environment actually is.

Theme 3: Perceived safety and travel behaviour

Introduction

3.2.33 Perceived safety plays a pivotal role in shaping individuals' travel choices, influencing both the uptake and demand for walking, wheeling and cycling. Beyond personal preferences, attitudes towards safety can significantly affect mode trip patterns, with variations observed across age groups, genders, and locations. This subsection explores how perceived safety impacts individuals' willingness to engage in active travel and highlights the factors that drive confidence in walking, wheeling and cycling.

Perceived safety and its influence on active travel patterns

3.2.34 In addition to individual preferences, mode trip patterns may stem from attitudes towards safety (Dill *et al.*, 2014; Chen *et al.*, 2017).

3.2.35 Dill *et al.* (2014) quantify how attitudes towards walking, cycling, and car safety may guide active travel uptake. Attitudes towards cycling, walking and towards the relative safety of cars were captured by qualitative survey questions reflecting overall positive sentiments and preferences for each mode of transport; attitudes were then linked to behaviour outcomes via regression analysis. Safety is identified as a component of positive attitudes towards walking, cycling and driving. Using Portland (USA) as a case-study, the models find that:

- **Walking:** for every one-unit increase in positive attitudes towards walking, based on the 5-point scale applied by the researchers, there is a 3.07-minute increase in walking. This shows that individuals with more positive attitudes towards walking are more likely to walk more. For every one-unit increase in positive attitudes towards walking, the odds of walking for longer than 20 minutes increase by 1.016.
- **Cycling:** for every one-unit increase in positive attitudes towards cycling, based on the 5-point scale applied by the researchers, the odds of a participant cycling for longer than ten minutes increase by a factor of 1.472, indicating that more positive attitudes strongly influence cycle journey duration. When analysing the effect of attitudes on journey times exceeding ten minutes, the regression analysis shows that for every one-unit increase in positive attitudes towards cycling, the number of cycling minutes increases by approximately 0.5 minutes. While this is a positive relationship, there are moderate increases in cycling duration once the ten-minute threshold is surpassed as attitudes improve.
- **Driving:** Conversely, car safety attitudes have a negative coefficient (B=-0.292), which indicates that indicates that individuals who find cars safer are less likely to cycle more than 10 minutes.

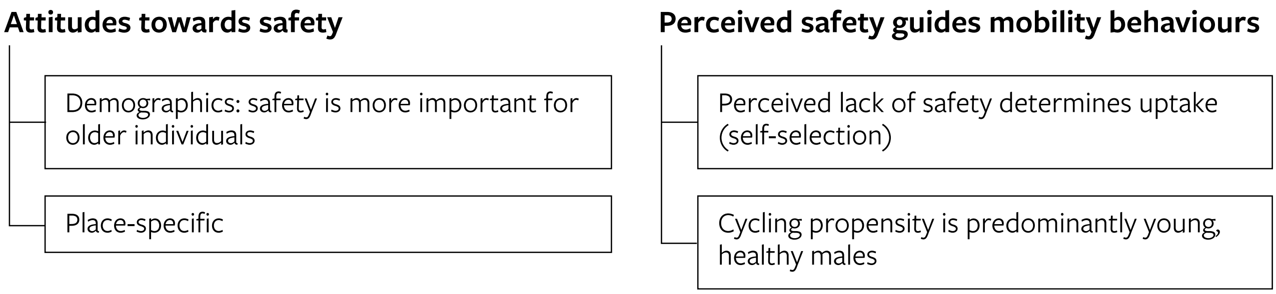
3.2.36 Therefore, those who feel safer walking or cycling – this is reflected in more positive attitudes – are more likely to walk or cycle, and to do so for longer journeys, whereas those who perceive car travel as safer tend to reduce their involvement in active travel.

3.2.37 It has been found that perceived safety is more important for older individuals than for any other demographic groups (Black and Street, 2014). Perceived safety, based on impressions, experience, and sometimes even misconceptions, refers to an individual's subjective feeling or belief about how safe a situation or environment is. This is in contrast to recorded safety data such as crime rates, collision reports, and other measurable safety indicators, that indicate the actual level of safety in a given situation or environment.

3.2.38 Perceived safety often guides mobile behaviours more than recorded safety data (Black and Street, 2014). For example, a potential rider's perception of the safety of cycling in their neighbourhood is the deciding factor that determines cycle use, whereby the "perceived possibility of collisions or conflicts plays a significant role in travel demand" (Hull and O'Holleran, 2014).

3.2.39 Self-selection, which occurs when users choose not to engage in active travel due to the perceived lack of safety (Branion-Calles *et al.*, 2020), may indicate that active travel demographics reveal a lot about perceived safety.

Figure 9. Key findings around perceived safety and demand



Addressing psychological severance for active travel

3.2.40 Interventions targeting improved walking, wheeling and cycling conditions have rarely considered psychological severance (Ogilvie *et al.*, 2010). Psychological severance refers to mental or emotional barriers that discourage people from using certain routes or modes e.g. active travel. Psychological severance may stem from excessive vehicle speeds, and features such as crossings and underpasses perceived as inconvenient or dangerous (ibid). For instance, Carlson *et al.* (2014) find that youths with fewer perceived barriers to active travel are more likely to walk or cycle to school than peers who have higher perceived barriers: their North American case studies indicate that for each additional perceived barrier to active to and from school, the likelihood of travelling by foot or cycle one to four times a week decreases by 73%, and the likelihood of travelling by foot or cycle five to ten times a week decreases by 85%.

3.2.41 Continuity of cycling infrastructure is also important for psychological (and actual) severance. Cyclist confidence and participation are higher where cycle infrastructure is segregated from other modes of transport, but it is noted that discontinuous cycle infrastructure poses a safety risk, particularly at junctions (Hull and O'Holleran, 2014). Crossings ensuring pedestrians' subjective safety also encourage walking and reduce collisions (McCartney *et al.*, 2012).

Addressing infrastructure quality for active travel

3.2.42 Road surfacing is also critical in promoting active travel. Most motorists and cyclists state that uneven surfaces are a nuisance or a danger (Hess *et al.*, 2023). The continual upgrading and maintaining of cycle infrastructure, particularly the surface material and condition, positively influences perceptions of comfort and safety (Hull and O'Holleran, 2014). This would suggest that a continual and consistent programme of maintenance of cycle infrastructure may have demand and safety benefits. Following cycleway developments in Fribourg (Switzerland), cycle-sharing increased from 5.6% to 9.8% in response to greater perceived safety (Rérat and Schmassmann, 2024).

3.2.43 Lighting plays an important role in perceived and actual safety as well. Collisions caused by poor visibility are typically significantly more severe than those with good visibility, and lighting makes users feel more visible, less at risk of collisions, and therefore more inclined to walk or cycle (Uttley and Fotios, 2017). Greenery also offsets the perception of fear, insecurity, and crime in public spaces and on routes (Sarkar *et al.*, 2015), supporting the inclusion of place-making and street environment measures in walking, wheeling and cycling schemes as well as more dedicated place-making or urban realm intervention.

3.2.44 Furthermore, in the United Kingdom, there is a strong relationship between road safety and the distance walked. Specifically, if an area that previously had no known collisions suddenly experiences a car-pedestrian collision, there is a significant drop in the distances walked in the surrounding area (Sarkar *et al.*, 2015). This suggests that improving the safety of an area may have wider, more macro effects on overall demand greater than just the prevention of those collisions.

Recommendations – safety

3.2.45 This final section reports a set of evidence-led recommendations that can be applied to the UK context. It also considers areas of further research that are needed to quantify the safety impacts associated with types of infrastructure in the ATE classification, in addition to areas the reviewed evidence recommends should be explored or taken forward to improve our understanding and quantification of safety impacts. These have been separated out into recommendations emerging from the literature, as well as those stemming from professional experience and knowledge of current appraisal guidance.

Table 6. Evidence-based recommendations – Safety

Point	Evidence-based recommendations – based on existing findings
Accessibility, connectivity and safety	Interventions should focus on accessibility, connectivity and safety, particularly in areas with mixed land-use where collisions risks are higher (Chen, 2015). Based on the evidence, interventions that have a positive impact on safety include: • Lighting • Greenery • Surface maintenance • Lower road speeds
Equal treatment for cyclists	To implement functional and adequate cycling facilities, cycling must be taken as seriously as other modes of transport (driving, walking, wheeling, taking public transport, etc.). It is therefore important to acknowledge that individuals feel safer when cycling infrastructure provides convenience and safety (Hull and O'Holleran, 2014). In practice, this suggests the potential positive safety benefits of: • Continuity of infrastructure • Segregation (from vehicles) over non-segregation • Appropriate wayfinding
Caution with shared footways	Shared footways shift the potential risk of injury disproportionately to pedestrians, particularly vulnerable users, and therefore would have lower benefits in terms of safety as a result. If shared pathways are necessary to ensure a complete network/route, enforce a speed limit of 10 km/h for cyclists to mitigate risks (Chong *et al.*, 2010).
Safey benefits of segregation	Findings from various studies (Hull and O'Holleran (2014), Reynolds *et al.* (2017), Chen (2015), Reynolds *et al.* (2009), McCartney *et al.* (2012)) potentially support the opportunity for AMAT to value the safety benefits of segregated infrastructure vs. non-segregated infrastructure.

Point	Evidence-based recommendations – further research needed to support appraisal guidance
Study localised cycle-pedestrian collisions	Research should focus on specific locations to identify exposure risks and understand the safety-in-numbers effect more accurately (Ram *et al.*, 2022; Elvik and Goel, 2019). Studies of specific routes and junction types with and without active mode infrastructure, in different locations, would support appraisal guidance by indicating where the higher risks of collisions are located and how different infrastructure types generate varying safety benefits.
Methodological limitations	Further research needs to be undertaken as data has not always been comparable, due to changes in British collision severity identification post-2015 and the under-reporting of non-vehicle collisions (Mulvaney *et al.*, 2015).
Data availability	Past studies tend to assess speed limits rather than actual speeds for cost- and time-efficiency purposes, so further studies could look at actual speed data instead (Aldred *et al.*, 2018).
Harmonise terminology and reporting practices	Different reporting practices currently hinder cross-regional analyses (Branion-Calles *et al.*, 2020). Injury severity studies compare outcomes within injured populations, focusing on the severity of injuries rather than the original risks of the events which does not shed light on all collision risks (Branion-Calles *et al.*, 2020; Reynolds *et al.*, 2009). In addition, “off-road cycling facilities” encompass a wide variety of facility types, which explains why it is still difficult to know exactly what facilities are the safest (Reynolds *et al.*, 2009).
Build on existing risk exposure assessment techniques to inform appraisal methods	Appraisal could be informed by current assessment techniques that researchers have developed. For instance, cycle mileage and time mileage used simultaneously can better represent risk exposure (Ram *et al.*, 2022). In addition, Ye *et al.* (2024) combine both the proportion of cycle accidents (PCA) and the severity of cycle accidents (SCA) in a metric called “Cycle Safety Level of Road Environment (CSL-RE)” to indicate cycling safety levels at the road segment level. Providing London with an overall accuracy of 83.4%, CSL-RE is a machine-learned tool that analyses risk factors for urban design and planning and can more effectively represent and quantify cycling safety levels than current methods.
Integrate additional analysis tools	Chen *et al.* (2017) advocate for the integration of Level of Traffic Stress (LTS) in ATE’s analyses to demonstrate the geospatial correlation between higher LTS roads and collision classification. Nellthorp (2023) calls to integrate AMAT with Transport for Greater Manchester’s (TfGM) Programme Entry Appraisal Tool to strengthen safety considerations.
Adopt multi-criteria risk evaluation	Changing a single built environment factor will not significantly lower collisions risks (Chen, 2015).

Table 7. Industry-based recommendations – Safety

Point	Industry-based recommendations – Further research needed to support appraisal guidance
Localised cycle-pedestrian collision analysis	Future research into collision risks, active travel and the impact of built environment interventions should explore how local factors and specific types of locations and built environments affect risk to better understand both context and the safety-in-numbers effect.
Methodological limitations	Recognise and address the limitations of current research and reporting methods for accident and collision data, such as the under-reporting of non-vehicle collisions.
Harmonised reporting	Develop consistent definitions for infrastructure types, active travel modes, and collision inclusion criteria to enable cross-regional analyses and facilitate future research.
Adopt multi-criteria risk evaluation	Future research and interventions should evaluate a range of built environment factors to effectively reduce collision risks, recognising that single-factor changes are unlikely to have a significant impact.

3.2.46 As can be seen across the research in this section, the impact of many factors on actual and perceived safety is context-dependent and sometimes inconclusive. However, there is evidence of safety benefits for certain infrastructure interventions that should potentially be built into appraisal guidance. Furthermore, as recommended by Chen (2015), future interventions should acknowledge that changing a single built environment factor will not significantly lower collisions risks; future research must instead continue to assess interventions via the evaluation of multi-criteria risk factors.

3.3 Place quality and urban realm

3.3.1 This section explores how place quality and urban realm improvements can shape an environment that is conducive to active travel, with a set of evidence-based recommendations and areas for further research following. The section focuses on the following themes:

- **Theme 1:** Urban environment quality and active travel uptake.
- **Theme 2:** Influence of competing modes, transport hubs and development-led infrastructure on active travel uptake.
- **Theme 3:** Street environment enhancements and their influence on active travel.
- **Theme 4:** Access to amenities via active travel.

Theme 1: Urban environment quality and active travel uptake

Introduction

3.3.2 This section explores how the quality of the urban environment influences active travel, and how urban realm improvements affect different groups.

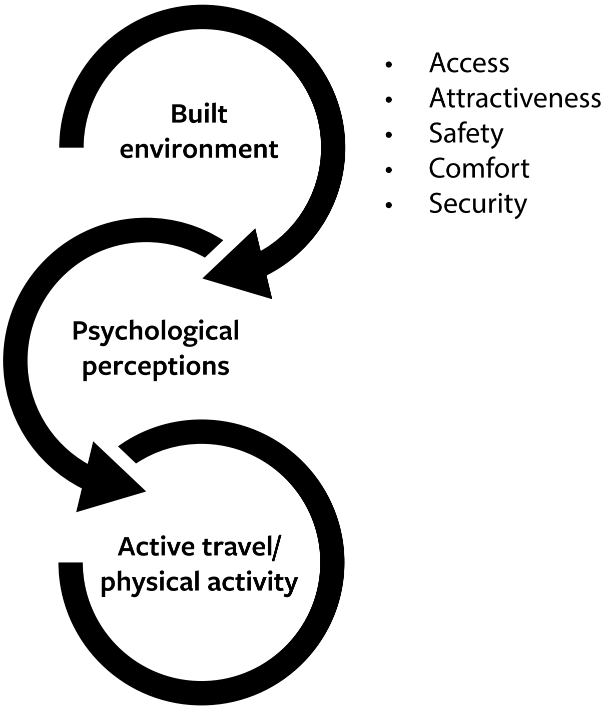
Encouraging uptake via urban realm improvements

3.3.3 Physical infrastructure, including elements such as planting, benches, fountains and other such urban realm features, plays an important role in encouraging travel by active modes.

3.3.4 Initially, it is such physical infrastructures that determine the quality of an environment in terms of access, attractiveness, safety, comfort, and security (Krizek *et al.*, 2009). The quality of the environment then determines behaviour (ibid), as changes in perceptions and psychological factors may directly impact walking, wheeling and cycling levels (Black and Street, 2014). Indeed, public realm improvements can, in themselves, encourage behaviour change (Aldred, 2019), and a supportive environment may be a prerequisite to driving more travel by sustainable modes (Panter *et al.*, 2016). This suggests that the quality of the environment – determined by initial quality and interventions to improve that quality – can increase levels of active travel.

3.3.5 It is noted that practitioners may be reluctant to invest in public realm enhancements without any existing evidence of the space being used for active travel, but Rérat and Schmassmann's (2024) findings of a 20% weekday increase in active travel following cycleway developments in Swiss towns support the "build it and they will come" argument. Qualitative studies often suggest that participants are interested in cycling more but consider that their environment is not conducive to active travel uptake and so choose other modes. For instance, over half of those who were not considering adopting active travel modes when surveyed ahead of the London Olympics (before infrastructure supporting such modes was built) eventually did go on to do so (Aldred, 2019). Public realm improvements leading to greater safety and comfort are therefore considered critical for encouraging car commuters to shift to cycle commuting (Chen *et al.*, 2017).

Figure 10. Interaction of the built environment, psychological perceptions and propensity to travel via active modes



Balancing active travel modes: addressing diverse needs and impacts of infrastructure

3.3.6 Walking, wheeling and cycling are not necessarily dependent upon the same criteria, expectations or standards: in Glasgow, for example, the highest levels of cycle commuting tend to occur where the cycling infrastructure is of highest quality, while pedestrian commuting takes place in areas where there is no significant severance (McCartney *et al.*, 2012). This shows that different urban realm improvements will influence different active travel users in different ways.

3.3.7 It is also key to note that public enhancements addressing one mode of active travel may poorly impact another mode: for instance, cycleway improvements may incur severance for pedestrians, potentially preventing less agile pedestrians from being able to cross carriageways within the time allotted by signalised crossings (Ram *et al.*, 2022). However, this must be considered in the round, as there are also potential benefits as new infrastructure tends to attract new users, rather than just increasing the activity of those who already walk or cycle (Panter *et al.*, 2016).

3.3.8 Changes to urban realm may have different impacts on different demographic groups. Older people are typically more sensitive to the urban environment when choosing their mode of transport (Black and Street, 2014), suggesting there may be greater benefits of improved urban realm amongst this demographic group. Furthermore, while women typically engage in fewer minutes of cycling than men on average, they are likely to walk for longer (Dill *et al.*, 2014), suggesting there may be differences in how men and women perceive and react to urban realm improvements, and the corresponding benefits that may be derived from them.

Theme 2: Influence of competing modes, transport hubs and development-led infrastructure on active travel uptake

Introduction

3.3.9 This theme examines how public transport, enhancements to public transport hubs, and infrastructure around residential developments influence the demand for walking, wheeling and cycling. Active travel is deeply interconnected with the broader transport network, and factors such as the quality, convenience, and cost of alternative modes impact the likelihood of walking, wheeling or cycling.

The relative cost and accessibility of active travel compared to other modes

3.3.10 Active travel uptake is contingent upon many factors, including potential users' access to alternative transport modes. For example, where public transport is unreliable, difficult to use, or inconvenient, users tend to walk more (Ogilvie *et al.*, 2010).

3.3.11 Active travel also varies depending on the costs of other modes of transport. In London, cycling data shows clear responses to Transport for London (TfL) fares, increasing when fares rise and decreasing when fares decrease (Mulvaney *et al.*, 2015).

Active travel infrastructure and connectivity

3.3.12 Improved cycling infrastructure at stations can also make a notable impact on levels of active travel. Rérat and Schmassmann's (2024) Swiss study indicated that 13% of observed cycling trips started at the train station that was connected to the newly implemented cycle lanes, and showed that the implementation of cycling paths near train stations increases intermodal accessibility, thereby potentially generating transport benefits beyond the cycle leg of the users' journey. The evidence suggests that cycle facilities significantly impact cycling commuting levels, potentially supporting further provision of cycle facilities at interchange hubs.

3.3.13 Conversely, disorganised transport infrastructure at hubs can hinder existing levels of walking, wheeling and cycling, steering users away from active travel. While the benefits of secure cycle parking have yet to be explored in a conclusive manner, there is evidence that overcrowded or disorderly parking in station forecourts or on cycleways, footways, in green areas or in open spaces has led to reduced levels of active travel (Hess *et al.*, 2023).

Residential access to active travel infrastructure

3.3.14 Building cycling infrastructure in proximity to residential developments does not always have significant impacts on active travel uptake (Dill *et al.*, 2014). It depends on other factors, such as trip destination and the scale of intervention, cycling infrastructure and easier cycling conditions significantly increase the amount of cycle sharing (via docked or dockless cycles). As an example, following the introduction of a new cycle lanes in Switzerland, Rérat and Schmassmann (2024) find that cycle sharing doubled (2024). Exposure to such facilities thus reinforces occasional and spontaneous uses and supports the convenient and visible provision at hubs.

3.3.15 Overall, these points support the provision of high-quality cycling infrastructure across networks, as well as interventions that increase the capacity and quality of existing facilities.

Theme 3: Street environment enhancements and their influence on active travel

Introduction

3.3.16 This section explores how street environment enhancements increase walking, wheeling and cycling. It examines how factors such as navigability, streetscape quality and infrastructure quality guide trip behaviour and impact individual preferences. The analysis considers the importance of features like lighting, direct routes and greenery, highlighting their role in shaping perceptions of safety, comfort and accessibility. Additionally, it addresses how the purpose of trips and user perceptions drive travel patterns, emphasising the need for tailored interventions that consider the varying needs of different population groups.

Navigability

3.3.17 The design or redesign of complex parts of a cycle route encourages more cycle use (Mulvaney *et al.*, 2015). For example, situations in which a "two stage right turn" is required for cyclists can be overly convoluted – however, providing an option that simplifies the junction so that cyclists can make all movements in one go would likely increase usage.

3.3.18 Visibility and lighting are also key design elements for active travel routes, as they determine the navigability, personal security and safety of a street environment (Chen *et al.*, 2017; Ye *et al.*, 2024). While habitual journeys may be less likely to be influenced by light conditions (as hazards and safety concerns on the journey are well known), light conditions have a significant impact on the decision of individuals to engage in active travel for recreational purposes (Uttley and Fotios, 2017). Comparing daytime vs. nighttime patterns, the volumes of pedestrians and cyclists in Virginia (USA) is 62% and 38% higher (respectively) during daylight conditions than after-dark (ibid). While it is noted that fewer people travel during the night in general (which may explain part of these results), these findings still indicate that there is "potential of road lighting as a measure to encourage active travel after-dark" (ibid). In particular, road lighting could encourage recreational travel or use of a space, which is typically the main goal of improving urban spaces. Similarly, survey respondents in studies often praise paving and lighting improvements, including improvements to local high streets or open spaces (Ogilvie *et al.*, 2010).

3.3.19 In addition, infrastructure interventions facilitating directness and decreasing the differential in journey time between cycles and cars have the potential to increase cycle uptake (Rérat and Schmassmann, 2024). Specifically, users have expressed their preference for cycle boulevards and tracks which enable faster, more direct links (Dill *et al.*, 2014). Indeed, as might be expected, cycle journey duration is negatively correlated with cycle use (ibid). Wayfinding measures such as clear, targeted signage also support directness, as users do not need to stop or second-guess their routing.

3.3.20 However, it is important to note that enhancing the attractiveness or safety of a cycling or pedestrian route has been found as more important than minimising the distance to a destination (Black and Street, 2014), potentially placing the quality of an urban environment or street corridor ahead of an intervention that prioritises directness, travel distance or speed.

Figure 11. Impacts of improved navigability

Visibility and lighting:	• Drives more active travel journeys at night. • In particular, encourages recreational usage of space at night.
Infrastructure interventions:	• Direct cycle boulevards and tracks most preferred. • Journeys of longer duration negatively correlated with cycle use, although environmental quality is typically more important.
Wayfinding measures:	• Signage can assist in making routes feel more direct.

Streetscape quality

3.3.21 The quality and diversity of the streetscape plays a notable role in attracting pedestrians and cyclists. Individuals are more likely to engage in active travel to or through places they find attractive or feel a personal connection with; conversely, they avoid places they do not appreciate (Black and Street, 2014). The evidence suggests that individual reactions to aesthetics and journey quality in and through a place significantly impact on personal mobility and physical activity levels.

3.3.22 Key issues are infrastructure quality or condition, the number of cycling facilities, and route connections (Hess *et al.*, 2023; McCartney *et al.*, 2012). Local street connectivity and the density of street trees within a kilometre along the road network are streetscape features likely to be positively associated with walking. Furthermore, the density of streets (e.g. streets closer to each other) is associated with higher propensity to walk (Sarkar *et al.*, 2016), with higher density resulting in greater local level street connectivity and proximity to services. This links back to navigability discussed above and demonstrates that street density can influence and improve more than one aspect of urban realm.

3.3.23 The diversity of the streetscape is a key factor in enhancing the likelihood of walking, wheeling and cycling (Song *et al.*., 2017), whilst diverse streetscapes also encourage longer durations of active travel (Zhou *et al.*., 2024). Diverse streetscapes include a range of built environment features, such as well-connected streets, sidewalks, buildings and green spaces (Song *et al.*, 2017), ideally with varied typologies within each of these categories.

3.3.24 Research indicates that an increase in the mean Green View Index, which measures urban greenery at street level using street-level imagery to assess vegetation from a human perspective, significantly enhances the likelihood of active travel (Yu *et al.*, 2024). Yu *et al.* analyse 26 academic articles that study the influence of greenery on active travel, and conclude that eye-level greenness is significantly associated with increased odds of walking, wheeling and cycling. For instance, increases in the Green View Index within 400m and 800m catchment areas increase the likelihood of walking by 14.9% and 19.3%[3] respectively, and lead to longer walking times. This is especially the case within 150m, 400m and 800m catchment areas for walking, and 400m, 800m, and 1600m catchment areas for cycling. The role of greenery in fostering active travel uptake is key, as it creates visually attractive, safe, and comfortable environments, facilitates

3 These statistics are for multiple Hong Kong case studies but similar patterns have been observed in European and North American urban environments.

social engagement, and "yields a significant direct effect on walking satisfaction through [...] the mediation of noise and PM2.5-related nuisances" (*ibid*).

3.3.25 In urban planning, blue corridors pertain to waterways and aquatic ecosystems, and green corridors are greenways such as wildlife corridors, parks and forests. Sarkar *et al.* (2015) found that the odds of people walking increase by 6% in London for each additional unit of tree density, and their sensitivity analyses – which were also supported by Yu *et al.* (2024) – revealed favourable associations between the distance walked and the presence of street trees. The development of blue and green corridors may support active travel uptake as streetscape diversity and aesthetics are conducive for active travel. Studies evaluating greenery and cycling that are reported by Yu *et al.* (2024) indicate that an increase eye-level greenery is associated with a 1.5% increase in cycling frequency on weekends and days. However, when considering greenway openness, findings show that greater openness is associated with a 0.5% increase in cycling frequency on weekends, but a 1.1% decrease in cycling frequency on weekdays, indicating that enclosed environments may be more conducive to cycling on weekdays whereas more open environments may be detrimental to cycling frequency on weekdays. These findings are relevant to Chinese study areas, but similar patterns have been observed in European and North American urban areas as well. In addition, research notes that higher greenery coverage can make the road environment riskier by increasing the number of features that users must perceive; a more complex environment potentially reduces users' attentiveness to others (Ye *et al.*, 2024).

3.3.26 Modal shifts following the implementation of public realm enhancements generally occur over a two-year period following intervention completion (Song *et al.*, 2017), indicating that there is a ramp-up period potentially to be built into the appraisal of public realm benefits, as users become familiar with and there is increased awareness of the improved environment.

3.3.27 It should be noted that, overall, evidence that built environment interventions lead to active travel is stronger for cycling than for walking (Song *et al.*, 2013).

Differential perceptions by demographic

3.3.28 As well as demographic characteristics impacting how population groups will react to safety improvements, as noted in the section on Safety, these characteristics also influence how population groups will respond to urban realm improvements.

3.3.29 Acknowledging different population groups' perceptions of new infrastructure may maximise the benefits of those interventions by understanding what is most important, for whom and in what context (Aldred, 2019). Furthermore, passive exposure to new transport infrastructure may not be sufficient to incur behavioural shifts in travel patterns (Branion-Calles *et al.*, 2020).

3.3.30 Although an infrastructure enhancement might seem helpful, it can inadvertently have adverse impacts on specific population groups, influencing their overall experience and accessibility in active travel. For instance, an underpass in Glasgow, implemented to provide a direct, traffic-free route for cyclists and pedestrians, was perceived as threatening or unpleasant by women, older people, and those with limited mobility (Ogilvie *et al.*, 2010). Similarly, well-designed places can attract large quantities of people, which, whilst achieving the common goal of activating urban realm, may make the space harder to navigate for those with mobility impairments or sensitivities.

3.3.31 Consideration of such varied perceptions should be taken into account when designing and appraising active mobility infrastructure.

Theme 4: Access to amenities via active travel

Introduction

3.3.32 This section explores how access to local facilities influences walking, wheeling and cycling. Zhou *et al.* (2024) note five factors that are considered in the urban development literature to explore how travel patterns are shaped. These five factors are referred to in academia as the 5Ds: density, diversity, destination accessibility, distance to transit, and design. Density refers to the concentration of activities and population within an area; diversity measures the variety of land-use types; destination accessibility is how easily individuals can reach locations; distance to transit is the shortest distance to public transport; and design encompasses street network features and amenities including connectivity. Zhou *et al.* (2024) point out that these are the five factors that, collectively, shape travel demand and determine active travel uptake. Enhancing the quality, aesthetics, and connectivity of urban environments around key origin points (such as residences) and destination areas (including workplaces, schools, and amenities) is crucial for fostering active travel.

Connectivity and its role in active travel

3.3.33 Accessibility to work and services is positively associated with active travel (Song *et al.*, 2013), and direct routes with good access to shopping, commuting and education can encourage cycling (Hull and O'Holleran, 2014). This is even more so for obligatory journeys, where distances to site is strongly influence modal choice (Song *et al.*, 2013). Interventions providing improved connectivity to services, particularly those that address a clear severance issue, as epitomised by the Clyde bridge in Glasgow (opened in 2006 as a new link between the city centre and southern suburbs), bolster active travel (McCartney *et al.*, 2012). However, as discussed previously, directness must be balanced with improving journey quality.

3.3.34 Given the greater impact on obligatory journeys, targeting school, work and home settings with built environment interventions is key. For example, creating environments in areas with younger demographics and on key desire lines to schools (through mixed land use allocations and marked street crossings) is positively associated with active travel to and from school (Carlson *et al.*, 2014).

3.3.35 Similarly, proximity to service destinations such as supermarkets is positively associated with walking (Sarkar *et al.*, 2016) and providing quality infrastructure close to university campuses could encourage young adults to engage in active travel early in life and reflect these mode choices as they age (Rérat and Schmassmann, 2024).

3.3.36 The evidence on residential proximity to active travel infrastructure and its impact on usage is mixed. Living closer to a town centre is associated with greater engagement in cycling, wheeling and walking (Dill *et al.*, 2014), and Panter *et al.* (2016) found that those living 4 km away from a new busway in Cambridge are 34% more likely to increase active travel commuting compared to those living 9 km away. However, convenience of access does not always lead to higher usage of greenways (Yu *et al.*, 2024). This may be because direct exposure to the use of infrastructure (seeing it in use) is more strongly correlated with a modal shift towards walking or cycling than passive exposure to the active travel infrastructure (merely living near it) (Song *et al.*, 2017). Therefore, while interventions near potential users may offer benefits, it is crucial to ensure that these interventions are well-connected to key destinations and services to effectively induce demand.

The role of networks in active travel

3.3.37 The evidence suggests that an active travel network, as opposed to single, discrete interventions, potentially generates greater benefits in a wider variety of areas. But currently the benefits of a wider network and connectivity between streets and corridors, as opposed to a corridor in its own right, are not captured in appraisal guidance.

3.3.38 Well-connected, dense urban networks play a key role in encouraging active travel as perceptions of environmental quality, aesthetics and accessibility are key predictors of walkability (Sarkar *et al.*, 2015). However, low objective street connectivity, whereby there are few intersections to cross, and high pedestrian safety, are related to more active travel to school (Carlson *et al.*, 2014). This means some balance must be struck between generally high street density to encourage active travel and low street connectivity around schools, which supports travel specifically to schools.

3.3.39 'Betweenness' is a measure of street network connectivity used in research. The betweenness of a road network link indicates the expected level of through-traffic based on its connectivity to other parts of the network within walking distance. Comparing these betweenness measures for different links enables researchers to identify which roads are likely to experience higher pedestrian flows. Measured within a 400m radius for pedestrian flows, findings indicate that walking trips increase with higher local-level street betweenness (access to each other) and with access to service destinations (Sarkar *et al.*, 2015).

3.3.40 Place quality benefits are also driven by changes in location attractiveness, such as changes in the level of walking, wheeling and cycling facilities and amenities in the area where the person lives and accessible from a person's home location are therefore crucial for active travel uptake (Nellthorp, 2023).

Figure 12. Impacts of design, proximity and networks of infrastructure

5Ds framework

- Higher population density is a support environment for active travel.
- Mixed land use encourages walking, wheeling and cycling.
- Accessibility to work, services, and schools boosts active travel.
- Proximity to transit options promote active travel.
- Design is key, as quality and connectivity of infrastructure influence mode choice.

Influence of infrastructure

- Direct routes encourage active travel, particularly for obligatory journeys.
- Users prioritise quality and safety over directness or duration.
- Improved links to services and connectivity enhance active travel.

Targeted interventions

- Built environment changes around schools and the workplace can increase active travel.
- Environments designed for young people promote long-term active travel.
- Close proximity to services and amenities encourages active travel.
- There is mixed evidence on the impact of residential proximity.

Exposure and usage

- Seeing infrastructure in use (direct exposure) is more effective in promoting active travel than merely living nearby (passive exposure).
- Well-connected Interventions are essential for inducing demand and ensuring effectiveness.

Designing cohesive networks

- Enhancing street betweenness for pedestrian flows correlates with increased walking trips.
- The availability of facilities and amenities is crucial for encouraging active travel.
- Network connectivity improves environmental quality, aesthetics, and accessibility, and enhances active travel.

Recommendations – place quality and urban realm

Introduction

3.3.41 This section outlines the key evidence that can be transferred to the UK context, as well as suggestions for primary research to better understand the public realm benefits associated with different types of infrastructure in the ATE classification. These suggestions for further research are based on both evidential findings and professional experience of appraisal guidance.

Table 8. Evidence-based recommendations – place quality and urban realm

Point	Evidence-based recommendations – Recommendations based on existing findings
Focus on the three pillars of active travel	Interventions should aim to improve accessibility and connectivity, enhance traffic and personal safety, and enrich the experience of walking, wheeling and cycling (Panter *et al.*, 2016).
Context-sensitive interventions	Implementing green spaces in poorly maintained or neglected neighbourhoods can lead to neglect of safety issues, thus reducing people's willingness to walk or cycle in those areas (Ogilvie, 2010). Therefore, interventions in all areas or circumstances without considering the wider context that could influence their success may have negative impacts.
Acknowledge short-term vs. long-term impacts	In the short term, active travel uptake does not indicate a replacement of car journeys but rather additional journeys; car journeys are partially replaced over time (Aldred, 2019). Furthermore, public realm schemes generally generate demand and modal shift benefits over a two-year period as awareness of the infrastructure increases (Song *et al.*, 2017).
Expand appraisal guidance to account for more local facilities and street-level factors	Include local facilities, green spaces, noise, pollution, collision risk, severance, and cleanliness in transport appraisal, recognising their impact on both place and movement functions (Nellthorp, 2023).
Holistic approach to severance	Severance may persist due to personal physical difficulties or due to the perception that an environment is unpleasant or unsafe (Ogilvie *et al.*, 2010), and therefore quantifying the impacts of severance should take these factors into account.

Point	Evidence-based recommendations – Further research needed to support appraisal guidance
Capture benefits for existing active travel users	Interventions should aim to increase active travel usage for those already involved, while simultaneously developing interventions to bolster cycling uptake for new individuals (Song *et al.*, 2013). Further research is needed to quantify existing user benefits.
Consider quality and proximity and amenities	Many studies continue to overlook the quality or proximity of amenities and the routes leading to them, which results in the inability to find strong links between active travel and spatial factors (Ogilvie, 2010). Studies that establish stronger links between these two in urban realm schemes would be beneficial.
Explore the link between quality of life and active travel uptake	While it is known that active travel levels are in part dependent upon quality of life and wellbeing, few studies have explored how quality of life may directly impact active travel, and further research should be undertaken to explore this "bidirectional relationship" (Black and Street, 2014). This could include factors such as residential density, street connectivity, retail floor area ratio, mixed-use development, cul-de-sac density, and green areas.
Research differential impacts on diverse groups	There is a lack of evidence around differential impacts of interventions, particularly for walking, with stronger evidence for cycling (Aldred, 2019).
Consider diverse populations	Vehicle owners and people with a disability tend to shift to walking less than those without a vehicle or without a disability (Sarkar *et al.*, 2015), and further research could quantify this for appraisal purposes.

Point	Evidence-based recommendations – Further research needed to support appraisal guidance
Strengthen methodological rigour	Much of the evidence supporting active travel interventions and the differential impacts of interventions is methodologically weak and limited to 'grey' literature (Aldred, 2019).
Benefits of secure cycle parking	There is limited existing evidence into the benefits and demand impacts of secure cycle parking at stations. Further research in this area would support the expansion of this type of infrastructure investment in appraisal.
Effects of different improvement types	There is limited evidence of the scale of modal shift benefits generated by different types of public realm improvements.

Table 9. Industry-based recommendations – place quality and urban realm

Point	Industry-based recommendations – Further research needed to support appraisal guidance
Acknowledge short-term vs. long-term impacts	Recognise in appraisal and in forecasting that short-term increases in active travel often result in additional journeys overall, rather than replacing car trips; car journeys are only partially replaced over time.
Holistic approach to severance	Redefine severance and any future studies into the impacts of severance, acknowledging that it is not merely alleviated by infrastructure improvements; personal physical challenges and negative perceptions of the environment can contribute to ongoing severance.
Capture benefits for existing active travel users	Research should focus on interventions that increase activity levels for current users and quantifying the level of impact on existing users, a benefit that is not currently included in appraisal guidance.
Understand behavioural shifts	Investigate long-term behavioural changes following active travel interventions, including the short- and long-term impacts on vehicle trips noted previously, and establish the best study designs to measure these changes.
Address differential impacts on diverse groups	Conduct more research on the differential impacts of interventions, particularly for walking where the research and existing evidence is weakest.
Consider diverse populations	The impacts on motorised vehicle owners and people with disabilities, and how these impacts can vary, in research into public realm and place quality impacts.
Strengthen methodological rigour	Improve the methodological quality of studies in active travel to provide more robust evidence for quantifying intervention impacts.

3.4 Journey quality

3.4.1 This section explores how journey quality can impact the experience and uptake of active travel. It is noted that compared to safety and place quality, this area is quite well-explored from the research perspective, and so there are limited additional factors to cover. The section is therefore organised around a singular theme: key components of journey quality and their impact on active travel uptake, which also outlines some common approaches to improving journeys. Following this, recommendations are made, as well as an outline of areas for further research.

Theme 1: Key components of journey quality and their impact on active travel uptake

Introduction

3.4.2 Journey quality plays a critical role in encouraging the uptake of walking, wheeling and cycling. Factors such as comfort, safety, continuity and overall experience influence an individual's decision to walk or cycle. High-quality infrastructure, including dedicated cycle lanes, well-maintained pathways and traffic-calming measures, enhances the experience, making active travel more appealing and accessible.

Assessing journey quality

3.4.3 Enhancing accessibility and connectivity, better handling traffic and personal safety, and the improving experience of walking, wheeling and cycling are three common resources that interventions provide to encourage active travel (Chen, 2015). This last element, journey quality, may be difficult to assess and determine as it relies on mostly subjective characteristics. Furthermore, there is an inherent overlap between connectivity, safety and journey quality, as one can perceive the quality of their journey in respect of how safe it is and how connected their route is. However, the current cycling demography (i.e. primarily adult males with high fitness levels) helps us identify who feels at ease with the infrastructure, and those who do not through their absence or lower propensity.

The components of journey quality

3.4.4 Coherence, directness, attractiveness, safety, comfort, spatial integration, experience, and social economic value are components of journey quality defined by Hull and O'Holleran (2014). These are defined as follows:

- Coherence refers to continuity, logically connected destinations.
- Directness is the extent to which infrastructure provides users with the shortest/fastest routes that consider costs of travel time.
- Attractiveness refers to safety-focused design.
- Safety refers to the cohabitation of users without conflict.
- Comfort refers to smooth navigation with adequate surfacing and low gradients.
- Spatial integration refers to the wider network and heritage.
- Experience is users' feedback.
- Social economic value considers facilities and developments (*ibid*).

3.4.5 Hull and O'Holleran (2014) also note that comfort, safety and continuity of the cycling network are factors which drive cycling uptake. Evidence shows that cyclists value a reduced frequency of stops, and a reduced time waiting at intersections (Nellthorp, 2023), which demonstrates that journey quality also relates to journey efficiency and continuity as well as the traditional measures that enhance the sense of 'comfort' while riding.

3.4.6 To differentiate between safety and comfort, the example of poor road conditions can be taken. Poor road conditions (e.g. with potholes) hinder cycling comfort levels (Hull and O'Holleran, 2014), which would suggest benefits for schemes that both improve and maintain surface quality. A route can, however, be comfortable without being considered safe: in the case of Branion-Calles *et al.* (2020)'s study on seven European cities (London, Zurich, Vienna, Rome, Antwerp, Barcelona, Orebro), while approximately 73% of all participants found cycling comfortable, only 20% found it safe from traffic.

3.4.7 Indeed, safety enhancements stemming from built environment interventions are perceived as being a basic requirement or precondition for many users (Rérat and Schmassmann, 2024). As expected, and consistent with current guidance (and the Findings section of this report), cycle infrastructure appeals more to cyclists when it is separated from traffic. The implementation of a cycle lane in Fribourg, Switzerland significantly enhanced participants' view on comfort with a 22% increase in the number of people finding it more "enjoyable" and "faster" than before (Rérat and Schmassmann, 2024). Comfort scores are even higher when cycleways are segregated in comparison to on-road lanes (Hull and O'Holleran, 2014). Users frequently draw attention to the lack of safety due to having to ride close to motorised modes, as was noted in the Findings section of this report in reference to painted on-street cycle lanes. Journey quality is reduced if users consider that cars are too close, if there are parked vehicles or if vehicle speeds are considered too high (Rérat and Schmassmann, 2024).

3.4.8 However, safety alone is not enough; surface quality, and therefore comfort, of these infrastructures is still an important factor in whether or not users choose to engage in active travel. Indeed, Hess *et al.* (2023) identified that most of their sample considered uneven surfaces to be uncomfortable or inconvenient. This demonstrates the importance of the aesthetic appeal through maintenance: well-maintained surfaces contribute to the visual appeal and reflect care and investment in an area, which can positively influence people's willingness to use the space and the infrastructure. This indicates that maintenance programmes would generate benefits and demand uptake for users, although these are not features currently captured in the appraisal guidance.

3.4.9 Separately, there is evidence that the diversity of street environments and interventions that increase the prevalence of green features play a role in improving users' journey quality. It is noted that "street greenness carries a notable direct effect on the level of satisfaction associated with walking" (Yu *et al.*, 2024) and that diverse streetscapes and navigable routes make active travel routes more appealing to individuals (Zhou *et al.*, 2024.

3.4.10 There is also a question of where to prioritise these route improvements. So far, active modes are typically used in a higher proportion of leisure trips than for mandatory trips (Branion-Calles *et al.*, 2020), meaning that further support for mandatory trips may be necessary. Given the impact of the varied aforementioned route improvements on active travel uptake, it is considered that enhancements on key walking, wheeling and cycling corridors used for mandatory trips may support long-term mode shift for those trips.

Common approaches for improving journey quality

3.4.11 Based on the components of journey quality above, there are a range of common tactics used to try to increase active travel uptake (and safety).

3.4.12 Many key approaches have already been outlined in the Findings section of this report, for example focusing on delivering segregated cycle tracks (instead of painted cycle lanes) and Dutch-style roundabouts (instead of junctions, where possible) – and supplementing these infrastructures with good lighting and wayfinding markets whilst reducing street clutter.

3.4.13 Traffic-calming measures such as reducing the presence of motor vehicles, reallocating street space, creating dedicated cycling lanes, and reducing congestion are other common approaches, and enhance safety, comfort, and overall journey quality for active travel users (Yu *et al.*, 2024).

3.4.14 Speed restrictions on roads may remove some psychological barriers to cycling. Indeed, the uptake in cycling in Cambridge following speed limit reductions illustrates this (Hull and O'Holleran, 2014), with these measures preventing fast overtaking and encouraging high volumes of cyclists that can increase driver awareness of vulnerable road users. Measures such as cycle boulevards that use traffic-calming, diversion, signage, and junction treatments to reduce the speed and volume of motorised vehicles (Dill *et al.*, 2014) aim to create a more cycling-conducive environment.

3.4.15 Similarly, road space reallocation can be a very effective method of increasing active travel uptake. However, potential conflicts must be considered in this approach. Providing infrastructure for all users in immediate proximity of one another may not suffice. For pedestrianisation schemes, it is safer to prohibit or control cycle access, notably by providing alternative cycleways (Hull and O'Holleran, 2014).

3.4.16 Pedestrianisation schemes tend to have varied responses. Brownrigg-Gleeson *et al.* (2023) found that in in Spain, one Madrid neighbourhood called Sol, occasional visitors in particular appreciated pedestrianisation, whereas in the adjacent neighbourhood of Olavide, it was the more frequent visitors who were most in favour of recent pedestrianisation schemes. Regarding the association between wellbeing, attractiveness, and active travel, 68% of residents in both areas were satisfied with the interventions, and half of the businesses viewed the schemes positively for their commercial activity (ibid). The authors note that there was a significant increase in the use of public space and local services following the implementation of the pedestrianisation schemes.

Impact of road reallocation on travel behaviour

3.4.17 Brownrigg-Gleeson *et al.* (2023) found that although cycling has been rerouted because of a pedestrianisation scheme in Madrid, cycling levels remained similar to those pre-intervention, whereas car use has significantly fallen – indicating that demand for car use in this situation was more elastic than that for cycle use. Following this pedestrianisation scheme, across all income levels, 32.8% of participants stated that they intended to reduce car use. 91.6% of all participants indicated that they would cycle the same amount or more after the pedestrianisation scheme, and 94.9% stated that they intended to walk the same amount of more following the scheme. It is noted that intervention appraisal models often fail to account for behavioural responses when analysing road reallocation. Indeed, it is also noted that reducing motorised vehicle capacity can lead to significant overall motorised traffic reduction (traffic "evaporation") rather than diverting traffic to other routes (Nellthorp, 2023).

3.4.18 Interventions that offer better active travel options often discourage driving, but increased active travel does not necessarily reduce driving (Krizek *et al.*, 2009); this is because not every active mode trip replaces a vehicle trip and active travel uptake may represent additional journeys that were not previously undertaken, particularly as vehicle ownership is strongly associated with travel mode choice (Song *et al.*, 2013).

3.4.19 It is also noted that the development of wider footways permitted by road space reallocation is not directly associated with an uptake in walking. Research indicates that the influence of traffic volume on walking may primarily affect the choice of routes rather than the propensity to walk (Ogilvie *et al.*, 2010), indicating that people will still generally walk the same amount, just via different routes. In fact, Aldred (2019) suggests that there is limited evidence on how reducing space, time, or facilities for motor traffic affects walking, wheeling and cycling, in comparison to the effect caused by the greater space for active modes the same intervention has generated. The evidential impact of road space reallocation schemes is therefore somewhat mixed.

3.4.20 Across these examples, there are a range of features not currently accounted for in appraisal guidance, such as reducing the prevalence of parked vehicles, reducing vehicle speeds and reducing vehicle flows that contribute towards a sense of journey quality for active travel users.

Recommendations – journey quality

3.4.21 This section reports a set of evidence-led recommendations that can be transferred to the UK context without need for further primary research. It also outlines areas of further research that are needed to value journey quality elements and scheme types associated with types of infrastructure in the ATE classification. As for the sections above, recommendations are formed both from the evidence and from professional experience of appraisal guidance.

3.4.22 It is noted that the recommendations tie together several items from the other types of findings on safety and place quality, as all three areas of study are inherently linked in their ability to promote or dissuade travel by active modes.

Table 10. Evidence-based recommendations – journey quality

Point	Evidence-based recommendations – Recommendations based on existing findings
Incorporate vibrancy and aesthetics	Addressing both perceived and actual environmental factors contribute to the overall experience of cycling (Black and Street, 2014), and therefore of journey quality.
Adopt dual perspective evaluations	The quality of an environment can be evaluated from two different and distinct perspectives: the technical expert and the layperson (Black and Street, 2014).
Understand travel patterns	Mode choice may differ according to trip purpose. As defined by Song *et al.* (2013), obligatory journeys are those that are "difficult for an individual to reschedule and often" such as work, business, and school journeys, while discretionary journeys "comprise non-compulsory forms of journeys, and shopping, personal business, and social journeys". Acknowledging the reasons behind mode choice and how these decisions are influenced by trip purpose would help to adapt interventions to more specific journey purposes and quantify their impacts. For example, walking is often associated with discretionary journeys while cycling is often for obligatory journeys as "people tend to choose a faster mode of transport for obligatory journeys" (Song *et al.*, 2013).

Point	Evidence-based recommendations – Further research needed in appraisal guidance
Incorporate time savings for active mode	The existing version of AMAT quantifies journey quality improvements but does not specifically incorporate time savings for active modes. AMAT could be updated to include time savings for active modes, using the existing TAG method for user benefits (Nellthorp, 2023).
Address omissions in appraisal guidance	The existing appraisal guidance omits certain journey quality features such as "pavement/lane width, continuity and absence of clutter, frequency of stops, advanced stop lines, turn facilities, traffic exposure, speed and HGV proportion, air pollution and noise" (Nellthorp, 2023).
Quantify benefits of greenery	LTN 1/20 recognises the importance of continuity, but TAG does not value it. Furthermore, TAG does not consider or attempt to quantify the benefits of increased greenery or tree planting (Nellthorp, 2023).
Use existing tools	It is recommended that evidence is incorporated from tools like TfL's Ambience Benefit Calculator and TfGM's Programme Entry Appraisal Tool into national guidance to address gaps (Nellthorp, 2023).
Review current perceptions	Most current evidence on journey quality impacts predates 2010 and may not reflect contemporary views on active travel (Nellthorp, 2023).

Point	Evidence-based recommendations – Further research needed in appraisal guidance
Examine frequency of stops	Cyclists value a reduced frequency of stops and a reduced waiting time at intersections (Nellthorp, 2023).

Table 11. Industry-based recommendations – journey quality

Point	Industry-based recommendations – Recommendations based on existing findings
Adopt dual perspective evaluations	Adopting both a technical expert and layperson perspective may create a more holistic approach to cycle promotion and infrastructure design, and may therefore point towards both technical design and softer aesthetic interventions as key facets of journey quality.
Understand travel patterns	Recognise the different purposes of trips, the reasons for these and how these differ by modes to tailor and quantify the impact of interventions that improve journey quality more effectively.

Point	Industry-based recommendations – Further research needed in appraisal guidance
Address omissions in appraisal guidance	Expanding AMAT, or incorporating additional journey quality features into another appraisal tool, would allow the quantification of these identified gaps in the guidance.
Quantify benefits of greenery	Integrate the value of increased greenery and tree planting into appraisal guidance as a feature of journey quality.
Review current perceptions	The undertaking of new primary research should be a priority to reassess journey quality perceptions and ensure current behavioural trends and insights are captured.
Examine frequency of stops	Further explore international evidence showing cyclists value reduced frequency of stops and waiting times at intersections, and consider the incorporation of these benefits into appraisal guidance.

3.5 Valuation methods for active travel interventions

3.5.1 Journey quality is one of the seven impacts listed in TAG to be accounted for in appraisals. However, in the context of active travel interventions, the guidance notes that the "…evidence in this area is fairly limited" (TAG A5.1, 2022, p.11).

3.5.2 Specific valuation estimates for some aspects of active travel journey quality are provided within the TAG data book (TAG, 2024). These cover different cycling infrastructure types (including segregated and non-segregated cycleway) from Wardman (1996, 1997), and seven specific pedestrian environment attributes (such as street lighting and benches) from Heuman (2005). The guidance states that these valuations should be used as a maximum in appraisals and that sensitivity tests should be undertaken as there is "significant uncertainty" surrounding these values (TAG A5.1, 2022, p.3). Place quality effects of active travel are currently not included as part of the appraisal TAG guidance.

3.5.3 This review therefore seeks to understand the extent to which some of these gaps in current appraisal guidance can be addressed through recent published literature, and if so, to outline the methods used in the literature to value improvements in journey quality and place quality associated with investments in active travel infrastructure. This includes looking at three broad themes:

- What attributes of place quality and journey quality associated with active travel investments have been valued in the literature and what were the resulting valuations?
- Which valuation methodologies have been used for those attributes and what are the accompanying data collection approaches?
- What are the advantages and disadvantages of the different valuation methods in the context of active travel investments?

3.5.4 This review also identifies where gaps remain in the current literature related to the impacts of active travel investments and their effects on journey quality and place quality.

3.5.5 The valuation methods in the active travel literature reviewed can be considered in two categories:

- Stated preference: this is a group of valuation techniques that are based on questionnaires given to respondents to elicit the respondent's willingness-to-pay (WTP) for active travel attributes or willingness-to-accept (WTA) compensation for giving up attributes they value – either directly or indirectly (Atkinson *et al.*, 2007).
- Revealed preference: this is a group of valuation techniques that seek out markets in which the value of a good or service to an individual might be revealed (Atkinson *et al.*, 2007).

3.5.6 Within these two categories, seven valuation methods were found in the reviewed literature and are described in the rest of this chapter:

- Stated preference:
  - Contingent valuation.
  - Choice experiments.
- Revealed preference:
  - Choice models.
  - Hedonic pricing using geographic variation.
  - Hedonic pricing using time variation.
  - Cost method.
- A third variation that combines stated and revealed preference.

Theme 1: What attributes have been valued (and what values have been derived)?

3.5.7 Table 12 outlines the different journey quality and place quality attributes that have been valued in the reviewed active travel literature. There is relatively little overlap in the attributes valued across the different sources, therefore this section looks at each paper in turn.

Table 12. Summary of results from reviewed literature

Paper	Attribute	Valuation
Atkins (2011)	Full pedestrianisation of an area as a townscape improvement.	£20-25/year[4]
Shore *et al.* (2012)	Security cameras (CCTV) over cycle parking	7.7p/journey
	Advanced stop boxes for cyclists at traffic lights	4p/journey
	Even pavement with no cracks	7.09p/journey
	Good, bright lighting after dark	7.39p/journey
	CCTV monitoring and recording	7.29p/journey
Ginkel (2014)[5]	Increased comfort of road (moving from standard to comfortable roads)	£3.08/hour (commuters)
		£2.27/hour (recreational cyclists)
Guo *et al.* (2017)[6]	Impact on house prices of increasing access to education via active travel i.e. making education 'one unit more accessible'	£52/m^2
Liu *et al.* (2017)[7]	Increase in house prices of reduced distance from house to an advanced cycle facility	£1,210/quarter mile closer to advanced cycle facility
	Increase in house prices if the local advanced cycle facility is made longer	£1,077/quarter mile additional length in cycle facility
Wichman *et al.* (2017)[8]	Willingness to pay to travel on a 100% cycleway	4-6p/journey
Flügel *et al.* (2019)[9]	Willingness to pay to travel on a cycle lane instead of a basic road	£2.37/hour
Gössling *et al.* (2019)[10]	Willingness to accept / pay by cyclists to avoid exhaust fumes, noise and perceived traffic risk	WTA: £4.25-£45.84/week WTP: £3.40 - £20/week WTA median: £0.20 per cycle-km
Douglas *et al.* (2022)	Extra time pedestrians willing to spend to walk along a high-quality route (with pavement edges, security cameras, lighting) compared with low quality	32.4 minutes

4 Valued in 2010 prices.

5 In this paper, road quality is determined by a package of attributes. Valuations for individual attributes are not provided. The paper finds a WTP of EUR 3.63/hour for commuters and EUR 2.69/hour for recreational users, which is converted using a rate of 1 EUR = 0.85 GBP.

6 The paper estimates a WTP of $104.4 (AUS) per m^2, which is converted using a rate of 1 AUS = 0.52 GBP.

7 The paper estimates a WTP for single-family homeowners of $1,571 to be a quarter of a mile closer to an advanced cycle facility and $1,399 for their nearest advanced cycle facility to be a quarter of a mile longer. These are converted using a rate of 1 USD = 0.77 GBP. Valuations for multifamily homeowners are $211 and $3,683 respectively.

8 The paper estimates the value of a cycleway as 5.5-7.3 cents, which is converted using a rate of 1 USD = 0.77 GBP.

9 The paper estimates a WTP of 32.9 NOK/hour, which is converted using a rate of 1 NOK = 0.072 GBP.

10 The paper estimates a range from €5-€53.93 per week, which is converted using a rate of 1 EUR = 0.85 GBP.

Paper	Attribute	Valuation
Nordstrom (2022)	Increase in house prices closest (within 1 km) to Complete Street[11]	10.5% increase in house price

3.5.8 These estimates demonstrate the variety of attributes that researchers have generated valuation estimates for, and the wide variation in units used. Underlying these estimates in the literature is a variety of valuation methods, as described next.

3.5.9 The strength and relevance of valuations is an important consideration for determining what may be appropriate to include in appraisal guidance in England. Studies such as Flügel *et al.* (2019), for example, provide relatively strong evidence on the value to existing cyclists of enhancing journey quality by improving road surfaces. Using their combination of methods (which enhanced robustness) and a sample of 815 participants (recruited from a nation-wide panel in the Netherlands, an on-street to reduce bias) they estimated a value of £2.37/ hour (equivalent) to cycle on a cycle line instead of a basic road. However, further work would be needed to consider whether values such as this generated in other countries, could be used in appraisal guidance for England given the differences in context and cycling behaviour.

Theme 2: What are the different valuation methodologies (incl. data collection)?

3.5.10 This section provides an overview of the seven valuation methods found in the literature, alongside their data collection techniques. This is split into the three broad categories of: stated preference, revealed preference, and a combination.

Stated preference

Contingent valuation

3.5.11 Contingent valuation is a type of stated preference valuation method where data is collected through surveys. Researchers directly ask participants – both users and non-users of active travel infrastructure – for either their WTP for experiencing attributes they value or their WTA to avoid certain attributes. This method can be used to estimate valuations for changes in both journey quality and place quality. Researchers take the sample mean to find the average WTP or WTA across all participants or for a specific subset of participants (e.g. women).

3.5.12 Gössling *et al.* (2019) uses this method to estimate the WTP of existing cyclists to avoid noise, exhaust fumes and perceived traffic risks on their journeys. The authors used an online questionnaire sent to all Twitter and Facebook followers of the German National Cyclists' Association (ADFC) and the Austrian Verkehrsclub Österreich (VCO), from which 491 responses were received and analysed. The authors note, however, that this sample represents a more active cyclist population as the average distance cycled per week per respondent was 83.9km/week (Gössling *et al.*, 2019).

11 Complete Streets are those that take all users – not just car drivers – into account in their design. There is no one definition of a Complete Street, though they typically include raised or protected cycleways, widened pavements for pedestrians, traffic-calming elements and 'right of way' for public transport (Nordstrom, 2022).

Choice experiments

3.5.13 Choice experiments are a stated preference valuation technique where participants are asked to make a choice between different hypothetical routes. Their response data is used to build a discrete choice model to determine valuations of different attributes by assuming those choices reflect the value participants place on the attributes of the routes they are choosing between. Currently, available evidence presents the use of choice experiments to estimate valuations of the impact on journey quality and not for valuations of impacts on place quality. In theory, however, choice experiments could be applied to estimate values of place quality as participants could be offered choices between places with different attributes. Conversion of these choices into monetary values could, however, be more challenging. Potential options could include investigating pedestrians' dwell time (and applying a value of time to monetise the choice difference); or other payment vehicles, such as payments to enter particular zoned areas such as parks or gardens.

3.5.14 Choice experiments are used in five of the reviewed papers: Atkins (2011); Shore *et al.* (2012); Ginkel (2014); Flugel *et al.* (2019); and Douglas *et al.* (2022). Each of these studies relies on a survey to collect data on participants' choices. Participants were recruited and asked to complete a survey either at the time of recruitment or online at their convenience. Different recruitment techniques are used across the different papers, including on-the-street, targeted flyers inviting participation in an online survey, push-to-web using a cyclist database and panel surveys.[12]

3.5.15 Choice experiments estimate journey quality valuations in three steps:

- **Data collection:** Researchers collect route choices from participants by asking them to choose between 'route cards'. In Douglas *et al.* (2022), each route card was made up of only two attributes whereas in the other papers route cards contained multiple attributes. Douglas *et al.* (2022) and Shore *et al.* (2012) asked participants to make a pairwise choice in each choice round (i.e. between two options only), whereas Atkins (2011), Ginkel (2014) and Flugel *et al.* (2019) asked participants to choose between more than two options. By asking participants to make multiple choices over several rounds, researchers collected multiple data points from each participant.
- **Building a discrete choice model:** Researchers use participants' route choice data to build a discrete choice model. This discrete choice model assumes that travellers will choose the route that leads to the highest 'utility', this reflects time, money and other factors such as inconvenience, quality and reliability and is also known as the lowest 'generalised cost' (TAG A1.3, 2022). This model assumes that the share of participants that chose a route represents the probability that any individual would choose that route. Researchers then carry out statistical analysis by regressing these probabilities on the attributes in the route choice data, where the resulting coefficients on each attribute estimate the relative contribution of that attribute to utility.

12 Atkins (2011) used on-the-street recruitment where 782 participants (deemed appropriate by a short questionnaire) were given a £5 incentive to complete a survey at a nearby indoor venue (either electronically or by hand). Shore *et al.* (2012) gathered 1,438 participants through on-the-street leaflets with instructions for participants to complete an online survey at their convenience. Ginkel (2014) gathered participants from two sources: a pre-existing database of cyclists collected from a previous study and flyers sent to students' dormitories offering a €25 incentive. Both groups were asked to complete an online survey at their convenience, which led to 523 responses. Flugel *et al.* (2019) gathered 815 participants from a nationwide panel and on-the-street recruitment. Both groups could fill in an online survey at their convenience, but the on-the-street participants were also given the option to fill in an electronic survey at the time. Douglas *et al.* (2022) used an internet panel to recruit 1,025 participants to complete an online survey at their convenience.

- **Converting results into monetary values:** Converting the relative importance of each attribute in decision-making into monetary values, in one of two ways:
  - If financial cost (such as a public transport fare or petrol cost) was included in the route choice cards (known as a 'payment vehicle'), then researchers compare the coefficient on the financial cost variable with the coefficients on other attributes. Comparing coefficients relative to each other elicits a WTP for each attribute. For example, if the coefficient on road steepness is three times the coefficient on cost (in £), then the coefficient on steepness can effectively be converted to a monetary value suggesting that participants would be willing to pay £3 to avoid a route that is one unit steeper. This approach was used by Atkins (2011), Shore *et al.* (2012), Ginkel (2014) and Flugel *et al.* (2019).
  - If time was included in the route choice cards, then researchers compare the coefficient on the time variable with the coefficients on different attributes (to effectively convert them into a time equivalent) and combine this with an appropriate value of time estimate. For example, if the coefficient on road steepness is twice the coefficient on time (in minutes) and an appropriate value of time estimate is 20p/min, this would suggest that participants would be willing to pay 40p to avoid a route that is one unit steeper. Douglas *et al.* (2022) uses this approach.

Revealed preference

Choice models

3.5.16 Choice models are a revealed preference valuation technique that use data on participants' actual route choices to estimate WTP for journey quality attributes.

3.5.17 This approach is used by Ginkel (2014) and Flugel *et al.* (2019). Ginkel (2014) collected data on participants' route choices through a survey, leading to 297 observations. The survey asked questions about recent trip length, time, quality, and both departure and destination post codes. Flugel *et al.* (2019) used an existing database that had been collected as part of an e-cycle programme evaluation in 2016 as it contained data on individuals involved in the e-cycle programme, as well as 10,000 randomly selected members of a cycle register. They were asked to download a GPS tracking application – 721 participants took part providing data on 42,367 trips.

3.5.18 The data relates only to chosen routes and not alternative routes, meaning researchers must simulate alternative routes. Based on distance and time, Flugel *et al.* (2019) simulated 10 alternative routes for each recorded route in the sample using OpenStreetMap.[13],[14] Using the data on actual and simulated routes, both papers create a discrete choice model that estimates coefficients in a utility equation, and a payment vehicle is used to convert these coefficients into estimates of WTP.

13 These alternatives were found using Dijkstra's algorithm that finds the shortest paths between two nodes over a network.

14 As the focus of Ginkel (2014) is on the choice experiment specification, the paper does not provide details on how alternative routes were simulated for the choice model specification.

Hedonic pricing using geographic variation

3.5.19 Hedonic pricing is a revealed preference valuation method where variation in house prices between houses that are closer to, and farther from, an active travel infrastructure intervention is used to estimate WTP. In a statistical analysis, the house price is regressed on a measure of the distance between the house and the active travel infrastructure of interest, as well as other house-related attributes – such as the number of bedrooms – that act as control variables. The resulting coefficient on the distance to active travel infrastructure variable is assumed to be the relevant WTP.

3.5.20 As this method relies on observed data, it can only be used to estimate valuations of impacts of the exact active travel infrastructure (package) that has been implemented retrospectively, and as a whole. In practice, this means this method cannot be used to estimate the WTP impacts of the individual active travel attributes within a package of investments, because the level of data required to do so would be prohibitively large. Therefore, hedonic pricing estimates the overall value that is reflected in house prices from proximity to an active travel intervention and is not able to decipher between journey quality attributes (which are valued by users) or place quality attributes (which are valued by those who dwell).

3.5.21 This is used by Guo *et al.* (2017) to quantify the WTP for pedestrian accessibility and land-use mix and by Liu *et al.* (2017) to estimate the WTP for advanced cycle facilities. Hedonic pricing relies on four types of secondary data: house prices, house attributes, active travel infrastructure data and spatial data. Both papers used Google Maps to gather distance estimates from houses to the active travel infrastructure of interest (spatial data) and used national statistics for all other types of data. Control variables used by each of the papers include: the physical attributes of the house, the size of the house, the crime rate, the time of year of sale, the property tax band and the year the house was built. Liu *et al.* (2017) collected 20,122 datapoints across the years 2010–2013; Guo *et al.* (2017) collected 2,674 observations across 2009.

Hedonic pricing using time variation

3.5.22 A similar form of hedonic pricing can provide further granularity as it uses both geographic and time variation to elicit WTP for given attributes. This method – also called difference-in-differences (diff-in-diff) – is used by Nordstrom (2022), where the author was interested in valuing 'Complete Streets'. This method compares the change in house prices before and after an active travel intervention, for houses that are close to and far from the intervention. If house prices increased over time by a greater amount for houses near the intervention than for those farther from the intervention, then the difference between the two is assumed to be the WTP for the active travel intervention. As above, because this method relies on observed data it cannot be used to differentiate between individual components of a package of active travel interventions, nor to isolate the value of journey quality attributes from place quality attributes (or vice versa).

3.5.23 Similar data is required for this hedonic price method, namely house prices, house attributes, infrastructure data and spatial data. Nordstrom (2022) initially collected 646,171 observations from across the years 2000–2020 from government or government-sponsored sources, which was then narrowed down to 28,075 relevant observations.[15] The final data included information on house prices as well as other attributes such as:

15 The data was narrowed down to remove duplicates and inconsistent data as well as to increase the relevance of the data. Criteria included houses that were: sold multiple times within the period, within 1 km of a Complete Street and sold within 3 years of the Complete Street being approved.

the date the property was listed, the number of bedrooms, the number of bathrooms, whether there was a garage and the date of sale.

Cost method

3.5.24 The cost method is a revealed preference method, where researchers can use costs incurred by individuals on making a particular trip to interpret their WTP for certain active travel attributes. This method is used by Wichman *et al.* (2017) to estimate cyclists' value of time and WTP for cycle lanes.

3.5.25 The researchers used data from 700 bicycles within the B-Cycle rental cycles scheme in Denver between 2010 and 2017, and were looking for individuals who were 'daisy-chaining'. This term is used to describe behaviour that arose in the context of a pricing model that involves cyclists paying a 24-hour membership fee and then paying for usage in 30-minute increments, where the first 30 minutes of each journey was free. This 'non-linear' pricing incentivised cyclists in the sample to daisy-chain – this means to ride for just under 30 minutes and then switch to another cycle so that they could continue to cycle for free for the next 30 minutes.

3.5.26 Researchers collected the route data and then combined it with Google Maps data to estimate what would have been the most direct route. The actual and alternative routes were put into a discrete choice model (as described above) to estimate different cyclists' valuations, in this case the value of time and the WTP for a cycleway.

Combining stated and revealed preference

3.5.27 Ginkel (2014) and Flugel *et al.* (2019) combine revealed preference and stated preference techniques. Ginkel (2014) principally uses a choice experiment with stated preference data (on hypothetical cycling route choices), and also collects a small amount of revealed preference data in the same questionnaire on actual route choices made. Two separate models were built with the different datasets. The results of the choice model (using revealed preference data) are used to corroborate the results of the choice experiment (using stated preference data), because data on similar journey quality attributes was collected in both datasets. This is done to check for hypothetical bias in the choice experiment – more details in Theme 3.

3.5.28 Flugel *et al.* (2019) undertook three specifications in their paper:

- A choice experiment using stated preference data collected through survey responses from an internet panel and on-the-street recruitment.
- A choice model using revealed preference data gathered from GPS tracking.
- A final specification where the authors take the results of the previous two specifications and scale the choice experiment results down using the value of time coefficient (common to both the choice experiment and choice model specifications).[16]

3.5.29 The authors state that the third specification is the primary result of the paper, and the other two specifications are to provide sensitivity tests and corroborate results.

16 Scaling is required because the coefficients may be different between the choice experiment and choice model specifications – for example, the coefficient on time in the choice experiment specification could be double that of the coefficient in the choice model specification. Therefore scaling is required, so that the coefficients on all attributes are at the same scale across the two estimations and are therefore comparable (normalising results to a common base). In practice, the value of time coefficients in both specifications were set to 1.

Theme 3: What are the advantages and disadvantages?

3.5.30 Having outlined the seven different methodologies used in the reviewed active travel literature, this section discusses the advantages and disadvantages of each. The papers did not generally discuss the advantages and disadvantages of different valuation methods, so expert opinion has been used to critically assess them.

Stated preference

Contingent valuation

3.5.31 Contingent valuation can be used to value any attribute – including those that are not easily measurable by other means (such as the perception of pollution) – and is relatively flexible to carry out, meaning it could be delivered in relatively short timeframes and with a lower budget than some other valuation methodologies (Atkins, 2011).

3.5.32 However, if issues are not overcome in the design, there may be a high likelihood of different forms of bias, such as:

- Strategic bias where participants may respond strategically to questions, and not provide what they perceive their true WTP to be (Atkins, 2011).
- Information bias where participants have imperfect information and responses are conditional on participants' prior knowledge (Atkins, 2011).
- Unconscious bias due to lack of psychological validity in the survey design and framing, meaning participants' stated WTP differs from their actual WTP because of how the information has been presented.
- Hypothetical bias where, even with full information, participants' perceived WTP may vary from their actual WTP in a real-life situation.

Choice experiments

3.5.33 Strengths and weaknesses of choice experiments can be considered in the three stages of the method: data collection; discrete choice models; and converting to monetary values.

Step 1: Data collection

3.5.34 While data collection is relatively easier for choice experiments than some other valuation methods – such as choice models which use real data on actual choices (Atkins, 2011) – the requirement to collect primary data can be expensive and time consuming compared to valuation methods that only require secondary data (such as hedonic pricing).

3.5.35 Choice experiments may suffer from the same information and hypothetical biases as contingent valuation techniques (Flugel *et al.*, 2019). The risk of these biases increases as participants are asked to consider more attributes in their decisions, and considerably heightens when more than seven attributes are involved (Douglas *et al.*, 2022). Box 1 outlines some techniques that the reviewed papers use to try and minimise these biases.

3.5.36 Choice experiments that use route choice cards cannot be used to value improvements in place quality, because they are designed for users of a piece of infrastructure (and hence are better equipped to consider alternatives) and not for those who dwell (who have a range of factors that influence their decisions on where to dwell). It is unclear from the literature whether choice experiments could be adapted (i.e. to use a method other than route cards) to value improvements in place quality. Moreover, choice experiments are generally not appropriate for valuing short journeys because there are typically a limited number of alternative routes, and payment vehicles are in many cases less applicable (Atkins, 2011; Ginkel, 2014), meaning the necessary data cannot be collected.

Box 1: Mitigating bias in choice experiments

- Atkins (2011), Shore *et al.* (2012) and Douglas *et al.* (2022) employ techniques to mitigate the potential for information or hypothetical bias in their choice experiments.
- Ginkel (2014) supplemented route choice cards with images that matched the road type, to reduce the risk that participants did not understand differences in road quality.
- Atkins (2011) used an initial round of 'framing questions' to help participants comprehend their valuations more precisely, reducing the risk of hypothetical bias. These questions asked participants to rate the importance of certain factors– such as traffic on the street and street cleanliness – in their decision-making.
- Shore at al. (2012) made the route choice cards increasingly complex as the participant progressed through the survey. This helped prevent participants becoming overwhelmed in initial rounds, but allowed more complicated route cards to be used in later rounds that increased the level of data that could be collected.
- Douglas *et al.* (2022) splits the choice experiment into two stages. In the first stage participants were asked to give a 'quality score' from 1–100 for different levels of attributes, such as a fully segregated cycleway compared to a partially segregated cycleway. In the second stage, participants were shown route cards with only two attributes – quality score and either time or financial cost. This was done to reduce the risk of hypothetical bias because participants cannot accurately comprehend a large number of attributes at once. However, this relied on participants having the same valuation of attributes in stages one and two, which the paper says may not always be the case.

3.5.37 Atkins (2011), Shore *et al.* (2012) and Flugel *et al.* (2019) use on-the-street recruitment, which is a relatively straightforward technique that allows researchers to collect data from a variety of different groups of individuals. If used in highly trafficked areas, the high frequency of potential respondents makes data collection relatively easier, even if most passers-by do not want to take part. However, this collection technique may be more time intensive than other alternatives. On-the-street recruitment tends to be used when targeting pedestrians rather than cyclists, which may be because stopping cyclists on-the-go is more challenging.

3.5.38 Ginkel (2014), Flugel *et al.* (2019), Gossling *et al.* (2019) and Douglas *et al.* (2022) use internet panels to recruit participants. This approach tends to be less resource intensive and therefore less costly for researchers (Flugel *et al.*, 2022), however it requires choosing a specific group to recruit, such as Facebook followers of the German Cyclists' Association (Gossling *et al.*, 2019). This could lead to sampling bias as participants are not necessarily representative of the broader population of interest – for example, members of cycling groups tend to cycle more frequently and longer distances than the average cyclist (Ginkel, 2014).

Step 2: Discrete choice models

3.5.39 Choice experiments can identify valuations on a variety of journey quality attributes, as long as these attributes have perceivable benefits to the user. Choice experiments can also indicate whether there are significant package effects,[17] and can consider socio-economic effects. These may be important in the case of active travel infrastructure – for example, women typically value street lighting more than men (Shore *et al.*, 2012; Douglas *et al.*, 2022). However, discrete choice models can also be computationally complex, making them difficult to operate and complicated for non-experts to understand.

Step 3: Converting to monetary values

3.5.40 A payment vehicle can be included in route choice cards, easing the transformation of route choices into monetary estimates for WTP. In contrast, using established value of time estimates to convert coefficients relies on these estimates being robust, risking bias if they are not.

Revealed preference

Choice model

3.5.41 Choice models have a number of the same strengths and weaknesses as choice experiments. They have been widely used to value a range of non-market assets and activities, including environmental assets like forests (Hanley *et al.*, 1998) or marine and coastal areas (Scottish Government, 2023). They can estimate package effects if the dataset is large enough. The models are computationally complex, and any external assumptions used (such as value of time estimates) must be robust for the choice model results to be valid. Short journeys cannot be easily assessed, but socio-economic characteristics can be taken into account.

3.5.42 However, choice experiments and choice models differ in two key ways:

- Choice model data records participants' actual behaviour and not hypothetical decisions, reducing the risk of information and hypothetical biases.
- Choice model data does not include a clear alternative route (required for discrete choice models) so researchers simulate alternative routes, risking bias (Flugel *et al.*, 2019).

Ginkel (2014) collects choice model data through survey responses whereas Flugel et al. (2019) uses GPS tracking data, which can be more expensive as it requires buying tracking devices that can be challenging to collect at the end of the study.[18] GPS tracking data allows researchers to collect multiple datapoints per participant – Flugel *et al.* (2019) had 721 respondents but were able to collect data on over 42,000 trips, whereas Ginkel (2014) was only able to collect one datapoint per participant. However, researchers using GPS tracking data must identify routes. For example, a participant may stop to buy a drink on their way to work, and researchers will need to identify whether this should be considered two journeys or

17 Choice experiments measure package effects by including interaction terms in the discrete choice model. However, this would increase the amount of data required.

18 A third method for data collection is referenced in the literature, but it was not undertaken in any of the reviewed papers and is therefore not discussed in detail. It involves asking participants to identify routes that they have taken on a map. This allows the possibility for researchers to ask participants what their alternative routes were – reducing the need to manufacture these alternatives and the corresponding bias – however, this method opens the data up to recollection bias, where participants misremember routes they have taken or alternatives that were available.

part of one commute. This can be challenging and has a significant impact on results.

3.5.43 Hedonic pricing with geographic variation

3.5.44 One of the key strengths of hedonic pricing is the accessibility of data. Hedonic pricing relies on secondary data sources, which can reduce the costs of data collection significantly compared to choice experiments and models that rely on primary data collection. In the case of Guo *et al.* (2017) and Liu *et al.* (2017), governments were already collecting data on house prices and attributes, which were central to the hedonic pricing approaches of these papers.

3.5.45 While data may be accessible, there may be issues with data availability – as houses are not sold very frequently – that introduce the potential for biases due to time-specific effects. For example, if data were collected over a period during which there were a recession, then house prices collected at the end of the period would be lower than house prices collected at the beginning of the period, due to factors that were totally unrelated to the active travel intervention. Therefore, ideally house price data would be gathered for all houses sold on a specific day, to limit biases due to these time-specific effects. However, as houses are sold infrequently, it can be challenging to collect sufficient datapoints if only a short window for data collection is used. Hence there is a trade-off between extending the time period to increase data availability and restricting the time period to reduce bias.

3.5.46 Another strength of hedonic pricing is that the WTP valuation can be directly inferred from the regression as the coefficient on each attribute. Choice experiments and choice models require an extra step in the specification to convert the coefficients from the discrete choice model into monetary values. As each step in a specification increases the risk of bias, by removing the need for this final step hedonic pricing reduces one potential form of bias.

3.5.47 Choice experiments are flexible and can be used to estimate valuations on many attributes, as long as these attributes have perceivable benefits to the user. However, hedonic pricing is only able to value attributes that have a sufficiently significant impact that they change house prices.[19] Therefore, smaller interventions – such as re-paving a cycleway – could be valued through choice experiments but on their own cannot typically be valued using hedonic pricing. Instead, hedonic pricing is more commonly used to estimate the impact of packages of active travel interventions.

3.5.48 Hedonic pricing can be used to estimate the value of a change in place quality as well as a change in journey quality. Though researchers are not able to use hedonic pricing to distinguish whether an overall increase in value is driven by journey quality or place quality effects.

Hedonic pricing with time variation

3.5.49 A hedonic pricing approach with time variation – also known as diff-in-diff – is similar to hedonic pricing with geographic variation in terms of their strengths and weaknesses. This section focuses on the difference between the two hedonic pricing methods, and the relative strengths and weaknesses of each.

19 This is because if the size of the intervention impact is likely to be much smaller than the size of the error term, the coefficients are likely to be statistically insignificant.

3.5.50 Diff-in-diff can help mitigate two biases that may be present when hedonic pricing relies only on geographic variation:

- **Omitted variable bias:** Not all house-specific attributes can be quantified, but these 'fixed effects' can be a significant driver of house prices. If fixed effects are not taken into account in the list of control variables, this risks introducing 'omitted variable' bias. By looking at the change in house prices over time, rather than the absolute house price, diff-in-diff removes any fixed effects that are constant over time (Nordstrom, 2022).
- **Time-specific effects:** Diff-in-diff can partially mitigate the bias caused by external factors – such as a recession – influencing house prices across the data collection window. By taking multiple data points in time and looking at the difference in the change in house price experienced by the treatment group (areas close to the active travel infrastructure) and control groups (those areas further away), any effects that would have impacted all house prices equally will be reduced. However, the validity of this method relies on the common trends assumption – which assumes that the houses in the treatment and control groups would have behaved similarly if the intervention had not taken place (Nordstrom, 2022). If there are lots of changes in an area over time, it may be unlikely for these changes to impact the treatment and control groups equally.

3.5.51 The need to have multiple datapoints for each house over time increases the data requirements for diff-in-diff compared to hedonic pricing that just exploits geographic variation. Given issues with the frequency of house price data, the traditional diff-in-diff method may need to be adapted. Instead of having multiple datapoints for the exact same house over time, researchers may choose to amalgamate house prices for similar houses that are a similar distance from the intervention. As this relies on the assumption that the fixed effects for these houses are similar, poor matching can introduce bias.

Cost method

3.5.52 A key benefit of the cost method is that data is collected on real-world decisions that individuals have made and the payment vehicle is clearly known to researchers. This is an advantage compared to choice experiments (where hypothetical bias may exist) and choice models (where researchers need to simulate alternative routes to have a payment vehicle). However, Wichman *et al.* (2017) note two weaknesses of their paper:

- Individuals who use cycle hire schemes tend to be from higher income groups than the general population, and therefore their preferences – especially their value of time – may differ.
- The methodology in this paper was designed around the fact that the cycle hire scheme offered free rides up to 30 minutes. It therefore looked at the extent to which people would be prepared to stop their ride a few minutes under 30 minutes and find a new cycle to avoid paying the fee. Therefore, it was not able to look at attributes on journeys less than 30 minutes long.

Combining stated and revealed preference

3.5.53 Two papers – Ginkel (2014) and Flugel *et al.* (2019) – combined a choice experiment with a choice model. Doing so requires two sets of primary data collection, which can be expensive and resource intensive.

3.5.54 If researchers run the specifications separately and find that the valuations from the choice experiment are similar to the valuations from the choice model – as in Ginkel (2014) – this allows researchers to have greater confidence in the robustness of their choice experiment results. The choice experiment results are unlikely to suffer from significant information and hypothetical biases if the results are similar to that of the choice model. However, if the results from the two specifications differ, researchers cannot identify whether it is the results from the choice experiment or the choice model that are poor.

3.5.55 If researchers combine stated and revealed preference data together into one specification – as in Flugel *et al.* (2019) – this allows researchers to extend the number of attributes that can be valued. However, this process requires scaling coefficients, and Flugel *et al.* (2019) notes the importance of choice in this process as estimates can fluctuate significantly if the choice experiment estimates are scaled to those of the choice model (as in the paper), as opposed to the other way around. Identifying the correct scale is not straightforward and qualitative judgement must be used. Whichever direction of scaling, the common factor estimates – values of time in this paper – will have uncertainty attached to them, and over-reliance on these attributes introduces potential bias.

Summary

3.5.56 Table 13 summarises the seven valuation methods, data collection requirements, and strengths and weaknesses that have been reviewed in the literature.

Table 13. Summary of valuation methodologies in reviewed literature

Group	Method	When to use	Data needed	Advantages	Disadvantages
Stated preference (SP)	Contingent valuation	When choice experiments and choice models are not available or proportionate	Reported WTP Potentially socio-economic characteristics	Can be used to elicit valuations on a wide variety of journey quality and place quality attributes	Greater potential for bias than other valuation methods
	Choice experiment	When researchers want to estimate valuations of journey quality of hypothetical attributes	Route choice and attributes Payment vehicle or value of time estimate Potentially socio-economic characteristics	Can identify a large range of journey quality attributes and package effects	Data collection could be significant and careful design needed to mitigate information and hypothetical biases
Revealed preference (RP)	Choice model	When researchers want to estimate valuations of journey quality and data on actual route choices is available	Route choice and attributes Simulated alternative routes Payment vehicle or value of time estimate Potentially socio-economic characteristics	Can identify a large range of journey quality attributes and package effects; Data reflects real-world decisions	Data collection can be significant and simulating alternative routes introduces bias
	Hedonic pricing (geographic variation)	When researchers want to estimate place quality effects and fixed/time-specific effects expected to be small	House prices and attributes at a snapshot in time Infrastructure data Spatial data	Data does not require primary research and can value package effects Place quality can be measured	Valuations of small interventions or individual attributes cannot be estimated Valuations of place and journey quality cannot be distinguished Trade-off between data availability and potential for time biases

Group	Method	When to use	Data needed	Advantages	Disadvantages
	Hedonic pricing (time variation)	When researchers want to estimate place quality effects and fixed/time-specific effects expected to be significant	House prices and attributes through time Infrastructure data Spatial data	Data does not require primary research and can value package effects Place quality can be measured Mitigates issues of fixed and time-specific effects	Valuations of small interventions or individual attributes cannot be estimated Valuations of place and journey quality cannot be distinguished Relies on common trends assumption and similar fixed effects across properties Requires more data than hedonic pricing exploiting only geographic variation
	Cost method	When researchers want to estimate valuations of journey quality and have decisions on actual choices and costs to individuals	Route choice and attributes Alternative routes Cost to individuals	Data does not require primary research Reduced risk of hypothetical bias Reduced bias from simulating alternative routes (and payment vehicles)	Need to find non-linear pricing model to exploit May not be reflective of shorter journeys
Combined	Choice experiment and choice model	When researchers want to estimate valuations of journey quality and have both SP and RP data available	Route choice and attributes Simulates alternative routes Payment vehicle or value of time estimate Potentially socio-economic characteristics	Comparison of choice experiment results with choice model to increase confidence in robustness Extends the number of attributes that can be valued	Requires greater data collection than a choice experiment or choice model individually Unclear which specification is inaccurate if results of choice experiment and model are not similar Scaling coefficients can introduce bias

4. Conclusions and recommendations

4.1 Key recommendations

4.1.1 Below is a summary of the key recommendations in the research areas of safety, place quality and urban realm, and journey quality.

Safety

Recommendations based on existing findings

- Interventions should focus on accessibility, connectivity and safety, particularly in areas with mixed land-use where collisions risks are higher (Chen, 2015). Based on the evidence, interventions that have a positive impact on safety include:
  - Lighting.
  - Greenery.
  - Surface maintenance.
  - Lower road speeds.
- It is important to acknowledge that individuals feel safer when cycling infrastructure provides convenience and safety (Hull and O'Holleran, 2014). In practice, this suggests the potential positive safety benefits of:
  - Continuity of infrastructure.
  - Segregation (from vehicles) over non-segregation.
  - Appropriate wayfinding.
- Shared footways shift the potential risk of injury disproportionately to pedestrians, particularly vulnerable users (Chong *et al.*, 2010), and therefore would have lower benefits in terms of safety as a result.
- Findings from various studies (Hull and O'Holleran, 2014; Reynolds *et al.*, 2017; Chen, 2015; Reynolds *et al.*, 2009; McCartney *et al.*, 2012) potentially support the opportunity for AMAT to value the safety benefits of segregated infrastructure vs. non-segregated infrastructure.

Further research needed to support appraisal guidance

- Research should focus on specific locations to identify exposure risks and understand the safety-in-numbers effect more accurately (Ram *et al.*, 2022; Elvik and Goel, 2019). Studies of specific routes and junction types with and without active mode infrastructure, in different locations, would support appraisal guidance by indicating where the higher risks of collisions are located and how different infrastructure types generate varying safety benefits.
- Further research needs to be undertaken as data has not always been comparable, due to changes in British collision severity identification post-2015 and the under-reporting of non-vehicle collisions (Mulvaney *et al.*, 2015).
- Past studies tend to assess speed limits rather than actual speeds for cost- and time-efficiency purposes, so further studies could look at actual speed data instead (Aldred *et al.*, 2018).

- Harmonise terminology and report practices, particularly with regard to injury severity studies and the study of a range of facility types (Branion-Calles *et al.*, 2020; Reynolds *et al.*, 2009). It would be beneficial to develop consistent definitions for infrastructure types, active travel modes, and collision inclusion criteria to enable cross-regional analyses and facilitate future research.
- Appraisal could be informed by current assessment techniques that researchers have developed, such as "Cycle Safety Level of Road Environment (CSL-RE)" (Ye *et al.*, 2024) and the use of cycle milage and time mileage simultaneously to better represent risk exposure (Ram *et al.*, 2022).
- Chen *et al.* (2017) advocate for the integration of Level of Traffic Stress (LTS) in ATE's analyses to demonstrate the geospatial correlation between higher LTS roads and collision classification. Nellthorp (2023) calls to integrate AMAT with TfGM's Programme Entry Appraisal Tool to strengthen safety considerations.
- Changing a single built environment factor will not significantly lower collisions risks (Chen, 2015). Therefore, future research and interventions should evaluate a range of built environment factors to effectively reduce collision risks, recognising that single-factor changes are unlikely to have a significant impact.
- Future research into collision risks, active travel and the impact of built environment interventions should explore how local factors and specific types of locations and built environments affect risk to better understand both context and the safety-in-numbers effect.
- Recognise and address the limitations of current research and reporting methods for accident and collision data, such as the under-reporting of non-vehicle collisions.

Place quality and urban realm

Recommendations based on existing findings

- Interventions that focus on the three pillars of active travel provide the greatest benefits (Panter *et al.*, 2016).
- Implementing green spaces in poorly maintained or neglected neighbourhoods can lead to neglect of safety issues, thus reducing people's willingness to walk or cycle in those areas (Ogilvie, 2010). Therefore, interventions in all areas or circumstances without considering the wider context that could influence their success may have negative impacts.
- In the short term, active travel uptake does not indicate a replacement of car journeys but rather additional journeys; car journeys are partially replaced over time (Aldred, 2019). Furthermore, public realm schemes generally generate demand and modal shift benefits over a two-year period as awareness of the infrastructure increases (Song *et al.*, 2017).
- Include local facilities, green spaces, noise, pollution, collision risk, severance, and cleanliness in transport appraisal, recognising their impact on both place and movement functions (Nellthorp, 2023).

- Severance may persist due to personal physical difficulties or due to the perception that an environment is unpleasant or unsafe (Ogilvie *et al.*, 2010), and therefore quantifying the impacts of severance should take these factors into account. This could include redefining severance and any future studies into the impacts of severance, acknowledging that it is not merely alleviated by infrastructure improvements. Furthermore, personal physical challenges and negative perceptions of the environment can contribute to ongoing severance.

Further research needed to support appraisal guidance

- Research should focus on interventions that increase activity levels for current users and quantify the level of impact on existing users, a benefit that is not currently included in appraisal guidance.
- Many studies continue to overlook the quality or proximity of amenities and the routes leading to them, which results in the inability to find strong links between active travel and spatial factors (Ogilvie, 2010). Studies that establish stronger links between these two in urban realm schemes would be beneficial.
- Further research should be undertaken to explore the "bidirectional relationship" between quality of life and active travel (Black and Street, 2014), including factors such as residential density, street connectivity, retail floor area ratio, mixed-use development, cul-de-sac density, and green areas.
- There is a lack of evidence around differential impacts of interventions, particularly for walking, with stronger evidence for cycling (Aldred, 2019). Therefore, conducting more research on the differential impacts of interventions, particularly for walking where the research and existing evidence is weakest would be beneficial.
- Vehicle owners and people with a disability tend to shift to walking less than those without a vehicle or without a disability (Sarkar *et al.*, 2015), and further research could quantify this for appraisal purposes. Furthermore, the impacts on motorised vehicle owners and people with disabilities, and how these impacts can vary, should be considered in research into public realm and place quality impacts.
- Much of the evidence supporting active travel interventions and the differential impacts of interventions is methodologically weak and limited to 'grey' literature (Aldred, 2019).
- There is limited existing evidence into the benefits and demand impacts of secure cycle parking at stations. Further research in this area would support the expansion of this type of infrastructure investment in appraisal.
- There is limited evidence of the scale of modal shift benefits generated by different types of public realm improvements.
- Recognise in appraisal and in forecasting that short-term increases in active travel often result in additional journeys overall, rather than replacing car trips; car journeys are only partially replaced over time. Therefore, investigating long-term behavioural changes following active travel interventions and establishing the best study designs to measure these changes would be beneficial.

Journey quality

Recommendations based on existing findings

- Addressing both perceived and actual environmental factors contribute to the overall experience of cycling (Black and Street, 2014), and therefore of journey quality.
- Adopting both a technical expert and layperson perspective may create a more holistic approach to cycle promotion and infrastructure design, and may therefore point towards both technical design and softer aesthetic interventions as key facets of journey quality.
- Acknowledging the reasons behind mode choice and how these decisions are influenced by trip purpose would help to adapt interventions to more specific journey purposes and quantify their impacts in terms of journey quality.

Further research needed in appraisal guidance

- The existing version of AMAT quantifies journey quality improvements but does not specifically incorporate time savings for active modes. AMAT could be updated to include time savings for active modes, using the existing TAG method for user benefits (Nellthorp, 2023).
- The existing appraisal guidance omits certain journey quality features such as "pavement/lane width, continuity and absence of clutter, frequency of stops, advanced stop lines, turn facilities, traffic exposure, speed and HGV proportion, air pollution and noise" (Nellthorp, 2023). Expanding AMAT, or incorporating additional journey quality features into another appraisal tool, would allow the quantification of these identified gaps in the guidance.
- LTN 1/20 recognises the importance of continuity, but TAG does not value it. Furthermore, TAG does not consider or attempt to quantify the benefits of increased greenery or tree planting (Nellthorp, 2023). Therefore, integrating the value of increased greenery and tree planting into appraisal guidance as a feature of journey quality would be beneficial. Furthermore, international evidence that shows how cyclists value reduced frequency of stops and waiting times at intersections should be undertaken, and the incorporation of these benefits into appraisal guidance should be considered.
- It is recommended that evidence is incorporated from tools like TfL's Ambience Benefit Calculator and TfGM's Programme Entry Appraisal Tool into national guidance to address gaps (Nellthorp, 2023).
- Most current evidence on journey quality impacts predates 2010 and may not reflect contemporary views on active travel (Nellthorp, 2023). The undertaking of new primary research should be a priority to reassess journey quality perceptions and ensure current behavioural trends and insights are captured.
- Cyclists value a reduced frequency of stops and a reduced waiting time at intersections (Nellthorp, 2023).

4.2 Gaps in the evidence

Research area 1: safety

4.2.1 Three key gaps are noted in the research reviewed on safety impacts:

- **Understanding the impact of safe infrastructure on active travel demand and uptake:** Studies indicate that the safety-in-numbers effect occurs as a response to poor infrastructure, with larger groups improving visibility and safety. However, few existing studies explore how safe infrastructure promotes increased active travel demand (Elvik and Goel, 2019) – and those that do have been presented in this report. This is a key limitation to identifying the impact of built environment interventions.
- **Methodological differences hinder long-term comprehensive assessments of built-environment interventions:** The literature identifies the need for clarifications of the methodological approach to safety-focused interventions. With relation to collision analysis, changes in 2015 to British methods of identifying collision severity hindering long-term impact assessments of built infrastructure interventions (Ram *et al.*, 2022), and collisions are generally reported if they involve vehicles, which may undermine individual or active travel related collisions (Mulvaney *et al.*, 2015). Furthermore, studies tend to assess speed limits rather than actual speeds for cost- and time-efficiency purposes (Aldred *et al.*, 2018). With relation to the built environment, few existing studies explore the effect of new infrastructure on changes in collision rates (Mulvaney *et al.*, 2015).
- **Undefined criteria and terminology:** The literature presents various criteria, terminology, and reporting practices, so each case study's findings are closely tied to its methodology. This makes it difficult for practitioners to have a wider understanding of built environment interventions across different contexts.

Research area 2: place quality/urban realm

4.2.2 Three key gaps are noted on place quality/urban realm impacts appear in the research reviewed:

- **Quality and network:** Many studies continue to overlook the quality of amenities and the routes leading to them, which results in the inability to find strong links between active travel and spatial factors (Ogilvie, 2010). Additionally, while it is known that active travel levels are in part dependent upon quality of life and wellbeing, "few studies have integrated an analysis of quality of life into research on the built environment" (Black and Street, 2014).
- **Understanding how features impact movement:** Built environment features such as residential density, street connectivity, retail floor area ratio, mixed-used development, cul-de-sac density, and green areas are still explored unilaterally in many studies instead of being considered holistically as a network (Carlson *et al.*, 2014). More specifically, while recognised for their place functions, local facilities, green spaces, and street-level factors such as noise, pollution, collisions risk, severance and cleanliness and their movement functions remain underestimated (Nellthorp, 2023).
- **Going beyond the built-environment intervention:** Psychological factors and perceptions of place quality or the built environment, such as severance, continue to be overlooked (Ogilvie *et al.*, 2010).

Research area 3: journey quality

4.2.3 One key gap arises in the literature on journey quality impacts:

- There is a pressing need to better understand the **components that make up the 'quality of the journey'**, particularly for cyclists.

Research areas 1–3

4.2.4 As noted in the introduction to section 3, 'wheeling' is relatively new in active travel terminology and there was little to no evidence on the impacts of infrastructure on this particular mode. Therefore, although it is assumed that the impacts of improved infrastructure on wheeling would be similar to that of walking and cycling, there is an evident need to understand how these impacts differ and what benefits can be derived in appraisal of infrastructure that improves conditions for wheeling users.

Research area 4: valuation methods

4.2.5 Six key gaps appear in the research into valuation methodologies used in the active travel literature:

- **Place quality valuation evidence is limited:** Choice experiments and choice models appear to be the most commonly used methods in the published literature for estimating the values of active travel journeys or interventions, and tend to focus on journey quality rather than place quality. Hedonic pricing has been applied to value the presence of new or improved active travel facilities, though this is likely to capture journey quality and place quality effects combined. Only one study reviewed (Atkins, 2011) applied a pilot version of a contingent valuation approach (choice model with hypothetical payment vehicle) related to place quality and estimated the value of enhancing townscape (such as full pedestrianisation). If well-designed, this approach can mitigate the potential risks of bias associated with contingent valuation approaches, though they remain resource intensive.[20]
- **Valuations of attributes on short journeys is limited:** Choice experiments and choice models can value journey quality estimates for longer journeys, but struggle to value attributes effectively on short journeys. This is because fewer alternative routes exist and a payment vehicle is more challenging to identify (Atkins, 2011; Ginkel, 2014).
- **Wheeling evidence is limited:** None of the papers reviewed cover attributes related to wheeling interventions. However, in principle there is no reason why these methods could not be applied to these attributes.

20 Atkins (2011) note that this study was a pilot owning to the time and resources required for this method. Risks of bias in the contingent valuation approach were mitigated in three ways. The payment vehicle to estimate the monetary values was perceived as 'real' by respondents (e.g. an increment to Council Tax). Respondents were familiarised with the subject matter before asking about their choices or whether they would be prepared to pay for enhancement. Finally, visualisations were offered to respondents so they could visualise changes relative to what was already there.

- **Valuation of attributes or interventions for new users is limited:** Active travel interventions can lead to new users of a piece of infrastructure, but their preferences may differ from existing users. The evidence is generated on the basis of people who are already cyclists (as in Gössling *et al.*, 2018) or pedestrians (as in Atkins, 2011). A rule of half could be applied (TAG A4.1, 2022) as per standard appraisal guidance, but estimating valuations for new users directly may be difficult as it is challenging to identify individuals who do not currently use a piece of infrastructure but may do if the infrastructure changed.
- **Valuation of the interaction of active travel infrastructure/facility improvements is limited:** While some studies value different types of cycleway (in-road, partially segregated, fully segregated), or different attributes (such as Shore *et al.*, 2012), it is not clear which combinations of interventions may have greater value for users than others. For example, an improved cycle lane surface may have value for users, but if this is combined with improved lighting or other attributes, it is not clear if the value is additive or higher/lower as a package.

4.3 Areas for future research

4.3.1 The research has identified the following in terms of area for future study that may provide benefits for appraisal guidance and assessing active travel schemes moving forwards. These areas will be expanded upon in the Scoping Note that will follow this report.

Research area 1: safety

- Data: improving the availability and quality of data, particularly at a local level, by expanding data collection coverage beyond primary vehicle corridors.
- Tools and analysis: explore the use of existing tools to expand and improve analysis of traffic levels and collisions risks. Incorporate additional cycling safety metrics, such as cycle mileage, time mileage and the “Cycle Safety Level of Road Environment (CSL-RE)”, to better represent cycle safety levels.
- Reporting: harmonise the use of terminology (such as infrastructure, modes and collision inclusion criteria) and reporting practices to enable future research. Any further research should assess interventions via the evaluation of multi-criteria risk factors.

Research area 2: place quality/urban realm

- New research to explore the benefits for existing users.
- Investigate how schemes affect behavioural change over the long term, and how these benefits differ between modes.
- Expand research to incorporate diverse populations less likely to shift to active modes.
- Strengthen the methodological quality of active travel studies in general to provide an evidence base that is robust.

Research area 3: journey quality

- Explore the potential to address omissions in existing appraisal guidance and tools, including:
    - Time savings for active modes.
    - Journey quality improvements, such as continuity, reduced clutter, turn facilities.
    - Greenery benefits.
    - The benefits of reduced frequency of stops and waiting times.
- Use of existing tools, such as the Ambience Benefit Calculator and Programme Entry Appraisal Tool.
- Update existing journey quality perceptions with new research.

Research areas 1-3

- New research into the impacts of infrastructure improvements and types on wheeling users specifically, and how these impacts can be incorporated into appraisal guidance.

Research area 4: valuation methods

4.3.2 Given the research gaps noted in section 4.2, evidence around the valuations of the following aspects of active travel is limited and would benefit from further research:

- Place quality attributes.
- The attributes of short journeys.
- Wheeling attributes.
- Active travel interventions for new users.
- Interaction of active travel infrastructure/facility improvement.

Appendix A: Initial Sift Inclusion/Exclusion Criteria

		RA1 – Safety	RA2 – Place quality and urban realm	RA3 – Journey quality	RA4 – Valuation methods	Justification
	Search sources	Google scholar, JSTOR, Contacts with experts (incl DfT)	Google scholar, JSTOR, Contacts with experts (incl DfT)	Google scholar, JSTOR, Contacts with experts (incl DfT)	Google scholar, JSTOR, Contacts with experts (incl DfT)	
	Search terms	Pedestrian accident/ collision/crash/casualty, cycle accident/collision/ crash/casualty, cyclist accident/collision/crash/ casualty, pedestrian injury/fatality/KSI/PIC, cycle injury/fatality/ KSI/PIC, cyclist injury/ fatality/KSI/PIC, safe cycle segregation, safe cycle infrastructure, safety of crossing facilities, LTN 1/20, Manual for Streets, ATE crossing selector tool, ATE route cross section tool, CROW Design Manual for Bicyle Traffic	Urban realm/space/ environment, public realm/space, street space/environment, green space, green/ blue routes/corridors, pedestrianisation, low traffic neighbourhoods/ LTN, road space reallocation, road closure, community space (active) place making, traffic-free, car-free, public transport interchange/hub, station forecourt/platform/ concourse, shared use/ space width, street/ urban/pulibc art, dwell time, LTN 1/20, Manual for Streets, ATE crossing selector tool, ATE route cross section tool, CROW Design Manual for Bicycle Traffic	Journey quality/ ambience, infrastructure quality, segregation/ non-segregation, surface quality, kerb level, kerbing, surface/ highway/road/street/ pavement/footpath/ cyclepath maintenance, potholes, resurfacing, lining, signage, lighting, width, LTN 1/20, Manual for Streets, ATE crossing selector tool, ATE route cross section tool, CROW Design Manual for Bicycle Traffic	Cycling AND Active travel AND Walking AND Willingness-to-pay, stated preference, contingent valuation, direct surveys, choice experiments, indirect surveys, revealed preference, hedonic pricing, travel cost approach, option value, total economic value, shadow pricing, benefits transfer, economic valuation, econometric analysis, avoided costs, opportunity costs	

		RA1 – Safety	RA2 – Place quality and urban realm	RA3 – Journey quality	RA4 – Valuation methods	Justification
Scope	Date	Past 10-15 years	Past 10-15 years	Past 5 years	Past 10-15 years	10-15 years reflects the study specification, with the journey quality RA focusing on more recent studies due to a previous study finalised in 2020 that DfT/ATE have shared.
	Geographic location of study	UK Potential to expand to EU, US, Australia if literature limited or international evidence is strong and transferable	UK Potential to expand to EU, US, Australia if literature limited or international evidence is strong and transferable	UK Potential to expand to EU, US, Australia if literature limited or international evidence is strong and transferable	UK Potential to expand to EU, US, Australia if literature limited or international evidence is strong and transferable	We expect the majority of evidence to be in a UK context, however we will consider international evidence as well if it is sufficiently strong and transferable to a UK context.
	Language	English	English	English	English	For proportionality and to reduce time and resource.
	Study design	No limitations	No limitations	No limitations	No limitations	

		RA1 – Safety	RA2 – Place quality and urban realm	RA3 – Journey quality	RA4 – Valuation methods	Justification
Quality	Type of publication (publication bias)	Include: Credible source: peer reviewed journal; independent research by professionally recognised consultancy/think tank; public body Exclude: Publications with a bias evident from the authors or who funded the research or it can be considered to be promotional literature	Include: Credible source: peer reviewed journal; independent research by professionally recognised consultancy/think tank; public body Exclude: Publications with a bias evident from the authors or who funded the research or it can be considered to be promotional literature"	Include: Credible source: peer reviewed journal; independent research by professionally recognised consultancy/think tank; public body Exclude: Publications with a bias evident from the authors or who funded the research or it can be considered to be promotional literature	Include: Credible source: peer reviewed journal; independent research by professionally recognised consultancy/think tank; public body Exclude: Publications with a bias evident from the authors or who funded the research or it can be considered to be promotional literature	Risk of publication bias high with promotional literature. Whilst there may be a risk of publication bias in grey literature, this will be assessed as part of the evidence synthesis with lesser weight assigned to evidence with a higher rsik of publication bias
	Sampling details (internal validity - risk of bias)	Include: Justification of sample size and indentification Exclude: No justification of sample size and identification	Include: Justification of sample size and indentification Exclude: No justification of sample size and identification	Include: Justification of sample size and indentification Exclude: No justification of sample size and identification	Include: Justification of sample size and indentification Exclude: No justification of sample size and identification	There is no consensus on what is a reasonable sample - instead, sample sizes should be explicitly considered in the context of each individual study e.g. refecting the size of relevant population of interest, and therefore we look for studies that show this to be the case. Further considerations if internal validity are considered as part of the quality evaluation for included studies

		RA1 – Safety	RA2 – Place quality and urban realm	RA3 – Journey quality	RA4 – Valuation methods	Justification
Relevance	Relevance score (out of 5)	1: Appears to have no relevance to most parts of the research question 2: Appears to have limited relevance to most parts of the research question 3: Appears to be relevant to some parts of the research question 4: Appears to be highly relevant to some parts of the research question 5: Appears to be highly relevant to most parts of the research question	1: Appears to have no relevance to most parts of the research question 2: Appears to have limited relevance to most parts of the research question 3: Appears to be relevant to some parts of the research question 4: Appears to be highly relevant to some parts of the research question 5: Appears to be highly relevant to most parts of the research question	1: Appears to have no relevance to most parts of the research question 2: Appears to have limited relevance to most parts of the research question 3: Appears to be relevant to some parts of the research question 4: Appears to be highly relevant to some parts of the research question 5: Appears to be highly relevant to most parts of the research question	1: Appears to have no relevance to most parts of the research question 2: Appears to have limited relevance to most parts of the research question 3: Appears to be relevant to some parts of the research question 4: Appears to be highly relevant to some parts of the research question 5: Appears to be highly relevant to most parts of the research question	Score is based on professional judgement by the Frontier and SYSTRA team as part of the literature sift
	Relevance description	Brief explanation of relevance score	Brief explanation of relevance score	Brief explanation of relevance score	Brief explanation of relevance score	

Appendix B: Quality Assessment Criteria

Assessment area	Criteria	Key considerations
Methodology	Clarity of purpose	Statement of study aims and objectives, linking of findings to study purposes. Conclusions linked to aims of study. Discussion of limitations.
	Research design	Discussion of overall research strategy meeting aims of study. Discussion of rationale and arguments for study design. Discussion of limitations.
	Sampling – internal validity	Discussion of study location/areas/population of interest and how the sample relates to it. Profile of achieved samples/case coverage. Discussion and justification for sample size, approach and potential bias. Documentation of non-participation reasons, discussion of how methodology may have influenced participation.
	Data collection	Discussion of who conducted data collection and procedures. Description of conventions for taking fieldnotes. Discussion of how fieldwork methods or setting may have influenced data collection. Consideration of background or historical developments.
Analysis	Credibility of findings	Support of findings by data/evidence. Description of evaluative judgements. Use of corroborating evidence to support findings. Display of negative cases and how they might lie outside the main theory/hypothesis/conclusion.
	Reflexivity and neutrality	Discussion of assumptions applied, and how they were derived and justified. Discussion of error or bias.
	Scope for drawing wider inference	Discussion on what can be generalised to wider population from the sample. Description of study context. Consideration of rival explanations and limitations of wider inference.
Ethics		Evidence of sensitivity about research contexts and participants. Documentation of how research was presented in study settings. Documentation of consent/confidentiality/anonymity procedures. Discussion of potential harms of participation and mitigations. Approval or not of ethics board/committee.
Peer reviewed		Whether paper has been peer reviewed.

Appendix C: Thematic Analysis

Reference	RA1	RA2	RA3	RA4	Type
Aldred *et al.*, 2018	✓	✓			Academic
Aldred, 2019		✓			Academic
Atkins, 2011				✓	Grey
Atkinson and Mourato, 2007				✓	Academic
Black and Street, 2014	✓	✓	✓		Academic
Branion-Calles *et al.*, 2020	✓	✓	✓		Academic
Brownrigg-Gleeson *et al.*, 2023	✓	✓			Academic
Carlson *et al.*, 2014	✓	✓			Academic
Chen *et al.*, 2017	✓	✓			Academic
Chen, 2015	✓	✓	✓		Academic
Chong *et al.*, 2010	✓	✓			Academic
DfT TAG Unit A1.3, 2022				✓	Other
DfT TAG Unit A4.1, 2022				✓	Other
DfT TAG Unit A5.1, 2022				✓	Other
Dill *et al.*, 2014	✓	✓			Academic
Douglas *et al.*, 2022				✓	Academic
Elvik and Goel, 2019	✓				Academic
Flügel *et al.*, 2017				✓	Academic
Ginkel, 2014				✓	Academic
Goodman *et al.*, 2013					Academic
Gössling *et al.*, 2918				✓	Academic
Guo *et al.*, 2017				✓	Academic
Hess *et al.*, 2023	✓	✓	✓		Grey
Hull and O'Holleran, 2014	✓	✓	✓		Academic
Krizek *et al.*, 2009		✓	✓		Academic
Liu and Shi, 2017				✓	Academic
McCartney *et al.*, 2012	✓	✓			Academic
Mulvaney *et al.*, 2015	✓	✓			Academic
Nellthorp, 2023	✓	✓	✓		Grey
Nordstrom, 2022				✓	Academic
Ogilvie *et al.*, 2010	✓	✓			Academic
Panter *et al.*, 2016	✓	✓			Academic
Ram *et al.*, 2022	✓	✓			Academic
Rérat and Schmassmann, 2024	✓	✓	✓		Academic
Reynolds *et al.*, 2009	✓	✓			Academic
Sarkar *et al.*, 2015	✓	✓			Academic
Shore and Pownall, 2012				✓	Grey
Song *et al.*, 2013	✓	✓	✓		Academic
Song *et al.*, 2017		✓	✓		Academic
Uttley and Fotios, 2017	✓	✓			Academic
Wichman and Cunningham, 2023				✓	Academic
Ye *et al.*, 2024	✓	✓			Academic
Yu *et al.*, 2024		✓	✓		Academic
Zhou *et al.*, 2024		✓	✓		Academic
Total Count	**25**	**28**	**12**	**14**	

Appendix D: Reference list

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