Overtaking cyclists in mixed traffic

Knowledge basis for recommendations for safer cycling

Katja Kircher
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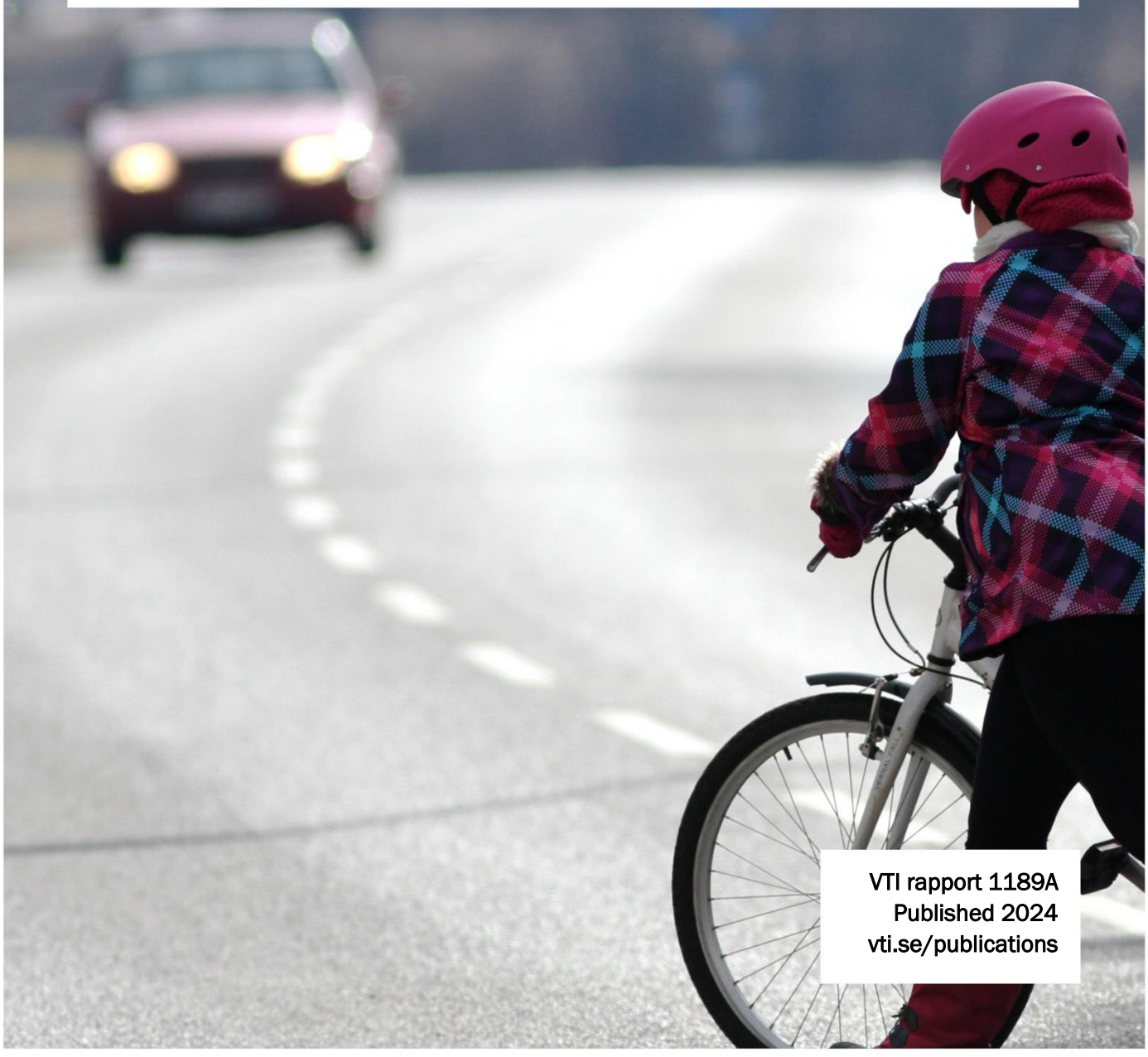
vti



VTI rapport 1189A
Published 2024
vti.se/publications

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VTI rapport 1189A

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Author: Katja Kircher, Anna Niska, VTI.
Reg. No., VTI: 2023/0307-9.1
Publication: VTI rapport 1189A
Published by VTI 2024

Publikationsuppgifter – Publication Information

Titel/Title

Omkörning av cyklister i blandtrafik. Kunskapsunderlag till rekommendationer för tryggare cykling./ Overtaking cyclists in mixed traffic. Knowledge basis for recommendations for safer cycling.

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Utgivare/Publisher

VTI, Statens väg- och transportforskningsinstitut/
Swedish National Road and Transport Research Institute (VTI)
www.vti.se/

Serie och nr/Publication No.

VTI rapport 1189A

Utgivningsår/Published

2023

VTI:s diarienr/Reg. No., VTI

2023/0370-9.1

ISSN

0347–6030

Projektnamn/Project

Omkörning av cyklister – kunskapssammanställning./ Overtaking cyclists – a knowledge compilation

Uppdragsgivare/Commissioned by

VTI

Språk/Language

Engelska/English

Kort sammanfattning

Den här rapporten relaterar till en del av det uppdrag av regeringen som Transportstyrelsen fick hösten 2021: att analysera och vid behov lämna förslag till hur ändrade trafikregler kan främja säker omkörning av cyklister. Transportstyrelsen skulle även analysera behovet av andra ändringar av trafikregler som kan medföra att andelen trafikanter som reser med cykel kan öka och anlitade då oss för att bistå i arbetet genom att beskriva kunskapsläget om cyklisters utrymmesbehov utifrån gällande forskning. Det uppdraget omfattade endast cykling på separerade cykelvägar och har avrapporterats i VTI rapport 1155 ”Cyklisters utrymmesbehov – Kunskapsunderlag till rekommendationer för utformning”. Den här rapporten presenterar extra material som sammanställdes samtidigt, men som inte ingick i uppdraget från Transportstyrelsen.

I rapporten sammanställs kunskap om cyklisters utrymmesbehov vid omkörning, främst på landsväg med beaktande av cyklisters framkomlighet, tillgänglighet, trafiksäkerhet och trygghet. Rapporten berör i samband med detta även relaterade frågor som cyklisters placering i sidled och cykling i bredd. Dessa två ämnen berör även utrymmesbehovet på cykelbanor, vilket innebär att delar av informationen här också finns med i VTI Rapport 1155. Resultaten i rapporten baseras på en internationell sammanställning av förordningar gällande cykling i frågorna ”hålla höger”, ”cykla i bredd”, ”cykla i körbanan” och ”omkörning av cyklande” samt relevant forskningslitteratur.

Forskningen visar att det krävs åtgärder för att säkerställa att bilars omkörningar av cyklister i blandtrafik blir säkra och uppfattas som trygga av cyklisterna. Detta är en grundförutsättning för en ökad och säker cykling inte minst på landsväg. Tänkbara åtgärder är regeländringar (för vilket det presenteras ett diskussionsunderlag i rapporten), informationskampanjer eller förbättringar av infrastrukturen för cyklister. En svårighet med dagens regelverk är att avgöra vad som avses med ”betryggande avstånd” och här behövs ytterligare forskning för att kunna ge tydligare vägledning.

Nyckelord

Cyklister, utrymmesbehov, omkörning, regler, cykling i bredd, sidoläge.

Abstract

This report relates to a part of the government commission that the Swedish Transport Agency received in autumn 2021: to analyse and, if necessary, submit proposals on how an adaptation of traffic rules can promote safe overtaking of cyclists. The Swedish Transport Agency was also tasked to analyse the need for other changes to traffic rules that could lead to an increase in the proportion of road users travelling by bicycle. They engaged us to assist with a compilation of the state-of-the-art about cyclists' spatial requirements based on current research. That assignment only covered cycling on separated cycle paths and has been reported in VTI rapport 1155 "Spatial requirements of cyclists - Knowledge basis for recommendations for designing cycling infrastructure". This report presents additional material that was compiled at the same time, but which was not included in the assignment from the Swedish Transport Agency.

This report compiles knowledge about spatial requirements of cyclists when being overtaken, mainly on rural roads, considering accessibility, traffic safety and security for cyclists. The report also touches on related issues such as the lateral positioning of cyclists and cycling abreast. These two topics also affect the spatial requirements on cycle paths, which means that parts of the information taken up here is also included in VTI rapport 1155. The results in the report are based on an international compilation of regulations regarding cycling and relevant research literature with respect to "keeping to the right", "cycling abreast", "cycling on the road" and "overtaking of cyclists".

The research shows that measures are required to ensure that overtaking of cyclists by motorists in mixed traffic becomes safe and is perceived as safe by the cyclists. This is a basic prerequisite for increased and safe cycling, not least on rural roads. Possible measures are rule adaptations (which is discussed in the report), information campaigns or improvements to the infrastructure for cyclists. A difficulty with today's regulation is determining what a "safe distance" implies. Further research on the topic is needed to be able to provide clearer guidance.

Keywords

Cyclists, spatial requirements, passing distance regulations, cycling abreast, lateral position.

Preface

In the autumn of 2021, the Swedish Transport Agency was commissioned by the Government to analyse regulatory issues with the goal of increasing the proportion of cyclists among road users (TSG 2021-10413). This assignment listed several specific proposals to be analysed, including overtaking cyclists and cycling abreast. The Swedish Transport Agency has also been tasked with issuing regulations on technical characteristic requirements for roads and streets, including the physical design of bicycle lanes and paths. In early 2022, we were engaged by the Swedish Transport Agency to assist in this work by describing the state of knowledge regarding cyclists' space requirements in different situations. Our focus was on minimum widths for cycle paths and lanes. This work was compiled in VTI rapport 1155, published in spring of 2023, and contributed to the Swedish Transport Agency's report "Analys av regelfrågor så att andelen som reser med cykel kan öka – delrapport 2" (Patten, Nilsson, et al. 2022).

In the present VTI report, we have, at our own expense, compiled material which was not included in our assignment from the Swedish Transport Agency, but which is related to their Government assignment. This concerns overtaking cyclists and cycling abreast in particular. Some of the material which we have compiled is relevant both to minimum widths for cycle paths and lanes and to overtaking cyclists. This applies to the information in the introduction and, elsewhere, mainly to the issues related to cycling abreast and lateral positioning of cyclists. These sections now appear in both reports, in places verbatim, and elsewhere adapted to the focus of the present report. This approach was adopted to clarify the interrelatedness of the topics and the application of similar reasoning to various issues concerning increased and safer cycling, while also permitting the two reports to be read individually.

Many thanks to Annika Nilsson, City of Gothenburg, who reviewed the report and provided valuable comments. Thanks also to the Swedish Transport Agency for lively discussions during the process.

Linköping, October 2023

Anna Niska
Project Manager

Granskare/Examiner

Annika Nilsson, City of Gothenburg

Table of contents

1. Introduction

1.1. Background

Domestic transport accounts for about one third of Sweden's territorial greenhouse gas emissions. Over 90 percent of such transport consists of road traffic, with passenger cars accounting for approximately two-thirds. By 2030, emissions must be reduced by at least 70 percent from 2010 levels. Changes to daily travel habits, namely the replacement of car trips by cycling or walking, has a significant impact on greenhouse gas emissions. By replacing all car journeys with walking or cycling for one day a week, an individual can reduce carbon dioxide emissions by 0.5 tonnes annually from a life-cycle perspective (Brand et al. 2021). Cycling also contributes to achieving many other Sustainable Development Goals (Karlström & Niska, 2022). The positive effects of cycling have been acknowledged by several international bodies, including the United Nations (UN), which in March of 2022 adopted a resolution to encourage cycling[1]. At European level, the Pan-European Master Plan for Cycling Promotion has also been adopted (UNECE & WHO/Europe, 2021). Within EU Member States, cycling has been identified as an instrument for sustainable development, and efforts to encourage cycling have intensified in several places in recent years, including as a result of the Coronavirus pandemic.

In Sweden, a national strategy for increased and safer cycling was adopted in 2017, to promote sustainable communities with high quality of life across the country (Ministry of Enterprise and Innovation, 2017). Nevertheless, this national strategy did not propose a target level for cycling's share of total travel. VTI, however, did propose a national target for increased cycling as part of a Government assignment. In simple terms, the goal proposes that cycling be doubled by 2035 (Eriksson, Niska, et al., 2022). One of the sub-targets specified in the assignment concerns journeys of less than 10 kilometres, as the potential to increase cycling is considered to be great for such journeys, since bicycles are often time-competitive with cars over such distances. A target based on distance, rather than on geography, prevents a biased focus on urban centres and highlights the potential to increase cycling in rural areas, which is in line with an equitable transport system that is accessible to everyone across the country. Doubling cycling by 2035 is a challenging but, in our view, realistic goal. However, it will require a variety of measures at different levels, and regulatory issues are an important component.

While the choice to cycle, particularly for transport (e.g., commuting), depends largely on distance and travel time, it is also influenced by perceived personal barriers including bad weather (cold and/or rainy), lack of time, poor cycling infrastructure, inconvenience, poor road safety, fear of bike theft, lack of facilities at work (e.g., secure parking and shower/changing facilities), need to carry luggage and having other errands en route (Forward, 2014b; Pooley & Turnbull, 2000; Rose & Marfurt, 2007; Ryley, 2006; Stinson & Bhat, 2004). Transport choices are also affected by the environments through which cyclists travel and whether they are perceived as stimulating or inhibiting (Swedish Transport Administration, 2018). Route environments can be divided into three categories: (1) the traffic environment (moving objects), (2) the physical environment (fixed objects), (3) the social environment (human interaction), (4) weather and (5) lighting conditions (natural or artificial). When seeking to recruit new cyclists, route environments are particularly important to consider, as they can pose greater obstacles for new cyclists than for more experienced cyclists (Swedish Transport Administration, 2018). Non-cyclists who wish to start cycling, when asked to rank environments according to their willingness to cycle in them, ranked environments similarly to actual cyclists, but were less willing to of cycle in the ranked environments (Winters & Teschke, 2010). Efforts are thus needed to improve

[1] https://press.un.org/en/2022/ga12408.doc.htm

the environment in several respects in order to increase cycling in the long term by recruiting new cyclists.

Effective measures aimed at increasing cycling must identify the needs and interests of road users while building on an understanding of perceived barriers. In this respect, a barrier may be actual or experienced. Travel habits are not always driven by 'rational' factors, and emotional or 'irrational' factors can be just as important, if not more so. One's willingness to cycle depends not only on whether one can cycle, but also on whether one wants to cycle (Eriksson & Forward, 2011). Road cycling is not always perceived as attractive. According to Kircher et al. (2022), this can be linked to the high speeds and dangerous overtaking of motorised traffic as well as the interaction of different road users. Road design is also important for cyclists' sense of security, and 2+1 roads, for example, diminish cyclists' sense of security (see examples in Annex 1).

A systematic review of 12 studies examining different incentives to encourage commuting by bicycle (such as advocacy campaigns or infrastructure changes, e.g., a new bridge), found a lack of reliable evidence regarding which incentives had the desired effect (Stewart et al., 2015). One conclusion was that incentives targeting several potential users may have a greater impact than more limited interventions, precisely because they reach a larger group of people. Thigpen et al. (2019) used the transtheoretical model (TTM) to investigate the potential for travel-mode changes among the population of three Canadian cities. The version of the model used by the authors describes the five change-process stages an individual may experience. The first stage is pre-contemplation, where the individual does not even consider cycling. The second stage is contemplation, where the individual starts to think about cycling. The third stage is preparation, where an individual actively takes the initiative to start cycling. In the fourth stage, the individual has started cycling and, in the fifth stage, they are cycling regularly. Place of residence, gender and age influenced an individual's stage in the model. In a Swedish context, Forward (2014a) found that incentives for changing transport mode must be adapted to an individual's stage in the change process. For an individual to change their habitual behaviour, some form of effort is required. A British interview study (Chatterjee et al., 2013) found that the decision to start (or even stop) cycling was often linked to 'life events', i.e., major changes in a person's life, but that an environment that encourages cycling encouraged individuals to start cycling.

Today's transport system is the result of choices and decisions made over a long period of time, since the end of the Second World War (for a detailed description, see thesis of Lundin (2008). As a result, cars now play a central role in the planning and regulation of the transport system. The current transport paradigm marginalises cycling, describing it with the same frame of reference as motorised transport, and cycling is not well represented in transport models or cost-benefit analyses (Freudendal-Pedersen et al., 2019; van der Meulen & Mukhtar-Landgren, 2021). Van der Meulen and Mukhtar-Landgren (2021) further describe how cycling is generally perceived as only able to replace short, urban journeys (usually up to 5 km), even though regular commuting over longer distances occurs, serving purposes beyond mere transport (Hansen and Nielsen, 2014; Larsen, 2018). Electric bicycles especially have the potential to enable longer cycling journeys for many users, even across hilly terrain and in headwinds (Haustein & Møller, 2016; Rérat, 2021). However, the research on cycling generally focuses on short journeys made in cities. This may be one reason why cycling is not a higher priority.

A further factor in the de-prioritisation of cycling by transport policy is the explicit or implicit portrayal of cycling as dangerous. Cyclists are described as 'unprotected' and 'vulnerable' rather than as 'active road users' or users of 'muscle-powered vehicles'. Such terms are used in education, helmet campaigns, general usage and the media, and are partly reinforced by physically separating cycling from motorised traffic, so that the road is no longer perceived as an appropriate place for cyclists to be (Horton, 2007). The car's self-evident centrality in today's transport paradigm also entails that cyclists are denied the right to use roads, making them targets of road rage, which in turn causes people avoiding cycling (Oldmeadow et al., 2019). Oldmeadow argues that aggression may be reduced if cyclists are perceived as legitimate road users. Better knowledge of rules and compliance from all

users can enable this, as can replacing car journeys with cycling. Rules that better suit cyclists' needs are likely to increase compliance, making cycling more legitimate for other road users.

Van der Meulen and Mukhtar-Landgren (2021) focus mainly on the situation in Sweden, where cycling, as a mode of transport, is devalued in relation to cars or trains. This is related, in part, to the centrality of speed, as travelling further in the same time interval is perceived as inherently positive, even if alternative models are conceivable. Models rewarding proximity and which consider factors such as health would, for example, create different conditions for cycling as an economically beneficial option. The Government has adopted a national strategy for increased and safer cycling (Ministry of Enterprise and Innovation, 2017) but it does not impose any restrictions or limitations on cars (Balkmar, 2018). Over shorter distances, cycling is competitive in terms of time with cars, and reducing the attractiveness of cars, e.g., in cities, can help increase cycling (Eriksson, Niska, et al., 2022). Adapting rules to the conditions of cycling can also be an important element, forming one of several building blocks in a comprehensive and system-changing approach. Thus, regulatory adaptation alone is probably not sufficient to bring about a major increase in cycling, but the signalling effect of such changes and their ability to facilitate communication about cycling as an important and sustainable mode of transport may be significant (Banerjee et al., 2022; Funk & Larsen, 2020; Hansen & Nielsen, 2014; Schneider, 2022).

In the autumn of 2021, the Swedish Transport Agency was commissioned by the Government to analyse regulatory issues with the goal of increasing the proportion of cyclists among road users. The assignment listed areas of particular interest for analysis:

- cycling in both directions on roads where motorised traffic is one-way
- 'simultaneous green' for cyclists at junctions
- cycling against red lights when turning right
- modified rules for overtaking cyclists by motor vehicles in mixed traffic (the safety aspect for cyclists being overtaken was also emphasised)
- any clarifications or changes to the rules for cycling abreast
- other changes to traffic rules that can increase the proportion of cycling journeys.

The Swedish Transport Agency's assignment stated that the proposed regulation must be easy for all road users to understand and that any proposed legislation must be carefully considered with regard to road safety in general and the safety of vulnerable road users in particular.

Pursuant to the Government assignment, the Swedish Transport Agency engaged VTI to assist by describing the state of knowledge based on current research. VTI rapport 1155 presented the parts included in the assignment. The present report deals with issues related to cycling abreast and overtaking in mixed traffic which, although related to the Swedish Transport Agency's Government assignment, were not included in the assignment given to VTI.

1.2. Aim and scope

The aim of this report is to review knowledge regarding requirements for space when overtaking cyclists, mainly on rural roads, taking into account cyclists' progress, accessibility, road safety and sense of security. In this context, the report also addresses related issues such as lateral positioning of cyclists and cycling abreast, especially in mixed traffic. These two topics also concern the space requirement on cycle paths, which means that some information is included both in this report and in VTI rapport 1155 (Egeskog et al., 2023).

Our starting point is to improve traffic safety so that more people want to cycle. This entails a focus in the report on highlighting cyclists' perspectives. Effects on other road users and societal needs are thus

not fully considered. Impact assessments and other contents of the report are limited to what could be accommodated within the framework of the report.

1.3. Methodology

In autumn of 2020, we carried out a literature review on overtaking cyclists with a focus on rural roads, in the framework of the HCT II project[2]. The literature search was conducted as an unstructured search on Google Scholar, TRID, DiVA, Web of Science and Scopus using keywords such as "overtaking", "cycling", "minimum passing law", "rural" or similar in various combinations. Then the so-called snowball method was used, to include articles from the references lists of relevant articles. In addition, legal texts related to overtaking, cycling abreast and lateral positioning of cycles were searched for on the official websites of different countries.

This resulted in a literature review which was used, among other things, to describe the problems with a regulation prescribing a minimum distance of 1.5 metres while overtaking. This regulation applies in many other countries, and Cykelfrämjandet, among others, has advocated for its introduction in Sweden. Based on the results, an alternative principle was proposed which would require the overtaking vehicle to completely change lanes, resulting in distances that differ depending on the width and design of roads and the lateral position of the cyclist. This review was published on the Swedish Cycling Research Centre's website[3].

Within the framework of the Swedish Transport Agency’s above-mentioned Government assignment, how “changed traffic rules can promote safe overtaking of cyclists” was to be analysed (Ministry of Rural Affairs and Infrastructure, 2021). This analysis must “take into account” VTI's literature review. Thus, the review was supplement and expanded with literature which had been added and made available to the Swedish Transport Agency in late February of 2022. Further additions have been made since then, resulting in the present report.

[2] https://www.vinnova.se/p/hct-ii/

[3] https://cykelcentrum.vti.se/omkorning-av-cyklister-alternativ-till-15-metersregeln/

2. Cycling rules: an international perspective

The Government assignment to the Swedish Transport Agency included analysing and proposing how changes to traffic regulations can promote safe overtaking of cyclists as well as reviewing the need for regulatory changes regarding cycling abreast. With the aim of contributing to this work, we have carried out an international review of cycling regulations related to the issues of "keeping right", "cycling abreast", "cycling in the carriageway" and "overtaking cyclists" as well as other issues that may be relevant in this context. The review included our Nordic neighbours of Denmark, Norway and Finland, as well as the Netherlands, Germany, the United Kingdom, France, Italy, Spain, the United States and Australia. But before considering national regulations in detail, the relevant international agreements under the Vienna Convention are briefly summarised.

2.1. Vienna Convention

The Vienna Convention on Road Traffic of 1968 is an international treaty designed to facilitate international road traffic and to increase road safety by establishing standard traffic rules among the contracting parties. The Vienna Convention on Road Traffic[4] presents the following basic rules (authors' translation):

> *Extract from Article 10, paragraph 3: Every driver of a vehicle [including cyclists, drivers of motorcycles and, e.g., horsemen] shall, to the extent permitted by circumstances, keep his vehicle near the edge of the carriageway appropriate to the direction of traffic.*
>
> *Extract from Article 27, paragraph 1: Notwithstanding the provisions of Article 10, paragraph 3, of this Convention, Contracting Parties or sub-divisions thereof shall be free not to prohibit cyclists from travelling two or more abreast,*
>
> *Article 7, paragraph 3 states that drivers shall take extra care of "the most vulnerable" road users such as pedestrians, cyclists and especially children, elderly people and people with disabilities.*

Thus, under the Vienna Convention, cycling abreast is permissible despite the keep-right rule (in right-hand traffic). The keep-right rule also applies under the Vienna Convention "to the extent permitted by circumstances", which leaves room for interpretation. It can be added that some countries have signed and ratified the Vienna Convention with reservations for certain local rules that contradict the Vienna Convention, or have added exceptions after signing.

The Vienna Convention succeeds the 1949 Geneva Convention on Road Traffic[5]. However, countries which have not ratified the Vienna Convention may still be bound by the Geneva Convention. Article 16 describes the rules regarding cycling, stating that cyclists shall use cycle tracks where there is an obligation to do so indicated by an appropriate sign, or where such obligation is imposed by domestic regulations; that cyclists shall proceed in single file where circumstances so require and, except in special cases provided for in domestic regulations, shall never proceed more than two abreast on the carriageway; and that cyclists shall not be towed by vehicles. Furthermore, Article 9 (Vienna Convention) requires every driver of a vehicle to maintain the appropriate direction of traffic, and that cyclists shall, to the extent permitted by circumstances, keep near to the edge of the carriageway appropriate to the direction of traffic. Overtaking must be done without endangering others.

[4] https://treaties.un.org/Pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XI-B-19&chapter=11&Temp=mtdsg3&lang=en

[5] https://treaties.un.org/doc/Treaties/1952/03/19520326%2003-36%20PM/Ch_XI_B_1_2_3.pdf

2.2. Overview of rules in different countries

In the UK, significant changes to the Highway Code have been made following extensive investigation[6]. The changes entered into force in January of 2022. A summary of the comments and responses (the equivalent of a formal consultation) is available on the UK Government website[7]. The most significant and comprehensive change (Rule H1) establishes a hierarchy of consideration/responsibility, which ensures that those road users who can do the greatest harm have the greatest responsibility to reduce the danger or threat they may pose to smaller/more vulnerable road users. Thus, pedestrians are at the top of the hierarchy, followed by cyclists. As a clarification, a rule (Rule H2) was also introduced stating that all road users must give way to pedestrians when turning, and that cyclists must give way to pedestrians on footpaths and bicycle paths. A third update (Rule H3) is directed at drivers of motor vehicles who, upon turning, must give way to cyclists continuing straight ahead. Other updates are also based on this hierarchy of road users. Since 1994, this hierarchy also applies in the Netherlands, where motorists are, in principle, always at fault in collisions with pedestrians or cyclists. Even when a vulnerable road user is at fault, the driver of the motor vehicle must pay at least 50 percent of the damages (Schepers et al., 2017).

Rules regarding the lateral positioning of cyclists in the road or lane, as well as cycling abreast and in what circumstances this is permitted, differ internationally. Overtaking cyclists is also subject to different rules in different countries. A summary of the main features of the rules in a selection of countries is provided in Table 2. Links to the national traffic regulations of each country can be found at Table 1. The summary in Table 2 is a brief extract, and translations of the legal texts are to illustrate similarities and differences. It is therefore not a direct and legally binding translation of the legal text, and is not to be interpreted as such. The translation was carried out using the authors' own language skills, consultation with native speakers and online translation services. The sample includes the other Nordic countries (except for Iceland), several European countries where cycling is relatively common and/or where laws have been recently amended to improve the situation of cyclists, as well as the US and Australia, since a large part of cycling-related research in scientific journals originates in these two countries. A relevant document in this context is *The State of National Cycling Strategies in Europe*[8].

With regard to overtaking cyclists, the introduction of absolute minimum lateral distances to be maintained by overtaking vehicles is increasingly common. While an overtaking distance of 1.5 metres is most common in European countries imposing absolute minimums, smaller distances are more common in the US. Variations in the minimum distance, based on speed or road type, do occur, but are rare. In Europe, Spain was the first country to introduce, in March 2022, an amendment requiring overtaking drivers to change lanes completely on roads with more than one lane per direction.

The rules in various countries vary significantly in terms of the level of detail. In the present sample, only the UK legislation provides detailed justification for the rules of conduct, and all other countries' laws basically just state the applicable rule. However, the recently introduced or soon-to-be-introduced rule changes are justified, in communications to the public, as promoting cycling and increasing the safety of cyclists. The actual basis for reformulated rules is usually not presented, and we were unable to ascertain whether any evaluations of the amendments are underway or planned.

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[6] https://www.gov.uk/government/consultations/review-of-the-highway-code-to-improve-road-safety-for-cyclists-pedestrians-and-horse-riders/summary-of-the-consultation-proposals-on-a-review-of-the-highway-code

[7] https://www.gov.uk/government/consultations/review-of-the-highway-code-to-improve-road-safety-for-cyclists-pedestrians-and-horse-riders/outcome/government-response-to-the-review-of-the-highway-code

[8] https://ecf.com/system/files/The_State_of_National_Cycling_Strategies_2021_final_0.pdf

A question that may be relevant in this context, as many new forms and types of bicycles emerge (Wennberg et al., 2015), is how laws consider the dimensions of bicycles and how vehicles outside the described framework will be treated. Some countries have rules regarding the width of bicycles, but these differ from country to country. Bicycle width may determine whether or not a mandatory bicycle path must or may be used. Sweden has no specific rules on bicycle width, but in Germany two-wheeled electric bicycles may not exceed one metre in breadth, and bicycles with more than two wheels cannot be wider than two metres (trailers are not specifically regulated, so the same rules apply as for cars). In the Netherlands, bicycles wider than 0.75 metres may use the roadway, even when a mandatory bicycle path is provided (note that modern mountain bikes may have handlebars wider than 0.75 meters, and cargo bikes can easily exceed 0.75 metres in width). Whether cycling on sidewalks is permitted and/or prescribed, and up to what age, also differs between countries, but is not systematically reported here. Norway is notable for permitting cycling on sidewalks even by adults.

Table 1. Links to the national traffic regulations of various European countries as well as Australia and the US, summarised in Table 2.

Country	Link to law and/or other relevant texts
Sweden	https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/trafikforordning-19981276_sfs-1998-1276
Australia	https://www.sa.gov.au/topics/transport-travel-and-motoring/cycling/cyclist-road-rules-and-safety?a=23438
Denmark	https://danskelove.dk/f%C3%A6rdselsloven
Finland	https://finlex.fi/sv/laki/ajantasa/2018/20180729
France	https://www.legifrance.gouv.fr/codes/id/LEGITEXT000006074228/ https://codes.droit.org/PDF/Code%20de%20la%20route.pdf
Italy	https://app.toga.cloud/codici/codice-della-strada/7
The Netherlands	https://wetten.overheid.nl/BWBR0004825/2021-07-01
Norway	https://lovdata.no/dokument/SF/forskrift/1986-03-21-747 https://www.vegvesen.no/trafikkinformasjon/langs-veien/trafikkregler/trafikkregler-for-syklister/ https://www.vegvesen.no/trafikkinformasjon/langs-veien/trafikkregler/vikeplikt-for-syklister/
United Kingdom	https://www.gov.uk/guidance/the-highway-code
Spain	https://www.boe.es/biblioteca_juridica/codigos/codigo.php?id=20&modo=2&nota=0&tab=2
Germany	https://www.stvo.de/strassenverkehrsordnung
USA	Laws differ between states, and even vary within states. These pages compare some laws related to cycling, the first of which refers to the legal texts. It is not known how quickly updates are made. https://bikeleague.org/content/bike-law-comparative-charts https://iamtraffic.org/advocacy-focus-areas/equality/u-s-bicycle-laws-by-state/

Table 2. Brief comparison of the main features of cycling regulations related to "keeping right", "cycling abreast", "cycling in the carriageway" and "overtaking cyclists" and, in some cases, other issues that may be relevant in the context (quotes not verbatim). The colour marking indicates whether a country has signed and ratified the Vienna Convention (dark green), "acceded" (same legal status as ratification via another procedure; light green), signed only (yellow) or neither signed/ratified nor acceded (no colour). Sources are provided in Table 1.

	Keeping right (or left)	**Cycling abreast**	**Cycling in the carriageway**	**Overtaking**	**Other**
Sweden	right-hand traffic, and, particularly for bicycles and mopeds: as close as possible to the right-hand edge of the roadway or lane in use *(special wording for bicycles)*	cyclists must travel single file, although they may travel abreast if this can be done without danger or inconvenience to traffic	cyclists must use a bicycle lane, if available, but may use the carriageway if they are at least 15 years of age and have a maximum speed of 50 km/h on the road, and if doing so is more suitable given the location of the destination	overtaking drivers must maintain a comfortable lateral distance from the vehicle being overtaken; cyclists may overtake other vehicles on the right	
Australia	according to Hatfield et al. (2018), encouraged to take the 'primary position', i.e. the position in the centre of the lane	cycling abreast permitted with lateral distance of max 1.5 metres, max two abreast, but overtaking as third permitted	*no rules relating to mandatory use of bicycle paths found*	at least 1 metre at up to 60 km/h at least 1.5 metres at higher speeds	
Denmark	as far to the right as possible under the circumstances (applies to all road users); bicycles must travel on the right in the right-hand lane	cycling abreast is not permitted, except where it can be done without danger or inconvenience and where there is sufficient space	must use the bicycle path when signposted, but only if the bicycle is not so wide (itself or when loaded) that it obstructs others	overtaking with sufficient distance; cyclists may overtake other vehicles on the right-hand side	
Finland	in the rightmost lane (no specific rules on cycling as close to the edge as possible)	*no rules relating to cycling abreast found*	on the right-hand shoulder of the road if available, otherwise on the carriageway; signposted bicycle paths must be used in the direction of travel; bi-directional cycle paths have an additional sign; if the (bi-directional) cycle path is only on the left, the right-hand side of the road or edge may be used	leave comfortable space for other road users	a vehicle travelling on a bicycle street must allow cyclists to pass freely, speed must be adapted to cycle traffic prohibited direction of travel can be repealed for bicycles by means of an additional sign
France	the rightmost lane intended for the vehicle	"ordinary" bicycles may never travel more than two abreast; must cycle single file in the dark or when traffic requires, especially when another vehicle seeks to overtake them	if there is a bicycle path in the direction of travel, it must be used; cyclists may use sidewalks in both directions if they do not obstruct pedestrians and travel at walking speed; shoulders may be used by cyclists	at least 1 metre inside densely built-up areas and 1.5 metres elsewhere, motor vehicle drivers must reduce speed when overtaking cyclists and others	

	Keeping right (or left)	Cycling abreast	Cycling in the carriageway	Overtaking	Other
Italy	vehicles must travel on the right-hand side of the carriageway and close to its right-hand edge, even when the road is clear *(general rule, no specific provisions for bicycles)*	cyclists must cycle in single file as the traffic situation requires, and may otherwise be no more than two abreast; outside densely built-up areas, cyclists must always cycle in single file, but cyclists under 10 years old must cycle to the right of any partner (Art. 182)	bicycle paths must be used where available (Art. 182)	when overtaking, drivers must keep a 'sufficient distance' laterally (a 1.5 metre rule seems to be under discussion, but nothing is decided)	Art 145 (4): motor vehicle drivers must give way to bicycles on bicycle paths or entering bicycle paths
The Netherlands	vehicles must keep to the right to the extent possible *(nothing specific about cyclists)*	cyclists can ride in pairs abreast (but not moped riders)	mandatory bicycle paths must be used (solid versus broken line); bikes wider than 75 cm may use the road	overtaking must be done on the left, even between cyclists (no reference to distance); cyclists may overtake other vehicles on the right	cycling right on red is permitted where an additional sign is present (Fietserbond, the equivalent of the Swedish Cykelfrämjandet, considers that this should always be permitted, in order to decriminalise a harmless and normal act)
Norway	as long as circumstances permit, vehicles should be driven on the right-hand side of the road; bicycles may use the hard shoulders	*no rules relating to cycling abreast found*	cyclists may only use the bicycle paths to the right of the road	no specific provisions on distance, consideration, etc.; cyclists may overtake other vehicles on the right-hand side	cycling on the sidewalk is permitted if pedestrian traffic is minimal and there is no risk of danger; the maximum speed for passing pedestrians is 6 km/h
United Kingdom until 29 January 2022	*no explicit mention of position in the roadway or lane*	never more than two abreast, single file on narrow or busy roads and on bends	use marked cycle routes and cycle-dedicated infrastructure where not dangerous; that this is optional based on personal judgment is explicitly stated; when using cycle tracks, the correct side/lane must be used; cycle lanes are not mandatory	don't get too close to the overtaken vehicle; e.g., give cyclists at least as much space as you would give a car	bus lanes can often be used by cyclists (signposted); special rules on being extra observant of motorbikes and bicycles, order to anticipate their actions, extra order to give them plenty of space

	Keeping right (or left)	Cycling abreast	Cycling in the carriageway	Overtaking	Other
United Kingdom as of 29 January 2022	when passing parked cars, keep at least one door's width apart Rule 72: Two basic road positions should be adopted, depending on the situation. 1: In the centre of the lane, to be as clearly visible as possible (on quiet roads/streets; in slower-moving traffic; at the approach to junctions); 2: When riding on busy roads, allow vehicles moving faster to overtake whilst keeping at least 0.5 metres away from the kerb edge.	cyclists must cycle single file if drivers of motor vehicles wish to overtake and it is safe to allow them to do so; when cycling in a large group on narrow roads, it may be safer to cycle two abreast	the use of bicycle paths remains non-mandatory; Rule 140 is updated with a text addressed to drivers of motor vehicles, reminding them that cyclists need not use bicycle paths	a clarifying guideline is added: at least 1.5 metres below 30 mph (nearly 50 km/h), at least 2 metres above 30 mph; large vehicles must always leave at least 2 metres; wait behind if it is not safe to overtake and/or the distances cannot be observed; be extra observant and leave more space in bad weather (including strong winds) and at night	
Spain	cyclists must stay as close as possible to the right-hand edge (mentioned in connection with two abreast); use the shoulder if possible, otherwise use as little space on the roadway as possible on long downhill curves, cyclists may leave the shoulder and occupy the right-hand side of the carriageway	cyclists may cycle two abreast as far as possible to the right, must cycle single file in case of poor visibility or heavy traffic	if a bicycle path exists, it must be used; on some motorways (so-called "autovia"), cycling is only permitted on the shoulder without ever using the carriageway; on other motorways ("autopista") cycling is completely forbidden	overtaking must be done by occupying part or all of the adjacent lane (regardless of the direction of travel) and by keeping at least 1.5 metres from the cyclist or moped; the solid line may be crossed if oncoming traffic is not endangered as of March 2022, overtaking vehicles must completely change lanes on roads with more than one lane per direction of travel[9]	

[9] https://euronewssource.com/new-fine-for-drivers-overtaking-cyclists-in-spain/

	Keeping right (or left)	Cycling abreast	Cycling in the carriageway	Overtaking	Other
Germany	all vehicles must keep to the right and cyclists in the lane must keep as far to the right as possible (not just in poor visibility); various courts have held that 'as far as possible' does not mean right at the edge, but that a distance of 1 metre is reasonable, or, alongside parked vehicles: 1.5 metres from the vehicle	cyclists are allowed to cycle abreast if this does not obstruct traffic, otherwise they must cycle single file, i.e., one after another	bicycle paths are mandatory only when signposted; bicycle paths on the right-hand side may always be used, while those on the left-hand side may be used only when signposted; shoulders may be used unless pedestrians are obstructed; if the width of the bicycle makes use unreasonable, cyclists may use the carriageway	motor vehicles overtaking cyclists must keep a minimum distance of 1.5 metres within densely built-up areas and 2 metres elsewhere; cyclists may overtake on the right at a moderate speed and in a particularly cautious manner where there is sufficient space	more than 15 cyclists may form a closed formation (column), which may not be obstructed by other vehicles and which counts as one vehicle even at traffic signals and junctions; long columns must be broken to permit other traffic to pass; the column most clearly form a unit
USA (different rules between and even within states)	for all vehicles usually "as far to the right as practicable", in some cases adding that the cyclist's judgement rules; some states only require cyclists to stay in the right-hand lane; there are specific exceptions to keeping right that apply in different states, e.g., when overtaking, when turning left, when encountering obstacles, when travelling at the same speed as other traffic, when the lane is too narrow to be "shared", on one-way streets, to avoid a right-only lane	two cyclists abreast are most commonly permitted, in many cases with the restriction that this only applies when it does not obstruct other traffic; six states do not regulate the number of cyclists riding abreast and two states require cycling in single file	a distinction is made between bike lanes, paths and shoulders; most often, the use of such infrastructure is not mandatory - in many cases an existing law has been removed; some states require the use of existing cycling infrastructure, only one state requires cycling on the shoulder (if it is of a good standard)	three feet minimum (approx. 90 cm) is most common, otherwise 4 feet, in some cases increased distance with increased speed, "safe distance", so as not to hit the cyclist if he/she falls, and a few other formulations	in some states, cyclists may treat a stop sign as a give-way sign and may ride through a ‘dead red’, e.g., after a certain period of time has passed (as not all traffic signal systems can detect cyclists); approximately 20 states in the US do not define bicycles as vehicles

3. Lateral positioning of cyclists

Cyclists' space requirements are related to and reflected by cyclists' position on the road, but also depend on the cyclist and his or her type of cycle, as well as differing according to site-specific characteristics that impact the cyclist's ability to maintain balance. Rules regarding the lateral positioning of cyclists on the road or bicycle path in different circumstances differ in different countries (see Table 2). In simple terms, the Vienna Convention requires cyclists to stay as far to the right as possible (see section 2.1), but different countries have different interpretations and formulations of rules concerning the position of cyclists in traffic.

Hatfield et al. (2018) examined the preferred lateral position of cyclists under different circumstances when cycling in mixed traffic. This was done using 'cycling diaries' and associated questionnaires in a study of over 1,500 participants in Australia. The study showed complex relationships between the adopted lateral position and external factors, and many of the participants' explanatory comments suggest that choices are rational and linked to the (perceived) safety of the situation, such as preventing drivers from making dangerous overtaking manoeuvres. A somewhat simplified interpretation could be that cyclists aim to facilitate overtaking motorised traffic except when it is perceived to be associated with danger, in which case they choose to 'take the lane', i.e., occupy the middle of the lane, to actively prevent potentially dangerous overtaking.

In a simulation study O'Hern et al. (2018) showed that cyclists' placement on dedicated bicycle paths can be influenced by visual nudging, such as painted lines, as also illustrated in real traffic by the blog "Trafik i stan"[10]. Visual guidance can also have an effect on motorists, as shown in a simulation study for rural roads (de Waard et al., 2004; Steyvers & de Waard, 2000). The drivers in the study positioned themselves closer to the right-hand edge when there was a centre line, compared to when there was not, and a centre line was found to counteract overly rightward positioning.

Van Houten and Seiderman, (2005) found that it is possible to use road markings to influence the lateral positioning of cyclists, in mixed traffic, relative to parked cars, as well as to reduce variance in the positioning of cyclists, but the lateral positioning of motorised traffic on the same street was not affected in the case studied. Thus a greater distance from parked cars, which is desirable to reduce the risk of collisions when opening car doors, diminished the distance between overtaking motorised traffic and bicycle traffic. The lateral positioning of car traffic on smaller rural roads could be moved centrewards by painting edge lines, which was also perceived positively by motorists. Motorists' expectations regarding cyclists' lateral positioning could be influenced by road signs, and the message 'Bicycles may use full lane' was found to have the greatest effect (Hess & Peterson, 2015; Still & Still, 2020). 'Sharrows,' or shared-line markings, according to a review of mainly North American studies by Vasilev et al. (2017), also lead to cyclists positioning themselves slightly further away from the edge, a slight increase in the overtaking distance of motor vehicles, and less cycling on sidewalks. A Norwegian study found no major changes in lateral positioning after the installation of sharrows, but on the studied street, more than half of cyclists chose a lateral position in the centre of the lane even before sharrows were installed (Vasilev et al., 2017).

In addition to the adopted lateral position, the cyclist's ability to maintain balance also affects lateral positioning on the road or cycle path. The variation resulting from balancing on a bike is often referred to as wobbling. The follow-up to the GCM handbook *Mobilitet för gående, cyklister och mopedister* (Swedish Transport Administration & SALAR, 2022) provides for a normal degree of wobble of 0.5 metres per cyclist, but there is limited knowledge in the research on how much wobble room is required in different situations.

[10] https://trafikistan.se/cyklisters-placering-pa-banan/

4. Cycling abreast

The overview of rules in Chapter 2 above showed that regulations regarding cycling abreast differ between countries. In some countries, single-file cycling is the only permitted mode of transport, while in other countries cycling abreast is the norm. In addition, the formulations of some rules fall somewhere between the two. Cycling infrastructure design in the Netherlands aims to permit two cyclists to cycle together abreast (CROW, 2016). In addition, a third cyclist should be able to overtake or join. As well as the need for parents to travel safely with children, such design is justified with reference to the social dimension of cycling journeys, during which travellers should be able to socialise, just as in a car (Veroude et al., 2022).

In Sweden, the basic rule is that cyclists must travel in single file, but are permitted to travel abreast when this can be done without danger or inconvenience to traffic[11]. A simple online search did not provide any help on how to interpret 'inconvenience'. Cycling abreast does not necessarily pose a greater danger than cycling single file, as described in detail in Chapter 5.

Apart from sports-science literature investigating the aerodynamic effects of peloton cycling, the research literature addressing group cycling, and cycling abreast specifically, is very limited. In recent years, a Spanish research group has begun to investigate overtaking of cyclists in different group constellations (e.g., Pérez-Zuriaga et al., 2021, Chapter 5), but social aspects related to community, safety and communication are largely unexplored. This applies to all types of cycling, from recreational cycling and transport/commuting to exercise cycling. Heeremans et al. (2022) reviewed the literature on the safety-related aspects of group cycling. Thirty-two scientific articles are reviewed, but only a few deal with communication beyond formalised communication in the form of predetermined signs and commands which cyclists give each other during peloton riding.

Based on data from the United Kingdom, Aldred (2012) finds that cyclists in mixed traffic often find cycling in a group to be safer than cycling alone. Aldred (2015) presents an analysis of the position of cycling in the traffic 'hierarchy'. This includes a discussion of how interviewed cyclists perceived the phenomenon of cycling abreast. One conclusion was the difference that exists between cycling culture in the UK, where cycling is marginalised, and the Netherlands, where cycling is entrenched as a mode of transport. While cyclists appreciated being able to socialise and talk to each other when cycling abreast, they remained aware that this was inappropriate, as they might obstruct motor traffic. According to Aldred (2015), cycling abreast violates unwritten rules about the right to space on the road, which is generally considered to be a space for purposeful transport. Generally speaking, driving a car is associated with a purpose, while cycling is perceived as pleasure. Aldred (2015) also describes how cyclists' actions are more visible than what occurs in a car, so that the 'inappropriate' socialisation of cyclists is more noticeable, in addition to the fact that cyclists are generally more stigmatised. McIlvenny (2015) describes in qualitative terms how cycling together can be a 'shared experience', in which communication among participants is an important element. Beecham and Wood (2014) present a quantitative approach based on London bike-sharing logs, which show that accompanied cycling trips differ in several respects from solo cycling trips, including day of the week, time of day and location, but how cyclists relate to one another was not investigated.

[11] The wording of the traffic regulation is: "Cyclists must travel in single file. However, when this can be done without danger or inconvenience to traffic, they may ride abreast." It is unclear whether cyclists are considered to be 'traffic' and whether the inconvenience of cyclists is to be included in the assessment, or whether only the inconvenience to other traffic is intended.

5. Distance when overtaking cyclists in mixed traffic

In the international overview of cycling regulations (see Chapter 2), we presented rules for overtaking cyclists in mixed traffic in both urban and rural areas. We found that, in other countries, absolute values for the minimum lateral distance which the overtaking vehicle must maintain are increasingly common. A minimum overtaking distance of 1.5 metres is commonly applied (see Table 2 on page 17). Here, we review the research literature on space requirements and distances when overtaking cyclists in mixed traffic. As minimum overtaking distance regulations have become more common, the body of research highlighting how motor vehicle drivers overtake cyclists has also grown, especially in the last 10 years. In section 6.1, we discuss current regulations in Sweden, possible alternatives and the potential effects of various approaches and perspectives. As elsewhere in this report, we emphasise the perspective of cyclists in pursuit of the goal of increased and safer cycling. The literature published in this field is based on data derived mainly, but not exclusively, from the non-urban road network.

In this context, it is worth highlighting that approximately half of fatal accidents involving cyclists in Sweden occur outside densely built-up areas (Adminaité-Fodor & Jost, 2020; Folksam, 2018). Approximately 65 percent of fatal accidents involve a collision with a motor vehicle. The most common fatal accident type for cyclists on the national road network was being hit while cycling along the side of the road, and the majority of such accidents occur on roads with signposted speeds of 70-90 km/h (Folksam, 2018). This is despite the fact that only a very small proportion of passenger transport by bicycle occurs in mixed traffic outside urban areas (Eriksson, Eriksson, et al., 2022). Vehicle impact speed is one of the parameters with the greatest impact on the risk of injury to vulnerable road users (Rosén and Sander 2009).

5.1. When is overtaking 'too close'?

Several papers present studies of 'close passes', with different definitions of what is 'too close'. This depends, in part, on legislation in different countries, where the minimum overtaking distance can be 3 feet (approximately 0.9 metres; in some states in the US, as little as 2 feet in North Carolina) to 1.5 metres (France, Portugal, Belgium, Spain, UK), or speed-dependent (as in Queensland, Australia, where 1 metre applies for speed limits up to 60 km/h, and 1.5 metres for greater speeds). In Germany, 1.5 metres in urban areas and 2 metres elsewhere. In Spain, as of March 2022, overtaking drivers must completely change lanes if there is more than one lane in the direction of travel. In Spain, a distance of 2 metres is also being discussed, in connection with reduced speeds when overtaking. How such distance should be measured, i.e., between which points, is not always clearly defined, and Llorca et al. (2017) showed that the same data gave a 9 percent illegal overtaking rate, when measurement was between the bicycle frame and the side of the vehicle, or a 36 percent rate, when measured between the outside of the handlebar and the outer edge of the rear-view mirror.

Data on the proportion of 'near passes' vary quite widely, not least because of different measurement methods and thresholds (Beck et al., 2019; Debnath et al., 2018; Kay et al., 2014; Love et al., 2012; Mackenzie et al., 2019, 2021). On Spanish rural roads in real traffic, the proportion of overtaking below the legal distance of 1.5 metres was 36 percent (Llorca et al., 2017), and in Australia, the proportion of illegal overtaking was 6.2 percent for stretches with a speed limit of 60 km/h or less and 31.8 percent at greater speeds (Nolan et al., 2021). Depending on the number of overtakes that occur in one hour, the absolute number of close passes during a cycle journey can be great. Nolan et al. (2021) conducted the largest collection of overtake data in real traffic to date, recording over 45,000 overtakes for 162 cyclists in different traffic environments. They found that just over 40 percent of all cycling journeys with 0-49 overtakes contained at least one close pass, and for cycle journeys with 100 or more overtakes this proportion was closer to 100 percent.

Close passes are perceived by many cyclists as one of the most common acts of aggression in traffic (Heesch et al., 2011). The perceived or anticipated discomfort during overtaking can lead cyclists to opt out of road cycling altogether (Kaplan & Prato, 2016), and the perceived danger of cycling can discourage prospective cyclists (Fernández-Heredia et al., 2014). Overtaking is perceived as more threatening/dangerous by lone sport cyclists than cyclists in a group (Garcia et al., 2020). Overtaking is also perceived as more dangerous when motorists overtake directly, so called "flying overtakes", compared to when motorists slow down behind cyclists before overtaking (López et al. 2020), as well as when the aerodynamic effect is greater (Garcia et al., 2020; Llorca et al., 2017). The combination of speed, distance and the frontal surface of the vehicle, as well as the size of the cyclist's lateral surface, determine aerodynamic impact. The amplitude of the pressure wave and the suction effect as well as the flip-over duration increase with increasing speed and decreasing distance (Gromke & Ruck, 2021). The greater the speed, the greater the lateral distance required for the same overtake experience on a 'comfort scale', and only at distances greater than 3 metres does the aerodynamic factor no longer play a role in the experience (Garcia et al., 2020; Llorca et al., 2017).

5.2. Factors affecting overtaking distance

The distance between the cyclist and the overtaking motor vehicle decreases on average in the presence of oncoming traffic (Dozza et al., 2016; Kay et al., 2014; Mehta et al., 2015; Shackel & Parkin, 2014), in the presence of a centre-line rumble strip (Kay et al., 2014; Savolainen et al., 2012), when the centreline is solid and there is no shoulder (Chapman & Noyce, 2012), and when the road is narrower (Love et al., 2012). According to one subset of the studies, overtaking distances for larger vehicles, such as SUVs, buses and lorries, are reduced (Kay et al., 2014; Walker, 2007). Results are inconclusive regarding whether signmarked bicycle lanes or other road markings (sharrows) have an impact on overtaking distance, and the proportion of variance explained by road markings (when provided) tends to be small (Beck et al., 2019; Chuang et al., 2013; Debnath et al., 2018; Love et al., 2012; Mehta et al., 2015; Nolan et al., 2021; Parkin & Meyers, 2010; Richter et al., 2019; Shackel & Parkin, 2014; K. Stewart & McHale, 2014). This is probably because other underlying factors, not included in the analyses, have a greater impact. A recently published study, with the largest number of overtaking measurements in real traffic to date, suggests that dedicated cycling infrastructure nevertheless leads to fewer close passes (Nolan et al., 2021). However, the design of cycling infrastructure makes a difference, and the position of cyclists in relation to the infrastructure has not been included in the analysis.

Almost no studies have investigated motorists' share of the variance, i.e., the extent to which motorists' personal experiences, attitudes, etc. impact overtaking. A simulation study and a survey study suggest that a more negative attitude towards cyclists leads to greater acceptance of smaller margins and higher overtaking speeds (Goddard et al., 2020; Saxton & Thorp, 2021), while a test-track study with a dummy cyclist showed that men are more likely to make close passes (Rasch et al., 2020). In an analysis of a naturalistic study, called the Safety Pilot Model Deployment, in Michigan, USA, driver behaviour during overtakes, plus the previous five seconds, was manually categorised from video recordings of 4,635 overtakes. One in thirteen cyclists were hit by a 'distracted' driver. In 4 percent of overtakes, drivers held a mobile phone to their ear or mouth in conversation, in 3.1 percent of overtakes drivers manipulated a mobile phone, and in 0.7 percent of overtakes drivers were otherwise occupied, e.g., adjusting the radio on the car's centre console (Feng et al., 2018). While the distance from the cyclist during the overtaking was not measured, it was found that drivers manipulating phones completed the overtaking with a less clearly defined lane change than drivers using phones in conversation and drivers not using phones. This was true with or without oncoming traffic.

Overtaking distance can rarely be unambiguously linked to the specific characteristics of the cyclist. There are studies showing that the overtaking distance increases on average when the bicycle appears

to contain a child (Ampe et al., 2020), in some cases for cyclists who appear female (Chuang et al., 2013; Sando & Moses, 2011; Walker, 2007), although this was not confirmed by Haworth et al. (2018)) and (arguably) if the cyclist is not wearing a helmet (Walker, 2007; Walker et al., 2014). A cyclist's lateral position on the road affects the overtaking distance, and being located closer to the shoulder increases the distance for cyclists (Kay et al., 2014; Walker, 2007), but at the same time, overtaking motorists move further laterally when cyclists are in the lane instead of on the shoulder of the road (Kay et al., 2014). Similarly, overtaking distances are smaller when cycling abreast (Garcia et al., 2020; López et al., 2020; Pérez-Zuriaga et al., 2021) but the speed of overtaking drivers is less and they are more likely to switch to the oncoming lane (López et al., 2020). Further, the overtaking driver is more likely to slow down behind the cyclists before overtaking ('accelerating overtake'), instead of overtaking directly without reducing speed ('flying overtake'), when a group of cyclists rides two abreast (Pérez-Zuriaga et al., 2021). Riding abreast, rather than single file, is more important than the size of the group.

A study which systematically evaluated 'share the road' signs showed no reduction in the number of close passes, but motor vehicles were slightly further sideways than without signs, particularly when cyclists were in the carriageway rather than on the shoulder (Kay et al., 2014). A study with roadside interviews in Norway showed that a 'share the road' campaign was generally perceived positively and found perceptions of an improved climate between cyclists and motorists (Høye et al., 2016).

5.3. Evaluation of minimum-distance laws

Virtually no evaluation has been carried out of overtaking laws with fixed distances using pre/post measurements. Some studies have measured overtaking distances after the introduction of a law, to investigate the extent to which offences occurred (see section 5.1). In the United States, a simulation study was conducted comparing lateral distances during overtaking of cyclists for drivers reportedly aware of the three-foot overtaking law and drivers who were not (Herrera et al., 2020). No significant differences were found between the groups, regardless of whether the oncoming traffic was light, medium or heavy. In an Australian survey, over 30 percent of respondents reported almost never following the 1.5-metre law (Haworth, Heesch, & Schramm, 2018). In an analysis of cyclist fatalities in the US (not only during overtaking), the three-foot law had no demonstrable effect on the fatality rate (Nehiba, 2018). However, analysis of the data required numerous assumptions, making it difficult to link fatality rates to the applicable overtaking law in a given state.

Lamb et al. (2020) argues that a legal minimum distance may be perceived as an invitation to leave only that particular distance, possibly leading to a reduction in distances. This hypothesis finds some empirical support in Feizi et al. (2021) and van Houten et al. (2018), which compared the different overtaking laws of various US states (no minimum distance, 3 ft or approx. 1 m, 5 ft or approx. 1.5 m) by combining an instrumented-bicycle field study and a survey of cyclists. A law requiring five feet of side clearance leads to greater measured overtaking distances than when the law requires three feet. Where there was no legal minimum requirement, measured distances fell somewhere in between. In general, the number of lanes had the greatest impact on overtaking distance, with greater distances and fewer offences on roads with three lanes compared to roads with two lanes. At the same time, however, the survey showed that over 70 percent of respondents were unaware of any legal minimum overtaking distance. Lamb et al. (2020) generally criticises laws based on absolute distances for being overly rigid, and showed in a video-based study that a law which allows for interpretation ("give cyclists at least as much room as you would give a car", Highway Code Rule 212) achieves better consensus between police officers and the population. An evaluation of the overtaking law in Australia was conducted using a pre/post survey study (Fruhen et al., 2021). Respondents reported that both their own and others' overtaking distances increased slightly with introduction of the law. Attitudes towards cyclists became slightly more negative in the post-survey, but the majority of respondents felt that the law increased cyclist safety and was good. The study found no increase in cycling associated

with introduction of the law, which the authors interpret to mean that such laws alone are insufficient to bring about a profound change in the views and treatment of cycling in society.

A further objection to legislation based on minimum distances, which emerges from the research literature, is evidence that road users have difficulty in correctly estimating lateral distances in absolute terms (Black et al., 2020; Haworth & Schramm, 2014; Schramm et al., 2016). This applies to those on the road as well as those observing. Van Houten et al. (2018) has shown that motorists tend to overestimate the distance at which they overtake cyclists. The difficulty of estimating lateral distances thus makes it difficult to ensure compliance with an absolute legal distance. This was one reason why Ireland, which planned to legislate a minimum distance when overtaking cyclists, chose not to introduce such a law (Labanyi, 2019).

6. Discussion

In this chapter, we discuss the results of our knowledge review. We start with a discussion of the conditions for cyclists and the role of cycling in the transport system, followed by a discussion of traffic rules in general and overtaking cyclists in mixed traffic in particular.

6.1. Adapting traffic rules to cyclists' conditions

No research suggests that a significant growth in cycling rates is achievable solely by changing traffic rules. However, this is one way to communicate that cycling is an important and sustainable mode of transport for the future. Adapting rules to the conditions of cycling is an important element and forms one of several building blocks in a comprehensive and system-changing approach.

Some regulations and rules must be considered together, as they are interrelated. One example is the introduction of bicycle streets, which cannot be fully effective if the right-hand rule remains in its current form, as the very idea of a bicycle street is to encourage lateral positioning closer to the centre of the lane. Another example is safe overtaking, which also requires that rules on keeping right and cycling abreast be more widely reviewed. Research has shown that cyclists themselves choose to 'take up space' for greater safety and sense of security (Bosen et al., 2023). Thus, a well-functioning whole must be assured so that the regulatory framework supports logical and sensible behaviour. This may also help to change the image of cyclists as immoral offenders (Ihlström et al. 2021; te Brömmelstroet et al. 2014). This report adopts the logic of such a well-functioning whole, and interrelated issues are therefore not treated entirely separately.

Another important premise of this report is the benefit to be drawn from rules that are simple and clear, enabling them to be understood, enforced and monitored. A case-by-case assessment should not be necessary, and it should be possible to follow the rules in all traffic situations. Unambiguous rules permit road users to know in advance what the rules are, reducing uncertainty and, especially for cyclists, with their more vulnerable position in traffic, increasing the sense of security. An important part of introducing regulatory changes is, naturally, reaching the public with relevant information. Once more, rules which are simple and clear, and which do not require personal interpretation, make such efforts easier.

Changes in the regulatory framework to facilitate increased cycling must be coherent and consistent. Rules should take into account the needs and conditions of cyclists, not only in terms of vehicle handling, but also in terms of the social aspects of travel. It is important to recognise that cyclists are, in many respects, a heterogeneous group. They encompass a wide range of ages, knowledge and ability. Vehicles classified as bicycles differ significantly in terms of manoeuvrability and speed. Such heterogeneity is only likely increase in the future, partly due to the introduction of new types of bicycles, and partly due to "new" cyclists possessing characteristics that are not yet represented in the current cyclist community. Rules which capture cyclists' preferences are likely to encourage more cyclists to follow the rules, which can be expected to increase the predictability of cyclists' behaviour and facilitate other road users. An important aspect here regards behaviour which under current rules may be illegal, but which is logical, desirable and even sensible from cyclists’ perspectives. Such behaviour might become legal and thus not only defensible or explainable, but normal (Ihlström et al., 2021; Leth et al., 2014; Tekle, 2017).

Aldred et al. (2016) notes that countries with a higher proportion of cycling trips also see a more even distribution in terms of gender and ages among cyclists. They examined trends in commuter cycling in English local authorities, and were unable to establish a direct relationship between more cycling and greater gender and age equality, while decreased cycling tended to be associated with a decreased proportion of women in cycling groups (see also Garrard et al., 2012). Aldred et al. (2016) assumes that new groups may take up cycling with a delay, but also argues that women and older people generally have a stronger preference for dedicated cycling infrastructure, while cycling in the UK is

traditionally characterised by the image of a younger man riding a sports bike and wearing cycling gear in mixed traffic (Aldred, 2012). She emphasises the importance of consciously including groups which do not currently cycle in infrastructure planning, marketing, policies and research.

To promote cycling 'across the country' (Ministry of Enterprise and Innovation, 2017) cycling of all kinds must be facilitated, which means listening to cyclists as well as those who do not yet cycle. This requires seeing cycling as something other than "driving a car with a smaller and slower vehicle", but rather as a unique form of movement, possessing qualitatively different conditions and limitations in terms of manoeuvrability, communication, use of momentum and other factors. Many assumptions applicable to car traffic may do not fit cycling (Freudendal-Pedersen et al., 2019; van der Meulen & Mukhtar-Landgren, 2021), and new planning tools may need to be developed. One important aspect here is cyclists' need to generate accelerative power (e-bikers less so), making frequent braking and stopping a hinder to cyclists, who therefore avoid speed changes as much as possible (Fajans & Curry, 2001; Nixon, 2012). Furthermore, widespread beliefs need to be reassessed, such as that cycling can only replace short journeys (5 km is assumed to be the limit for cycling) and that it is almost exclusively suitable for urban journeys.

6.2. Lateral position of cyclists and cycling abreast

The lateral position of cyclists on a road or street is associated with many different factors, both those affecting the cyclist's behaviour and those affected by the cyclist's chosen position, which in turn can affect the cyclist's situation in traffic. The position of cyclists is, of course, often the result of conscious choices rather than random or unconscious behaviour, and may be related to the quality of the road, fixed and moving objects/traffic participants, or additional circumstances such as crosswinds and other factors. This may include gravel or debris on the roadway edge, road damage, puddles, rumble strips, etc. In the spirit of "decriminalising" sensible behaviour, adapting rules to the natural and sensible behaviour of cyclists would entail removing the requirement for cyclists to remain as close to the right-hand edge as possible as possible. This does not entail rescinding the requirement to keep to the right-hand side of the road. As in mixed traffic, drivers would still be required to keep to the right when meeting other traffic. The removal of this rule would therefore only have a noticeable effect in mixed traffic, as most pedestrian and bicycle paths are too narrow to entail any difference between the 'right-hand side of the road' and 'as far to the right-hand edge as possible'.

Such a rule change would also encourage cyclists to 'take the lane' and position themselves in the centre of the lane, especially in urban traffic, to effectively avoid the phenomenon of "dooring", i.e. a motorist opening a door in the cyclist's path and the cyclist colliding with the car door. Experienced cyclists already report using this tactic (Bosen et al., 2023). 'Dooring' can lead to serious accidents (Schimek, 2018)the frequency of which, at least in the US, is underestimated because they are not counted as collisions between motor vehicles and cyclists. Even in Sweden, 'dooring' is not always considered a collision with a motor vehicle, but often as a single-vehicle accident (Niska et al., 2013). On the other hand, statistics regarding these and other cycling accidents have a much lower non-response rate due to the Swedish Traffic Accident Data Acquisition (STRADA) database, which also includes accidents reported by the health service.

Cycling abreast has both social and safety aspects and improves experiences of group cycling trips. The desire to communicate with others while travelling is a human trait, which is reflected in the design of cars. Room for a passenger is provided alongside the driver, facilitating communication both verbally and via body language, and the soundproofing against the outside world facilities verbal communication with passengers in the rear as well. Communication is a social need for cyclists in the same way (Aldred, 2015). Therefore, a regulatory change in line with cyclists' wishes and conditions should include support for cycling abreast. In addition to its social benefits, cycling abreast is also safer than cycling single file under certain circumstances (see Chapter 5). Further, when cycling with cyclists requiring help or supervision, such as children, being able to cycle abreast improves safety.

6.3. Overtaking in mixed traffic - current regulations in Sweden

The current provision of the Traffic Regulations (1998:1276), Chapter 3, reads:

> *Section 33 The overtaking driver must leave a comfortable lateral distance between his vehicle and the vehicle being overtaken.*

This wording applies to overtaking between all vehicle types. It does not specify what is meant by "comfortable" and from whose perspective it applies. The obvious differences between overtaking a motor vehicle and overtaking a cyclist can partly be derived from the collection of facts in Chapter 5:

- The width of a motor vehicle takes up the entire lane (except for motorcycles and mopeds), so that overtaking a motor vehicle almost always requires the overtaking vehicle to occupy the lane to the left of the overtaken vehicle. A motor vehicle being overtaken (except for motorcycles and mopeds) usually has a mass that is similar (or greater, in the case of trucks) to the overtaking vehicle. This means that issues such as wind drag do not play the same role as when overtaking a cyclist. In addition, their difference in speed and therefore kinetic energy is much smaller, and both parties have collision protection (except for motorcycles and mopeds).
- Collision with a motor vehicle at high speed brings a great risk of death or serious injury to cyclists due to the large difference in kinetic energy and the lack of collision protection, making safe overtaking and special consideration of the cyclist's vulnerable situation particularly important (e.g. Kaplan et al., 2014).
- An overtaking motorist may not be able to fully put himself in the position of the cyclist he is overtaking. For example, a survey conducted by the Finnish Liikenneturva ("Traffic Protection") shows that car drivers underestimate the space requirements of cyclists[12].

Given that cyclists risk the most serious injuries in the event of a collision, while remaining unable to influence the overtaking distance to any great extent under the current regulation, the cyclist's perspective should be the measure of what is a 'comfortable' distance during overtaking. It is reasonable to assume that different cyclists will have different opinions on the matter, and of course it is impossible to ascertain an individual's opinion before every overtaking. As research shows (see Chapter 5), current overtaking behaviour does not seem to meet the requirement that overtaking distances be generally perceived as 'comfortable'. On the contrary, there is evidence that cyclists opt out of road cycling altogether due to discomfort, perceived or expected, during overtaking (Kaplan & Prato, 2016). Research also shows that cyclists request a greater distance at higher speeds and increasing wind speeds, which is not clearly reflected in the current legal text.

6.4. Compliance and monitoring

For rules to be understood, complied with and monitored, it is beneficial if they are simple, clear and irrefutable, while, at the same time, it remains possible to comply with the rules all traffic situations. Unambiguous rules permit road users to know in advance what the rules are, reducing uncertainty and, especially for cyclists, with their more vulnerable position in traffic, increasing the sense of security. See Table 3 for a summary our considerations regarding the extent to which different versions of the rules discussed above can be interpreted and monitored.

[12] https://www.liikenneturva.fi/sv/aktuellt/man-kor-om-cyklister-pa-landsvagen-med-for-litet-avstand/ (in Swedish) - the corresponding Finnish site contains more statistics: https://www.liikenneturva.fi/ajankohtaista/maantiella-pyorailija-ohitetaan-liian-lahelta/#0577c5e6

Table 3. Description of how different versions of the 'keep right', 'cycle abreast' and 'overtaking cyclists' rules impact clarity, interpretability and monitoring.

rule	different versions of the rule	clarity	monitoring
keep right	as close as possible to the right-hand edge	difficult to interpret, differs depending on the nature of the road surface, parked cars, manhole covers, etc.; unclear who decides what is "as close as possible"	either on-site or possibly by camera, but requires interpretation by a higher authority (who may not have access to all information)
	on the right side of the road; in the right lane	simple, either to the right of the centre of the road or in the rightmost lane; visually unambiguous	on-site or by camera, easy to determine with reference to surroundings
cycling abreast	single file, abreast if possible without danger or inconvenience to traffic	according to the research, cycling abreast can be a safety-enhancing measure, so that "without danger" does not automatically mean "single file" "inconvenience" is difficult to interpret and suggests that the unimpeded passage of (motor) traffic is valued above the safety, security and travel experience of cycling	especially in retrospect, difficult to determine whether 'inconvenience' arose, no clear definition of where 'inconvenience' starts - is a delay inconvenient, or is more required?
	abreast by default (possibly limited to a certain number, or unlimited as long as you stay in the right lane)	no interpretation is required other than staying in the right lane (or counting the number of cyclists abreast), the cyclists' journey is valued equally to that of motorised traffic	no monitoring required
overtaking cyclists	overtaking with 'comfortable distance'	unclear who has the right of interpretation; perceptions of "comfortable" vary; it is difficult to justify giving one person's interpretation more weight than another's	monitoring requires interpretation by a higher authority (which does not necessarily have access to all information)
	overtaking at a defined minimum (e.g., 1.5 metres)	in principle unambiguous, if measurement points can be accurately determined, but difficult to measure on site, not always feasible in practice on narrow roads	monitoring requires the availability of data permitting at least a fairly accurate measurement of distance
	overtaking in the next lane or where oncoming traffic would be positioned	clear, easy to understand and predictable for both cyclists and motorists; cyclists and motorists are valued equally	surveillance requires access to visual information where the road/lane and at least the right pair of wheels of the overtaking vehicle are visible; a camera on the bike is in theory sufficient

When introducing regulatory changes, it is of course important to ensure that information reaches the public as much as possible. Once more, rules which are simple and clear, and which do not require personal interpretation, make such efforts easier. Information campaigns, combined with enhanced monitoring, help to change habitual behaviour. If film from cameras attached to bicycles is accepted as evidence, and if vehicle-owner responsibility is considered sufficient for prosecution, this could significantly increase the incentive to comply with the overtaking rule, which would have a significant effect on cyclists' safety, especially on rural roads. Finally, it is strongly recommended to evaluate any

regulatory changes by means of pre/post studies. This will enable empirical evaluation of the changes as well as adjustments in the light of unexpected outcomes, while at the same time the material can help other regions to introduce changes which (in the event of a positive outcome) demonstrably increase cycling and safety.

6.5. Proposed principles as a basis for discussion of amended rules for overtaking cyclists

One possible measure to contribute to increased and safer cycling is to change and clarify the rules for overtaking cyclists. With regard to the reasoning in section 6.3, a proposal for a rule change has previously been presented on the Swedish Cycling Research Centre website[13]. The purpose of the proposal is to achieve a clarity similar to what applies today for speed regulation: Vehicles may not be driven faster than conditions allow, and never faster than the posted maximum speed. This ultimate limit is clear and measurable. By analogy, it is proposed that overtaking may only occur in accordance with clear and measurable limits which do not require individual drivers to interpret what is "comfortable" for the overtaking person. To summarise, the proposed rule change is based on the following:

- To increase safety and security for cyclists, the principle of Highway Code Rule 212 should be applied: "give the cyclist at least as much space as you would give a car".
- Rules based on minimum distances are difficult to monitor and can result in low levels of compliance, as lateral distances are difficult to estimate. They do not reflect cyclists' sense of security, as they do not take into account factors such as speed and wind speed. They also risk being interpreted as a recommended distance which, in some situations, may be insufficient. Therefore, there are better options than, e.g., a 1.5 metre rule.
- A rule that is linked to the design of the road would be easy for road users to understand and comply with, and for the police to monitor. Combined with the above, the proposed basic rule is that cyclists may never be overtaken by motor vehicles in the same lane, i.e., cyclists "must be overtaken as if they were a car". For narrow roads without a centre line, this is interpreted to mean that the overtaking driver will move into the lateral position which any oncoming traffic would have had. How this would be implemented in practice is illustrated in Figure 1. For further details we refer to the description on website of the Swedish Cycling Research Centre[10].

In order for the proposed overtaking rule to be fully effective, the rules requiring cyclists to keep as far as possible to the right in the lane, and rules forbidding cycling abreast, also need to be removed or revised. Combined with a rule on overtaking in the oncoming lane, this would create a situation where cyclists can use their entire lane to choose the most appropriate route for the conditions, as well as to cycle abreast. This permits cyclists to actively participate in the overtaking process and influence the lateral distance. The need for road users to show consideration for and facilitate others is a general rule, preventing the use of the rules merely as a provocation.

[13] Omkörning av cyklister – Cykelcentrum (vti.se)

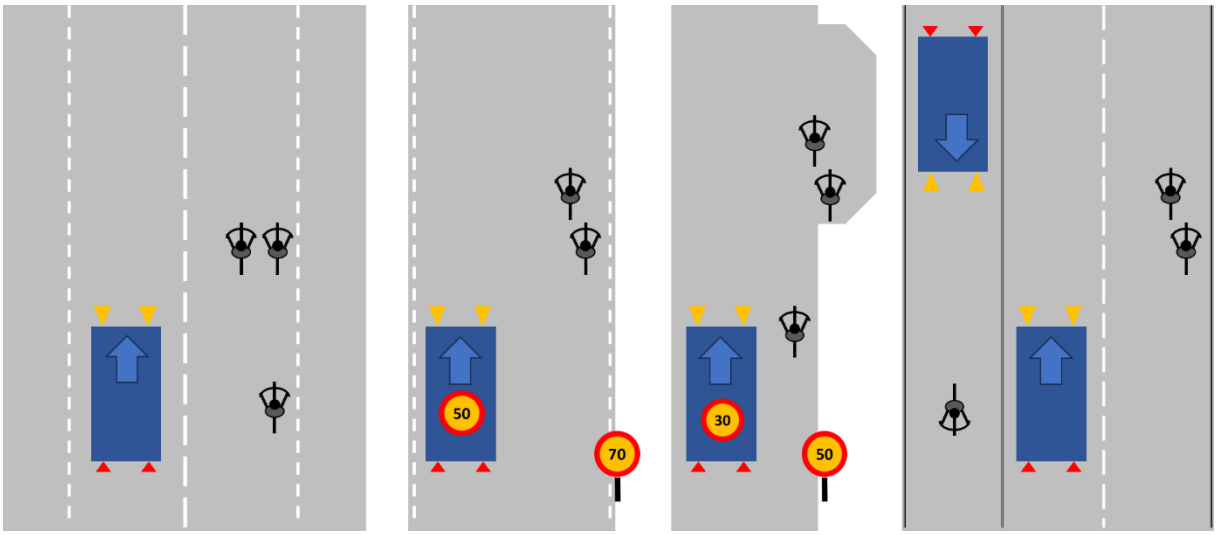

Figure 1. Illustration of practical implementation of the proposed overtaking rule. How the overtaking driver's speed is to be adapted can be seen as a proposal for an inquiry. From left to right: Rural road with centre line, rural road without centre line, narrow rural road with lay-by, 2+1 road.

The Swedish Transport Agency has, in two interim reports (Patten, Nilsson, et al., 2022; Patten, Thors, et al., 2022), reported its Government assignment (Ministry of Infrastructure, 2021) to analyse regulatory changes to enable increased and safer cycling. In particular, the proposal for a new overtaking rule, described above, has been analysed. The Swedish Transport Agency concluded that traffic rules for cycling should not be changed, arguing that other factors encourage more people to cycle. Here we disagree, as shown in the discussion above. Our different roles and perspectives may explain why we arrive at different conclusions. It is certainly true that no direct link has been proven to exist between a change in the rules for overtaking cyclists and increased cycling. At the same time, our literature review in this report shows significant deficiencies in current regulations regarding cyclists' safety, security and accessibility - factors which, all together, impact decisions about cycling. In addition, adapting traffic rules to better take into account the conditions and needs of cyclists can help clarify the hierarchy of consideration and responsibility, helping drivers of larger vehicles to take special consideration of "vulnerable road users". Legislation in the Netherlands has long made such a distinction, and the UK and Spain have recently followed suit. The Swedish Transport Agency's conclusion indicates that such an approach is still considered not applicable in Sweden. At the same time, the Swedish Transport Agency describes that the atmosphere among road users has worsened, indicating a need for clear information regarding existing traffic rules (Patten, Thors, et al., 2022). For overtaking, this means clarifying what a 'comfortable distance' entails in different circumstances, which is a prerequisite for clear communication. More knowledge is clearly needed on this issue, and further investigation of overtaking cyclists in mixed traffic is needed to improve the situation for cyclists, especially when cycling on rural roads. For example, the scale of the problem must be better understood: when, how often and in which situations are different road users impacted? This will help determine whether a regulatory change is possible which can be understood, complied with and monitored, or whether other solutions for the different situations are possible.

6.6. Effect of maintaining current legislation and conditions

Without any change to legislation or the communication of the existing legislation, i.e., maintaining the status quo, the behaviour of individuals will presumably not change significantly. At the same time, the Swedish Transport Administration (2020) forecasts greater vehicle mileage and the Swedish Transport Analysis Agency (2017) notes a trend of increasing numbers of registered vehicles. However, this increase has levelled off somewhat in recent years (Mobility Sweden, 2022). Given the high proportion of SUVs sold, many vehicles are both wider and heavier than previous models. SUVs

have also been shown to be more dangerous than regular passenger cars for pedestrians and cyclists (Edwards & Leonard, 2022; Tyndall, 2021).

Thus, unchanged overtaking behaviour on the part of motorists is likely to lead to more overtaking in the future. More of these overtakes will be made with less lateral distance, since the number of encounters increases with increasing traffic volumes, and overtakes with oncoming traffic are on average made with less margin, and that larger vehicles, on average, overtake with smaller margins. The literature review in Chapter 5 shows that, at the same speed, smaller distances are perceived as riskier and involving a greater risk of collision. Thus, if the present trend in vehicle sizes and traffic is not reversed, cyclists are likely to experience more unsafe overtaking rather than less. Thus, fully maintaining the status quo is unlikely to lead to increased cycling, as cyclists' sense of safety will decrease and the risk of collisions will increase, and the sense of safety among cyclists is a contributing, and perhaps decisive factor in their choice to cycle.

Vision Zero seeks to prevent road users from being exposed to kinetic energies that may lead to death or serious injury (Kristianssen et al., 2018). All else being equal, heavier vehicles have a greater kinetic energy. The speeds at which motorists currently travel on rural roads, and often even in cities, make collisions between motor vehicles and cyclists highly likely to result in death or serious injury to cyclists. Collisions must therefore be prevented, or speeds reduced to safer levels. Collision risk decreases with increasing lateral distance, as the safety margin for misjudgement and unplanned and/or unforeseen lateral movements increases. Thus, in accordance with Vision Zero, lateral distances need to increase with greater overtaking speeds and vehicle weights. The subjective values of cyclists, as discussed above, are in agreement.

Some form of measure is required in order to increase cycling and improve safety for cyclists in mixed traffic. Theoretically, monitoring might be increased. However, it is not clear how this could be realised in practice. One possibility is to permit video evidence, e.g., from bicycle-mounted cameras, but this would also require that licence plate numbers suffice for identification. In addition, whether the filmed overtaking occurred at a comfortable distance must also be determined. This cannot be easily determined based on video material alone. Greater numbers of police officers on patrol is conceivable. In the UK, action days are held where plainclothes officers on bikes fine or educate drivers overtaking too closely (Aldred et al., 2019). However, we have not found any studies evaluating the impact of such measures. Campaigns to increase consideration and understanding, similar to 'share the road' in Norway (Høye et al., 2016), could also provide a measure of improvement, but here, too, the extent and permanence of the effect is unclear.

One recommendation is to make the term "comfortable" easier to interpret. Given the more vulnerable position of cyclists (European Commission, 2021), their perception of the situation should have the greatest weight. This is also in line with the Stockholm Declaration[14], which emphasises the importance of increased road safety in general and the safety of so-called "vulnerable" road users in particular, as well as the Aktionsplan för säker vägtrafik 2022–2025 (Swedish Transport Administration, 2022) where safe cycling is identified as one of the most highly prioritised action areas. The methodology for evaluating this term needs to be developed. An important aspect is to consider the experiences of those not currently cycling but who wish to. As described above, their values may differ qualitatively and/or quantitatively from those of current cyclists. In order to increase cycling, the needs of potential cyclists must also be met. A clear definition of "comfortable" can be used in future communication efforts, campaigns, monitoring, prosecution, calculation of delays, etc. Lacking this definition, the impact of different interventions is more difficult to assess, as the baseline is not clear.

[14] stockholm-declaration-pa-engelska (roadsafetysweden.com)

Compliance with the law should be the basis for comparative assessments. Even if the term "comfortable" has not been adequately described, that overtaking is presently carried out in a manner which many cyclists perceive as uncomfortable can be assumed (see, e.g., the Finnish *Liikenneturva* study above). The current situation cannot therefore be a yardstick for how cycling should proceed.

If amendments or campaigns cannot increase the safety and sense of security of cyclists in mixed traffic, deploying more dedicated cycling infrastructure is the only option. At present, dedicated cycling infrastructure exists mainly in urban areas, but a large proportion of cycling in cities is done in mixed traffic. Expecting a comprehensive dedicated cycle-track network in the foreseeable future, especially in rural areas, is unreasonable. Even in rural areas, however, the potential for increased cycling is great (Eriksson, Niska, et al., 2022). Several regions have studied the potential for cycling in their geographical area, mainly for journeys between home and work or school. The results indicate that between 22 and 55 percent of the population can commute in less than 15 minutes by bike and 37-70 percent in less than 30 minutes. For all journeys in the regions, this figure is currently between 6 and 16 percent (ibid.). The potential studies analyse which route is the fastest for each individual and how long it takes to cycle. In most cases, the entire road network has been included, including motorways, even though cycling is not permitted there. Convenience, safety and security have also not been taken into account in the potential studies. To establish reliable figures which consider factors essential to cycling, improvement is needed.

In summary, the current situation fails to satisfy the requirement of "comfortable" overtaking, and there are indications that the growth of traffic will worsen this situation. Thus, merely to maintain the current level, interventions will be needed.

6.7. Overtaking rules from a system perspective

To deepen our evaluation of the pros and cons of changing the current regulations on overtaking cyclists in mixed traffic specifically, it may be valuable to consider which system level to use as a starting point. Should the evaluation be done in the framework of the traditional mode of thinking, where travel time is a significant factor which is valued differently for different modes of transport? Should factors such as cycling conditions and living environments also be considered, and should it be possible to compensate between these different perspectives, or is there even a need for certain minimum requirements for the latter that cannot be compensated by time savings for car traffic? Or should we take a broader perspective, not least in light of the fact that the latest report of the Intergovernmental Panel on Climate Change (IPCC) clearly emphasises that the window for securing a habitable and sustainable world is closing? If so, traditional cost-benefit models may no longer be calibrated for the current situation.

That values and perceptions change over time must also be considered, and how a new rule appears upon introduction may differ from how the same situation is assessed after road users become familiar with the change and accept it as standard. It is generally difficult to imagine a situation which is wholly new in order to fully assess how it might feel once it has become normal.

With this in mind, several considerations can be made:

6.7.1. Motorists' perspective

Normally, motorised traffic moves faster than cyclists. If car traffic and cycle traffic share space, this means in practice that motorists must adjust their speed or overtake cyclists, just as they overtake other slow-moving vehicles, such as tractors, category A tractors or even pedestrians. Depending on the traffic situation, the overtaking motor vehicle may only need to move sideways to leave a "comfortable distance" to the person being overtaken, or may need to brake and wait for a suitable gap to overtake. Objectively, this can bring about delays compared to an ideal situation of unimpeded progress. See, e.g., Carlsson et al. (2013) for examples of calculating delays resulting from single

slow-moving vehicles on routes without overtaking possibilities. Such delays are evaluated in socio-economic calculations and must be evaluated against other factors such as cyclists' lives or injuries, cyclists' delays and other factors. We refrain from such a macro-level assessment and examine individual's perspectives instead.

Interacting with other road users in traffic, and waiting for each other, is a natural part of a functioning system. Waiting can nevertheless be annoying, and research suggests differences between types of road users. For an in-depth look at this subject, we recommend Balkmar (2018) as an entry point. The proposed rule could then be perceived as making the overtaking distance unnecessarily large, i.e., the "comfort limit" would be reached before the overtaking driver has moved fully into the oncoming lane. This could mean that delays arising when it is no longer possible/permitted to overtake with oncoming traffic are perceived as unnecessary perceived as unnecessary. In order to calculate this effect, the frequency of such delays, i.e., when overtaking manoeuvre with oncoming traffic could otherwise have been carried out with a comfortable lateral distance, must be analysed, which in turn requires a definition of 'comfortable' in this context.

Major delays can affect delivery times and punctuality in freight and public transport. This can be stressful for drivers when scheduling is tight. Whether or not a change to the overtaking rule results in major delays, driving schedules must be adapted to the prevailing traffic conditions to ensure safe and relaxed driving.

As stated above, research suggests that drivers with negative attitudes towards cyclists tend to overtake with less margin. The proposed rule would thus probably require these drivers to change their behaviour to greater degree than those with no negative attitudes towards cyclists. If offences were to be prosecuted, this could merely reinforce the views of negatively predisposed drivers. To address this phenomenon, measures should be taken early in a driver's career, with the aim of preventing such attitudes from even occurring.

The proposed rule change can provide clarity for motorists who are concerned about the safety of their fellow road users. According to the above-mentioned research, it is difficult to achieve a certain lateral distance, i.e., to estimate the width of a car accurately. Further, ‘comfortable’ can be difficult to interpret, perhaps especially for drivers who have no experience of cycling. Interpretive support can thus be perceived as positive, also to the extent of providing motorists a rule to follow when granting cyclists ‘comfortable’ distance while simultaneously feeling crowded by subsequent motorists.

6.7.2. Cyclists’ perspective

In the current traffic situation, cycling may be wholly or partially rejected as a mode of transport due to feelings of insecurity (Horton, 2007; O'Connor & Brown, 2010; Ravensbergen et al., 2020; Whitelegg, 2021). Other factors, such as distance, weather, heavy loads, etc., can constitute practical reasons for not cycling, while fear and insecurity are reasons for avoiding cycling as a mode of transport more generally. How many car journeys would be replaced by cycling if the road network was perceived as safer is not known. Nor do we know whether and to what extent cyclists’ sense of security would increase following the proposed rule change, or if such a change would be sufficient to increase the share of cycling trips. However, the introduction of minimum overtaking distance rules in other countries has been motivated by a desire to promote cycling and increase cyclists' safety. In many cases, such rules were part of a package of several measures and regulatory changes.

Presumably, road users who choose to cycle will continue to avoid busy roads and, in particular, 2+1 roads, as factors beyond cyclists’ sense of security are involved in the attractiveness of such roads for cycling (see Annex 1). Although research on the subject is limited, there are indications that cyclists do not wish to obstruct traffic (Aldred, 2015) or be followed by a queue of cars over long distances, as this probably constitutes an unpleasant feeling for most cyclists. The level of discomfort likely differs depending on how long cyclists are in this situation and how motorists treat cyclists in this situation.

Cyclists feel safer and more secure on roads with light to moderate traffic (Alhomaidat & Eljufout, 2021). On higher-volume roads and 2+1 roads, where the possibility of overtaking is physically limited, the choice is between being an obstacle, being subject to frequent close passes or not cycling on this road. Cyclists and potential cyclists are not likely to experience any of these options as positive. The solution is to change the current traffic situation, either by providing reasonable alternative infrastructure for cyclists or by bring about a discourse in which the life, well-being and accessibility of every road user is equally valued.

6.7.3. Other considerations

The introduction of the proposed rule could be perceived as a reason to ban cycling on 2+1 roads. These problems have also been discussed by the Swedish Transport Administration at a number of workshops (Swedish Transport Administration, 2010). Workshop participants from the Swedish Transport Administration were aware of the problems that 2+1 roads pose for cycling. During the workshop series, the inequality which results from making roads less accessible was also discussed, with children and other vulnerable groups being impeded more than relatively strong groups. Especially in Norrland, workshop participants considered that construction of 2+1 roads has led to the creation of a parallel road network, as residents require access to their properties. This road network may be suitable for cycling, but not for commuting, probably because it is usually unpaved and involves a detour. Participants also considered information on alternative routes for cyclists to be insufficient. The issue of a ban was raised, and participants assumed that this could put pressure on planners and public authorities to come up with a reasonable solution for cycling. This could therefore improve cycling in the long run. According to the report, as long as cycling is permitted, it is possible to "bury the problem" (p. 40) by avoiding taking a stand.

According to one study (Swedish Transport Administration, 2010), cycling and walking cannot be banned on 2+1 roads without their being classified as motorways or expressways, unless an alternative route is available. In addition, the Swedish Transport Administration and municipalities may not direct cyclists to private roads, which often form (parts of) the parallel road network. Parallel cycle tracks are not built due to their expense, and the workshop participants find it difficult to value cycling against car traffic using current calculation models. It was also mentioned that the health effects of cycling are not sufficiently taken into account in socio-economic calculations, but that these could drastically affect the results. The discussion also touched on the fact that building new cycle paths along the road network could be problematic from an environmental point of view.

We were unable to find clarification regarding what is considered a reasonable parallel road in Sweden or what factors would be included in such an evaluation. Clear criteria should be established to enable a meaningful discussion of directing road users to parallel road networks, regardless of whether cycling on busy roads will be banned. Some 'connectivity' models in the US assume that a detour which is 25 percent longer than the shortest possible route is a reasonable option (Crist et al., 2019). This in itself is questionable, given that, in rural areas, it can lead to long absolute distances. In addition, the extra elevation, road surface, maintenance and similar factors affecting travel time, delay, comfort, etc. should also be included.

7. Conclusions and recommendations

The conclusions and recommendations emerging from this work are presented below and are of particular interest to highlight.

7.1. Measures for safe overtaking in mixed traffic are needed

According to the research, measures are necessary to ensure that cars overtake cyclists in mixed traffic in a way that is reliably safe and which also ensures a sense of security for cyclists themselves. Such measures are a prerequisite for increased and safer cycling, especially on rural roads. Any regulatory change must therefore not be seen as an end in itself, but as a means to improve the current situation and to prevent the deterioration that is likely to occur if traffic volumes and vehicle widths continue to increase. At present, close passes are common, and parts of the public road network are perceived as "unsafe and uncomfortable" by cyclists, according to the Swedish Transport Administration's own classification (Wirsenius et al., 2021). To promote increased and safe cycling, these perceptions must change. All measures to improve safety during overtaking are therefore important pieces of the puzzle.

There are several reasons to review the current regulatory framework. Its unclear wording makes the overtaking rule difficult to interpret both for guidance and monitoring. As mentioned above, it is unclear who decides what "comfortable" is. Ex-post monitoring is also difficult. Clearer guidance regarding the interpretation of ‘comfortable’ is therefore desired. Ideally, such guidance would be based on research, and greater speeds have been shown to require greater distances.

As is the case today, not all road users can be presumed to comply with amended legislation, and dangerous overtaking is likely to occur even with new and clearer wording. However, a regulation related to infrastructural design can be monitored via filming. Video footage recorded from bicycles can then be used as evidence in court, possibly helping to strengthen the position of cyclists in the transport system. This particular aspect is important for influencing public discourse. A clear position regarding the promotion of safe cycling, as a step towards a sustainable transport system, constitutes a powerful signal with the potential to influence general attitudes towards cycling as a mode of transport.

Increasing automation in motor vehicles will inevitably require a formalisation of overtaking rules before autonomous vehicles share the road with cyclists in mixed traffic (see also the paper by Rasch, 2023). Doing so in accordance with a clear regulation that can be translated into a functioning vehicular algorithm will be advantageous, not least because it requires different vehicle manufacturers to adopt the same basic conditions. Cyclists can also expect similar behaviour from overtaking vehicles. Whether an amendment is introduced with the aim of changing the behaviour of road users, or a campaign is carried out to increase consideration and understanding, we recommend that pre/post studies be carried out to evaluate the effects. Such studies are often missing when measures are taken, making it difficult for others to assess the potential of regulatory change, etc. If no measures are taken, investigating the current situation to improve knowledge regarding Swedish conditions is nevertheless recommended.

7.2. Suggestions for further studies

Our knowledge review has clearly shown a great need for further studies to improve cyclists' safety and security, especially on rural roads, in order to increase the accessibility of the road network for cycling, which can be a contributing factor to increased cycling. This includes issues directly related to overtaking as well as topics such as cycling abreast and keeping to the right. Below are some suggestions for further studies.

- group cycling/cycling abreast from different perspectives
    - visibility

    - journey quality (social and safety aspects)
    - group behaviour, both internal and towards other road users
    - scope in different traffic environments and types of infrastructure
- keeping right versus positioning towards the centre by individuals/groups with respect to
    - visibility
    - perceived safety
    - accessibility for cycles and motorised vehicles (including simulation)
- overtaking of individual cyclists versus groups of cyclists, quantitative and qualitative aspects including
    - road markings (roadway edge, cycle lanes, and positioning of cyclists and motorists in relation to the same)
    - personal experiences, attitudes, etc. of overtaking driver and cyclist being overtaken
    - experience of the same overtaking from the perspective of the motorist and the perspective of the cyclist, what factors play a role?
    - how delays caused by overtaking affect cyclists as well as drivers subjectively, and how progress is affected throughout the journey (e.g., simulation).

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Annex 1. Example of the 2+1 road problem

The following situation illustrates how 2+1 roads can prevent cycling. The situation clearly shows how cyclists avoid 2+1 roads, using them when no other reasonable alternatives are available. This is one example among several, and shows that cyclists are often on 2+1 roads only for short distances. Helping cyclists to travel securely can have a major impact here.

This stretch of road is on route 23/34, between Linköping and Rimforsa. Without cycling on the 2+1 road, this road can only be crossed west to east north of Skeda Udde (where a connecting cycle path adjoins the 2+1 road) or in Rimforsa. This distance is just over 20 kilometres on the main road, and just over 25 kilometres and considerably more uphill to the west of the main road, via Törnevik.

Figure 2. Google Maps, 2022: Centre-divided section without roadway edge discussed in the example. Route 23/34 at Brokind.

Cyclists must be able to pass between these two points. Using the Strava Metro database, we calculated the distribution of cycling trips on different parts of the network north of Brokind during 2021. These are data from cyclists who log their activities with the Strava app and make it readable. To what extent these activities are representative of rural cycling in general has not been studied, so we refrain from estimating the absolute number of trips in the area. However, it can be presumed that few or no activities begin or end there, so it can be assumed that this distribution represents how cyclists choose or reject the 2+1 route if there are alternatives.

The portion in Figure 3 shows the number of trips (Strava Metro rounds to five, and several trips probably continued on gravel roads, so totals are not exact) on the centre-divided 2+1 route (here, in fact, a 1+1) for different sections. Travel directions are merged, as Strava Metro only provides separate data for the centre-divided road. The figure is viewed from the top down: 25 activities are recorded on route 23/34. A gravel road to the west of this road is thereafter probably used by some cyclists, as the number of trips on route 23/34 drops to 15. To cross route 23/34, the only alternative is to travel the centre-divided road for a few hundred metres, to an inferior gravel road to the east, followed by a paved road to the north, just under a kilometre away. On the shorter section without alternatives, 135 trips are recorded. Cyclists then proceed on the inferior gravel road for 30 trips, while 105 trips are made on route 23/34 to/from the paved road to the north. South of this junction, the number drops again to 35, then to 20, with the gravel road to the west of the road taking up 20 trips. How many cyclists avoid this stretch of road completely, and either choose a long detour, a completely different route or do not cycle at all, is not clear from the data.

Cyclists clearly avoid centre-divided roads wherever possible, but they are still used when there are no alternatives. The data also suggest that gravel roads are not considered an adequate alternative. In this particular situation, some sort of measure - a parallel cycle track, reduced speeds on this stretch of road (possibly a variable speed limit when cyclists share the road), the application of a safety-enhancing overtaking rule, or something else entirely - could increase the safety of cyclists on the road.

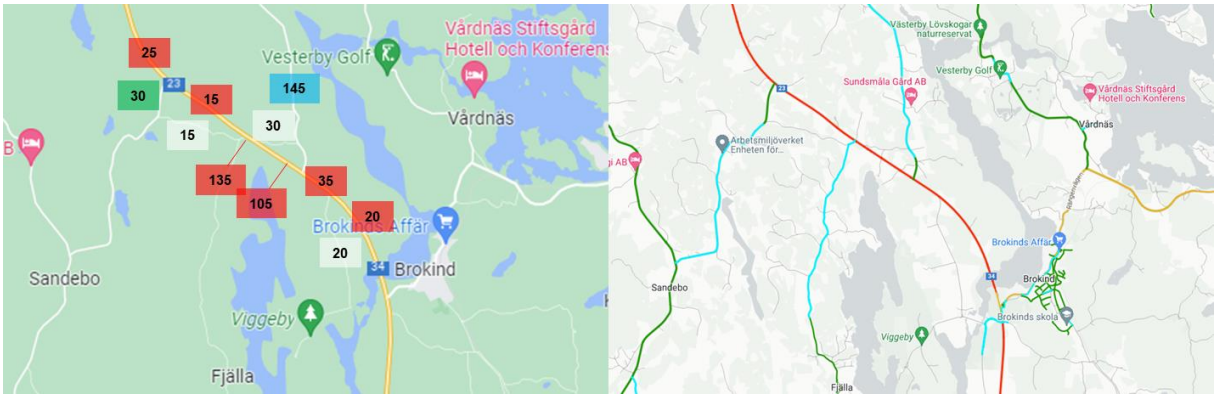

Figure 3. Google Maps, 2022 (left) and roadfinder.se (right). To the left is the number of cyclists, according to Strava Metro, on different sections of route 23/34 and surrounding roads; the colouring corresponds to the classification in the picture on the right. The automated "cyclability rating" is calculated from the variables of road width, speed limit and traffic volume with data from 2018 (blue: "very good road", green: "good, safe and pleasant", yellow: "quite OK but not perfect", red: "unsuitable but rideable", black: "forbidden or dangerous!"). Gravel roads, which are not classified, are highlighted in white in the image on the left.

As mentioned above, information regarding the representativeness of Strava Metro data is lacking for the absolute number of trips. A 2013 Canadian study, conducted in an urban environment, manually counted 51 cyclists for each trip logged with Strava (Jestico et al., 2016), giving a rough indication. Assuming that each logged trip in the example represents 100 actual cycling trips, this would entail approximately 2,500 cycling trips annually on the 2+1 route where there are alternatives, and 13,500 trips where there are no alternatives. According to Strava Metro, the trips take place mainly during the summer. Thus, the directions of travel for trips being equal, one can calculate 6 to 8 cyclists per day, per direction of travel, during the summer on the stretch of road where there are alternative routes. The stretch of road without alternatives would be used by about 30 to 40 cyclists per day. As each cyclist likely does not travel alone, the number of cycling groups is very likely to be less. A factor of 100 is likely also an overestimate, entailing fewer cyclists per day, and some cycling trips are made winter, so that the number of cyclists in summer is actually somewhat lower.

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