Cycling in Rural Areas

An overview of national and international literature

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Kort sammanfattning

Att cykla på landsbygd skiljer sig från att cykla i tätorter. Motorfordonens hastigheter är vanligtvis högre och samspelet med andra trafikanter utgörs nästan uteslutande av mötande trafik eller av omkörningar på den omkörandes villkor. Samtidigt fokuserar forskning och politik främst på cykling i tätort vilket inte alltid kan överföras till förhållandena på landsbygd. Syftet med denna rapport är därför att sammanställa kunskapsläget genom en litteraturöversikt med fokus på cykling på landsbygd avseende framför allt säkerhet, komfort, lämplighet och barriärer för cykling. Resultaten presenteras och diskuteras ämnesvis och följs sedan av en mer generell diskussion med fokus på frågeställningar kring ökad och säker cykling. Detta inkluderar även identifiering av kunskapsluckor.

I dagsläget är cykling, framför allt på landsbygd, marginaliserat i den offentliga debatten, i politiken, vid tillhandahållande av infrastruktur, samt vid finansiering och forskning. För att få till stånd en markant ökning av cykling räcker det inte med att de som cyklar börjar cykla ännu mer. Människor som i dagsläget inte cyklar måste också börja cykla vilket innebär att åtgärder måsta vidtas för att tillgodose dessa människors behov. Även om ytterligare forskning är nödvändig vet vi redan att cykelvänliga och väl sammanlänkade vägar är en grundläggande förutsättning, vilket även bör kombineras med effektiva incitament för ökad cykling. Detta kräver en övergripande omdaning av transportpolitiken där hållbart resande, systematiskt måste prioriteras med hänsyn till heterogeniteten hos dagens så väl som framtidens cyklister. Skillnaderna mellan förhållandena i staden och på landsbygden måste i detta sammanhang särskilt beaktas för att tillvarata cyklingens fulla potential.

Nyckelord

Cykling, cykel, landsbygd, cykelvänlighet, turism, infrastruktur, emotioner, interaktion, omkörning

Abstract

Cycling in rural areas is different from cycling in urban areas in that speeds of motorised vehicles are usually higher, and the interactions with other traffic almost exclusively consist of encountering oncoming traffic or being overtaken at the discretion of other traffic. Most cycling related research and politics focus on urban areas and the acquired knowledge cannot always be transferred to rural areas. The aim of this report is to provide an overview of the literature focusing on cycling in rural areas mainly with respect to safety, comfort, adequacy for cycling, and barriers and enablers for cycling. Findings and results are presented and discussed by topic, followed by a higher-level discussion focusing on issues and possibilities for increased and safe cycling. This also includes an identification of knowledge gaps.

Presently, cycling is marginalised as a mode of transportation in the public discourse, in policies, provision of infrastructure, financing and research, and this is even more distinct for cycling in rural areas. For cycling to increase substantially in modal share, it is not enough to increase the number of cycling trips made by people who already cycle today. It is necessary that also people who do not cycle must take up cycling, which means that provisions have to be made that cater to those people's needs. While further research is necessary here, it is known that bikeable routes that are well connected are a basic precondition, which must be coupled with effective incentives to increase cycling. This requires a remaking of the transportation policy as a whole with a systematic prioritisation of sustainable travel, which incorporates the heterogeneity of current and prospective cyclists. Special care must be taken to also consider the conditions in rural areas, to make the most of the total potential for cycling.

Keywords

Cycling, bicycle, rural, bikeability, tourism, infrastructure, emotions, interactions, overtaking

Sammanfattning

Att cykla på landsbygd skiljer sig från att cykla i tätorter. Motorfordonens hastigheter är vanligtvis högre och samspelet med andra trafikanter utgörs nästan uteslutande av mötande trafik eller av omkörningar på den omkörandes villkor. Samtidigt fokuserar forskning och politik främst på cykling i tätort vilket inte alltid kan överföras till förhållandena på landsbygd. Syftet med denna rapport är därför att genomföra en litteraturöversikt med fokus på cykling på landsbygd avseende säkerhet, komfort, lämplighet, barriärer och möjliggörare samt relaterade ämnen.

Generellt sett vet vi ganska lite om förekomsten av cykling på landsbygd eftersom inga systematiska mätningar görs och det tillgängliga datamaterialet är mycket begränsat och av okänd representativitet. Det finns dock belägg för att cykling faktiskt förekommer långt ifrån närmaste tätort och det finns indikationer på att potentialen för ökad cykling är stor även på landsbygd. Dessa faktorer illustrerar vikten av ökad kunskap om cykling på landsbygd.

Litteraturen i denna översikt kommer från en semistrukturerad sökning i flera vetenskapliga databaser och från webbplatser och rapporter från relevanta myndigheter, organisationer och administrativa organ. Referenser i hittade artiklar har också inkluderats. Organiserade lopp och cykling i särskilda områden så som cykelparker, har inte inkluderats i översikten. Trots att vi fokuserar på cykling på landsbygd hänvisar vi till forskning i tätort i de fall där vi anser att resultaten är överförbara till landsbygd.

Den ämnesvisa uppdelningen av rapporten gjordes för att skapa struktur i resultaten, men innebär inte att de olika ämnena ska behandlas separat. Andra indelningar hade varit möjliga.

Cykelvänlighet

Begreppet cykelvänlighet beskriver i vilken utsträckning en miljö är lämplig och säker för cykling och inkluderar både subjektiva och objektiva faktorer. Bortsett från cykelturism härstammar merparten av forskningen inom detta område från cykling i tätort. Exempel på forskning relaterat till cykelvänlig miljö är sammanlänkning av vägar och vägval. Forskningen kring sammanlänkning av vägar fokuserar på om det cykelvänliga vägnätet är sammanlänkat utan betydande omvägar medan forskningen om vägval undersöker vilken väg cyklister föredrar givet den infrastruktur som finns.

Cykelvänligheten bedöms utifrån olika perspektiv vilka inkluderar statistiska modeller som kopplar samman infrastrukturegenskaper med cyklisters skattningar, ”experters” skattningar baserade på kategorisering av infrastrukturen samt modeller baserade på olycksstatistik. Dessa skattningar kan även inkludera aspekter så som hälsa och ruttens attraktivitet i form av tillgänglighet och service. En del av modellerna tar hänsyn till olika ”cyklisttyper” med olika behov och preferenser. Vanligtvis presenteras dock dessa cyklisttyper på en linjär skala av hur mycket skydd mot motortrafik de önskar. Ett multivariat perspektiv som kombinerar olika faktorer så som syftet med cykelturen, vilken cykel som finns att tillgå och om resan görs i sällskap med andra saknas. Alla dessa faktorer kan dessutom variera för en och samma cyklist. Även om vissa faktorer (exempelvis lutning och trafikmängd) kan göra cykling på en specifik rutt mer eller mindre behaglig finns det även absoluta barriärer som gör cykling direkt olämplig. Detta innebär att en specifik rutt kan vara omöjlig att cykla under vissa omständigheter (exempelvis att cykla på 2+1-vägar tillsammans med barn) vilket antingen leder till en omväg eller omöjliggör hela resan. Vi noterar även att studier om behov och preferenser hos människor som inte cyklar, men som under andra omständigheter skulle vilja göra det, är ganska ovanliga. Vi vet dock att tröskelvärdet hos dem som ännu inte cyklar oftast är högre än hos dem som redan cyklar vilket innebär att de potentiella cyklisterna upplever fler barriärer i dagens infrastruktur. Medan barriärerna påverkar cykelvänligheten för dagens cyklister kan de, för framtidens potentiella cyklister, utgöra en absolut barriär för att börja cykla. Istället för att helt förlita sig på antaganden om vilka infrastrukturegenskaper som upplevs som lämpliga och säkra för cykling rekommenderar vi empiriska studier med både dagens och framtidens potentiella cyklister. Dessa studier skulle kunna

identifiera barriärer och möjliga åtgärder som kan bidra till ökat cyklande på landsbygden. Särskild uppmärksamhet bör ägnas åt absoluta barriärer eftersom även ett kort vägsegment som upplevs som olämpligt gör en annars fin rutt helt oanvändbar.

Omkörning av cyklister

Ett ofta studerat ämne är när, och hur, motorfordon kör om cyklister, och i dessa fall brukar studierna utföras på landsväg. Resultaten visar att avståndet mellan omkörande motorfordon och cyklist minskar där det finns en mittlinje i form av frästa räfflor, en heldragen mittlinje, mötande trafik, och vid så kallade ”flygande” omkörningar. Avståndet minskar också med storleken på det omkörande motorfordonet. Vad gäller förekomsten av cykelfält samt cyklistens klädsel och utseende är resultaten mer motstridiga. Omkörningar på nära håll är en obehaglig upplevelse för cyklister och kan avskräcka från att överhuvudtaget cykla. Den subjektivt upplevda risken tycks vara relaterad till en kombination av ökad omkörningshastighet och minskat avstånd.

En del länder har antagit lagar om minimiavstånd vid omkörning av cyklister. Dessa lagar har sedan implementerats på olika sätt. Lagarna baseras oftast på ett absolut minimiavstånd vilket ibland modifierats beroende på skyltad hastighetsbegränsning eller om vägen ligger inom tätbebyggt område. Inga före/efter-utvärderingar av lagarna har gjorts men mycket talar för att omkörningar på nära håll är frekvent förekommande även i länder som har implementerat minimiavstånd vid omkörningar.

Vi förespråkar att en reglering av omkörning av cyklister ska baseras på tillgänglig forskning vilken pekar på att det behövs ett större minimiavstånd vid omkörningar i högre hastigheter för att cyklister ska vara och känna sig trygga. En rimlig riktlinje skulle kunna vara att köra om cyklister som om de ”vore bilar”, det vill säga att det omkörande motorfordonet byter fil för att köra om. Detta skulle göra omkörningen säkrare och upplevelsen mindre obehaglig för cyklisten.

Cykling som social aktivitet

När man cyklar i grupp, med vänner, familj eller på organiserade turer är det sociala umgänget en viktig del av upplevelsen. Samtidigt som det sociala umgänget är naturligt integrerat i de flesta typer av motorfordon, där två personer kan sitta bredvid varandra, får man i många länder enbart cykla i bredd när det inte stör motortrafiken, eller så är det helt förbjudet. Tyvärr är kunskapen om de sociala aspekterna av att cykla i par eller i grupp mycket begränsad. Det lilla vi vet tyder dock på att cyklister kan uppleva en konflikt mellan att vilja umgås med varandra och viljan att följa den rådande normen och inte vara i vägen för övrig trafik.

Cykling i grupp skiljer sig antagligen på många olika sett ifrån att cykla själv och här finns en stor kunskapslucka. Vi menar att samhällets acceptans och politiskt stöd för att cykla tillsammans kan vara viktig faktor för att göra cykling till ett mer attraktivt färdsätt.

Svenska infrastrukturlösningar

I Sverige finns ett antal infrastrukturlösningar som i dagsläget inte används i så stor utsträckning på andra håll i världen. De som är av särskild betydelse för cyklister är den så kallade 2–1-vägen, 2+1-vägen och sommarcykelvägen. På 2–1-vägen är vägrenarna breda, för att underlätta för cyklister och fotgängare, samtidigt som körbanan för motorfordon är för smal för två bilar att passera varandra. För att ta sig förbi en mötande bil måste vägrenarna alltså användas vilket bara får göras med hänsyn tagen till de cyklister och andra oskyddade trafikanter som färdas där. Denna design förväntas leda till lägre hastigheter och ömsesidig hänsyn. I själva verket har utvärderingar hittills visat lägre hastighets-minskningar än förväntat, minskat avstånd vid omkörningar av cyklister och en allmän upplevelse av att bilisternas beteende blivit svårare att förutse.

2+1-vägen är rekonstruerade landsvägar som tidigare bestått av ett körfält i vardera riktningen med bred vägren på varje sida. För att med en fysisk barriär förhindra frontalkrockar och samtidigt

möjliggöra omkörningar har vägen delats upp i tre körfält med omväxlande ett eller två körfält i en given riktning med mitträcke emellan mötande trafik. För att få plats med tre körfält har vägrenarna tagits bort samtidigt som vägräcken ibland satts upp längs vägkanterna. Körfälten är ofta smalare än på vanliga landsvägar och den skyltade hastighetsbegränsningen högre. Även om det tekniskt sett är tillåtet att cykla på dessa vägar är de inte populära bland cyklister som inte känner sig säkra och bekväma med designen. Detta skapar ett dilemma då alternativa vägar ofta saknas, vilket gör att 2+1-vägarna blir funktionella hinder för cykling då de inte bara hindrar cyklister från att använda vägen, utan också från att korsa den där det saknas fyrvägskorsningar. År 2018 fanns det mer än 3 000 km 2+1-vägar i Sverige och fler byggs. För att få rimliga förutsättningar för cykling måste man implementera bra lösningar så att 2+1-vägar inte utgör barriärer i cykelnätverket.

Sommarcykelvägen introducerades som en potentiell lösning till problemet med 2+1-vägar. Dessa cykelvägar är vanligtvis inte asfalterade eller upplysta och underhållet är mycket begränsat. De kan således vara lämpliga för cykelturer utan tidspress under sommarhalvåret men de är inget fullgott alternativ till 2+1-vägar. Forskning om olika ”cyklisttypers” behov och preferenser under olika typer av cykelturer skulle kunna ge en uppskattning om hur stor andel av samtliga cykelturer sommarcykelvägar lämpar sig för. Man måste dock komma ihåg att lösningen måste vara tillförlitlig för att rent generellt ses som funktionell.

Den känslomässiga upplevelsen av att ”dela” vägen

På landsbygden färdas cyklister och motordrivna fordon ofta på samma yta. Inom litteraturen kallas detta vanligtvis för att ”dela vägen” trots att det inte sker på lika villkor. Det kan upplevas som obehagligt för cyklister och därmed förhindra en mer omfattande användning av cykeln som transportmedel. Samspelet med motorfordon upplevs också som mer obehagligt och genererar mer ilska än samspelet med fotgängare och andra cyklister. Detta antas vara kopplat till att motorfordon utgör en större risk. Att känna ilska tar sig inte nödvändigtvis uttryck i aggression samtidigt som aggression kan uppstå utan att man först känner ilska. Cyklister är mer utlämnade och inte lika anonyma som bilister vilket ses som en förklaring till varför cyklister inte uttrycker ilska lika starkt som bilister gör.

Hos både bilister och cyklister identifieras tre huvudsakliga strategier för att hantera ilska. Dessa strategier är dock inte de samma för de båda trafikantgrupperna. Bilister kan konfrontera cyklister och argumentera verbalt eller rent fysiskt. Mindre vanliga strategier är problemlösning och tillkallande av hjälp utifrån, exempelvis att ringa polisen. Cyklister är mer benägna till undvikande kopplat till rädsla. Mindre vanliga strategier är att konfrontera bilister eller att omdirigera ilskan till andra trafikanter.

Rent generellt har man kunnat se att bilister som också är cyklister, och vice versa, ökar den ömsesidiga förståelsen för den andres situation. Att få fler att cykla kan därför även bidra till att förbättra det sociala klimatet på våra vägar.

Allmän slutsats

Den allmänna slutsatsen från denna litteraturöversikt är att cykling är marginaliserad i den rådande diskursen om transport och mobilitet, vilket går hand i hand med att cykling är strukturellt missgynnat som transportmedel.

Om målet för en ökad och säker cykling är allvarligt menat och dessutom inkluderar rekrytering av nya cyklister, och inte bara öka cykelsträckan för dem som redan cyklar, måste vi ta oss an ämnet på ett systematiskt sätt. Detta omfattar borttagande av barriärer i cykelinfrastrukturen. Det omfattar även en anpassning av trafikregler och bestämmelser till cyklisters behov, vilket kan bidra till att psykologiska hinder undanröjs men också till att göra cykling trevligare och därmed mer attraktivt. Det omfattar ett erkännande av cyklisters lika rätt till vägen och till Nollvisionens etiska ställningstagande att ingen ska dödas eller skadas allvarligt i trafiken. Detta innebär att cyklister, precis som bilister, måste skyddas från skadlig rörelseenergi.

Även om vi har tillräckligt med kunskap för att börja vidta åtgärder för att förbättra situationen för cyklister, inte minst på landsbygden, finns det också kunskapsluckor. Ett stort område är avsaknaden av information om behov och preferenser hos dagens, så väl som framtidens, cyklister. Det finns dock belägg för att attityden hos dem som ännu inte cyklar, men skulle vilja göra det, skiljer sig från attityden hos dem som redan gör det. För att öka andelen cyklister är det därför viktigt att öka kunskapen om de speciella behov och preferenser som finns hos dem som skulle vilja börja cykla. Data bör samlas in på olika sätt, med hänsyn tagen till olika kombinationer av personliga faktorer, syftet med cykelturen, vilken cykel som finns att tillgå och om resan görs i sällskap med andra. Ett närbesläktat ämne är bedömning av cyklingens potential. Detta bör inte utgå ifrån nuvarande cykling utan istället kopplas till start- och slutdestinationer inom ett område.

Ett annat forskningsområde som har försummats är hur cykling i grupp skiljer sig från att cykla ensam. Detta inkluderar önskan om att umgås under cykelturen, att kunna hålla ihop gruppen samt möjligheten att ta hand om exempelvis mindre erfarna cyklister och så vidare. De sociala aspekterna av att uppmuntra människor att börja cykla faller under detta ämne.

Cykling ses ofta bara ha potential att ersätta bilresor i tätorter och där avstånden är korta. Det finns dock belägg för att långpendling är möjligt under rätt omständigheter och i samband med elcykelns intåg ökar potentialen för längre turer. I och med detta är avsaknaden av kunskapsuppbyggnad om cykling på landsbygd problematisk och bör åtgärdas. Ökad kunskap i ämnet kan hjälpa till att rikta åtgärder dit de behövs för att effektivt kunna leda till ökad och säker cykling.

Sammanfattningsvis, för att uppnå en varaktig förändring av andelen cykelresor, måste vi ta ett systemperspektiv med målet om ett framtida trafikscenario som tillgodoser alla trafikanter, med hänsyn taget till och införlivandet av allas speciella behov, där hållbart resande systematiskt prioriteras. Detta kräver en övergripande omdaning, med förändrade prioriteringar, policyer, samhällsnormer och attityder, utifrån en trafikanthierarki, som konsekvent sätter behoven hos de mest hållbart resande, och relativt sett mest utsatta, trafikantgrupperna högst.

I samband med denna omdaning måste vi komma ihåg att cyklister är en heterogen grupp som inkluderar olika åldrar och konstellationer, med olika syften och skicklighet, utbildning och kompetens. Behoven och preferenserna hos dagens cyklister, men också hos framtidens cyklister, måste beaktas. På så sätt kan vi uppnå en ökad och säker cykling samtidigt som vi skapar ett långsiktigt hållbart transportsystem som främjar ett säkert och hälsosamt resande för alla trafikanter på lika villkor.

Summary

Cycling in rural areas is different from cycling in urban areas in that speeds of motorised vehicles are usually higher, and the interactions with other traffic almost exclusively consist of encountering oncoming traffic or being overtaken at the discretion of other traffic. Most cycling related research and politics focus on urban areas and the acquired knowledge cannot always be transferred to rural areas. The aim of this report is to present an overview of the literature focusing on cycling in rural areas with respect to safety, comfort, adequacy for cycling, barriers and enablers, and related topics.

Generally, little is known about the prevalence of cycling in rural areas, as no systematic measurements are made, and the available data are sparse and of unknown representativeness. There is evidence, however, that cycling occurs far from the nearest built-up area, and there are indications that the potential for more cycling is high also in rural areas. These factors indicate the need for increased knowledge about cycling in rural areas.

The literature for this review stems from a semi-structured search in several scientific databases, and from websites and reports from relevant agencies, organisations, and administrative organs. References in found articles could be included, too. We excluded organised races and cycling in dedicated areas such as bike parks. While we focus on cycling in rural areas, some references are made to research from an urban setting, where we assume that a transfer of results may be possible.

The subdivision of the report into several topics was done for structural reasons but does not imply that these should be treated separately. Other divisions would have been possible.

Bikeability

Bikeability describes to which extent an environment is convenient and safe for cycling, including both subjective and objective factors. Most available research stems from urban areas, except for cycle tourism. Research on connectivity and route choice are related to bikeability, where the former focuses on whether the cycling network is connected without requiring substantial detours. The latter investigates instead which route cyclists prefer, given the available infrastructure.

Bikeability is assessed using different approaches, including statistical models that link infrastructural features to cyclist ratings, “expert” ratings based on infrastructural categories and models based on crash statistics. Ratings can also include features related to health and route attractiveness, like accessibility and service. Some of the models acknowledge the existence of different “cyclist types” with their respective needs and preferences. However, these cyclist types are normally represented on a linear scale reflecting the desired degree of protection from motorised traffic. What is missing is a multivariate approach assessing a combination of factors such as trip purpose, the bicycle available for the trip and if the trip is made in company with others. All these factors can vary within one and the same cyclist. Whilst some factors can make cycling more or less pleasurable on a specific route, like gradients and the amount of traffic, there can be absolute cut-offs. This means that a route can become unbikeable under the given circumstances, which either leads to a detour or renders the trip impossible to complete. We also noted that studies on the needs and preferences of people who do not cycle but would like to, are rather rare. What we can say is that if they start to cycle then their thresholds are usually higher than for those who already cycle, meaning that they experience more absolute barriers in today’s infrastructure.

These barriers constitute a connectivity issue for people who do cycle and a barrier to take up cycling in the first place. Instead of relying on assumptions what road characteristics are experienced as bikeable or not, we recommend conducting studies both with people who currently cycle and with prospective cyclists. This would help in identifying barriers and countermeasures to enable increased cycling. Special attention has to be paid to absolute barriers, as even a short route segment that is experienced as unacceptable can make an otherwise fine route useless.

Overtaking of cyclists

One frequently researched topic is how and when motorised vehicles overtake cyclists, and in this case studies tend to be conducted on rural roads. Absolute overtaking distance was found to decrease in the presence of central rumble strips, a solid centre line, oncoming traffic, larger overtaking vehicles and during so-called "flying" overtaking manoeuvres. The absence of a road shoulder and riding two abreast is also associated with a narrower overtaking distance. Less unanimous results exist for the presence and absence of cycle lanes and the outfit and appearance of the cyclist. Close overtakings are a stressful experience for cyclists and can be a deterrent to cycling at all. The subjectively experienced risk seems to be linked to a combination of increased overtaking speed and decreased lateral distance.

Some countries have adopted minimum passing distance laws with various implementations. Most are based on an absolute distance, sometimes modified by the posted speed limit or whether the area is built-up or not. No before/after evaluations of such laws have been conducted, but evidence exists that close overtaking is a frequent occurrence also in countries that have implemented a minimum passing distance law.

We suggest that a regulation of overtaking of cyclists should be based on available research, which indicates that larger passing distances are needed at higher speeds for cyclists to feel safe. A reasonable approach might be to overtake cyclists as if they "were cars", that is, with a full lane change. This would make the situation less stressful and safer for the cyclists.

Cycling as social activity

When cycling in a group, with friends, family or in an organised ride, being able to practice social interaction is an important part of the experience. While this is inherently integrated into the design of most types of motor vehicles, which are constructed such that two people can be seated next to each other, many countries either only permit cycling abreast when it does not disturb motorised traffic or do not allow it at all. The body of research on the social aspects of cycling in pairs or groups is unfortunately very limited, and the little evidence available tells us that cyclists can experience a conflict between wanting to socialise with each other, but at the same time refraining from doing so based on feeling in the way for other traffic.

Cycling in a group is probably qualitatively different from cycling alone with respect to several aspects and therefore we see a large research gap on the topic. We also believe that societal acceptance and political support of cycling together could be an important factor in making cycling more attractive as a form of transportation.

Swedish infrastructure solutions

While not completely unique to this country, Sweden has implemented a few infrastructure designs that are not widely used elsewhere. Those that are of special relevance for cyclists are the so-called "2 minus 1-road", "divided 2+1-road" and "summer cycle path". The first is a type of road where the road shoulders are wide, with the intention to encourage cycling, but where the centre lane is so narrow that it does not allow two vehicles to pass each other. Thus, to get past an oncoming vehicle, the road shoulders must be used, but this can only be done under consideration of cyclists and other active road users travelling there. This is expected to lead to reduced speeds and mutual consideration. In fact, however, results were variable at best, with speeds not decreasing as expected, overtaking distances decreasing and a general feeling that motorists' behaviour became more difficult to predict.

Divided 2+1-roads are reconstructed rural roads that previously consisted of one lane per direction with a wide hard shoulder on each side. To prevent frontal crashes with a physical barrier while still providing the possibility to overtake, the road was divided into three lanes with the middle lane alternating direction. The additional spatial need required removing the hard shoulders, and in some cases a physical barrier was also added to the outer edges. The lanes are often narrower than on

undivided rural roads and the posted speed limit is higher than on undivided roads. While cycling technically is allowed on these roads, it is unpopular, as cyclists tend not to feel safe and comfortable. This creates a dilemma, because often no alternative routes are available, such that the 2+1-roads become functional barriers to cycling, not only preventing cyclists from using the road, but also from crossing it in cases where there is no four-way crossing. By the year 2018 more than 3000 km of divided 2+1-roads existed in Sweden, with more being constructed. To provide reasonable preconditions for cycling a good solution needs to be implemented to circumvent these barriers.

The summer cycle paths were introduced as a potentially viable solution to bridge the barrier created by the divided 2+1-roads. These paths are typically not paved and not illuminated with very limited maintenance. Thus, they can be suitable for summer touring without time pressure, but they are no adequate alternative to divided 2+1-roads. Research into needs and preferences of different cyclists with different trip purposes could provide an estimate of the share of trips that could be provided for with this type of infrastructure. It has to be kept in mind, though, that a solution needs to be reliable to be seen as generally functional.

The emotional experience of "sharing" the road

In rural areas cyclists often occupy the same space as motorised vehicles, which is commonly referred to as "sharing the road", even though it does not occur on equal terms. This can be stressful for cyclists and consequently prevent a more widescale use of the bicycle as a mode of transport. The interaction with motorised vehicles is also more stressful and generates more anger than the interaction with pedestrians and other cyclists. This was assumed to be connected to the greater risk emanating from motor vehicles. Anger does not necessarily lead to a response containing aggression, while at the same time aggression can occur without the preceding emotion of anger. Cyclists are more exposed and not as anonymous as drivers, which is seen as an explanation for why cyclists do not express their anger as strongly as drivers do.

Three main coping strategies were identified for both drivers and cyclists, even though the strategies were not the same between groups. Drivers could act confrontationally, getting into a vocal or physical argument with the cyclists. Less frequent strategies were described as problem-solving or summoning outside help, like calling the police. Cyclists were more likely to resort to avoidance connected to feelings of fear. Less common strategies were confrontational or a redirection of one's anger to other road users.

Generally, being a user of the other mode of transportation has been shown to help in creating mutual understanding. Therefore, successfully encouraging more people to cycle could also improve the social climate on the roads.

General conclusion

The general conclusion from this literature review is that cycling is marginalised in the prevailing discourse on transport and mobility, which goes hand in hand with its being structurally disadvantaged as a mode of transportation.

Thus, if the goal of increased and safe cycling is meant seriously and includes a recruitment of new cyclists as opposed to only increase the mileage of people who already cycle, it is necessary to tackle these issues systematically. This includes the removal of barriers in the infrastructure. It also includes an adaptation of traffic rules and regulations to cyclist needs, which can function as a removal of psychological barriers, but also make cycling more pleasant and therefore more attractive. It includes an acknowledgement of cyclists' equal right to the road and to remain unharmed as established by Vision Zero, which means that cyclists should be effectively protected from harmful kinetic energy, just as motorists are.

While enough is known to start taking immediate steps for an improvement of the situation for cyclists not least in rural areas, there are also knowledge gaps. One large area is the lack of data on the needs and preferences of both current and prospective cyclists. There is evidence that people who do not cycle yet but would want to differ in their attitude from people who already cycle. Therefore, to increase the share of people who cycle, it is vital to increase our understanding of this groups' special needs and preferences. Likewise, data should be collected differentially, considering different combinations of personal factors, trip purposes, type of bicycle used and potential company on the ride. A connected topic is the assessment of cycling potential, which should not be extrapolated from current cycling, but rather be linked to the presence of origins and destinations in the area.

Another area of research that has been neglected is how riding in groups is different from riding individually, which includes the wish to socialise on the ride, to be able to stay together as a group, possibly to take care of for example less experienced riders and so on. The social aspects in encouraging people to take up cycling fall under the topic.

Cycling is often treated as only having the potential to replace car trips in urban areas and where distances are short. There is evidence, however, that long-distance commutes are feasible given the right circumstances, and the proliferation of e-bikes is likely to increase the potential for longer rides. Therefore, the neglect of knowledge acquisition about cycling in rural areas is problematic and should be addressed. A better and up-to-date knowledge on the topic may help direct measures to where they are needed and will be effective in increasing cycling under safe conditions.

To conclude, to achieve a sustained change in modal share, we need to take a system perspective with the goal of a future traffic scenario that caters to all road users, considering and incorporating everybody's special needs, where sustainable travel is systematically prioritised. This requires a remaking from the beginning, with changed priorities, policies, societal norms, and attitudes, based on a road user hierarchy, which consistently puts the needs of the most sustainable and relatively most vulnerable road users highest.

In this remaking, it is important to remember that cyclists are a heterogenous group including different ages and constellations, with different purposes and levels of skill, education, and competence. The needs and preferences of all these cyclists, as well as of those not yet choosing the bicycle, must be taken into consideration. When doing so, we can increase cycling and make it safe, and create a long-term sustainable transport system which promotes safe and healthy travelling for all road users on equal terms.

Preamble

In the national strategy for increased and safe cycling, which was presented by the Swedish government in January 2017, it was pointed out that research and knowledge acquisition are paramount. Therefore, the Swedish National Road and Transport Research Institute (VTI) was commissioned to host a national centre concerned with research and education about cycling – the Swedish Cycling Research Centre. This report presents the results of a strategic project commissioned by the Swedish Cycling Research Centre. Strategic projects include compilations of knowledge, external analyses or pilot studies with particular relevance for cycling as a research area, but where external financing is not available.

The project reported here encompassed a knowledge compilation about cycling in rural areas with the ambition to contribute to a strategic approach in the encouragement and support of increased cycling. It is urgent to do so given the climate crisis and the necessary actions detailed in the latest IPCC-report. To quote UN Secretary-General Guterres, the bicycle cannot only transport us "to school, stores and work but to a more sustainable future", but we have to enable it to do so.

This report is the result of a collaboration between the three authors. Katja Kircher coordinated the work and was the main contributor to Chapters 3–5, Sonja Forward was the main contributor to Chapter 7 and Henriette Wallén Warner was the main contributor to Chapters 3.2 and 6. The introduction and general discussion are a common effort.

Linköping, April 2022

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De slutsatser och rekommendationer som uttrycks är författarens/författarnas egna och speglar inte nödvändigtvis myndigheten VTI:s uppfattning./The conclusions and recommendations in the report are those of the author(s) and do not necessarily reflect the views of VTI as a government agency.

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1. Background

Cycling in rural areas is different from cycling in urban areas in that speeds of motorised vehicles are usually higher, and the interactions with other traffic are almost exclusively longitudinal, that is, they mainly consist of encountering oncoming traffic or being overtaken at the discretion of the other traffic. It is also likely that the reason for cycling in urban and rural areas differ (McAndrews, Okuyama, & Litt, 2017). Cycling speed is generally higher in rural areas, but this differs between bicycle types and genders within each type of area (Twisk, Stelling, Van Gent, De Groot, & Vlakveld, 2021). Also crash types seem to differ between rural and urban areas (Macpherson et al., 2004). The motivation for cycling probably differs, too, given that cycling in urban areas can be the fastest mode of transportation, while this is rarely the case in rural areas. There are indications, though, that the rise of the e-bike can change some factors influencing motivation, due to its ability to lessen the physical effort associated with distance, gradient and headwind (Rérat, 2021). Most research and politics focus on cycling in urban areas and the acquired knowledge cannot always be transferred to rural areas (McAndrews, Tabatabaie, & Litt, 2018). The aim of this report is therefore to present a non-exhaustive overview of the national and international literature investigating cycling in rural areas with respect to safety, comfort, adequacy for cycling, barriers and enablers, and related topics.

1.1. International and national strategies for cycling

In 2015, the UN General Assembly adopted Agenda 30 for Sustainable Development. As a step towards meeting the global sustainability goals, the Swedish government adopted the so-called "National strategy for more and safer cycling – contributing to a sustainable society and a high quality of life throughout the country" (Regeringskansliet, 2017). In addition to meeting the sustainability goals, the strategy also aims at decreasing crowding in urban areas and to improve public health by creating societal conditions for good health on equal terms for the entire population. The strategy for increased and safe cycling thus includes cycling in rural areas which we in this report define as 'cycling outside built-up areas' regardless of type of cyclist, purpose of trip and type of bicycle or infrastructure used.

Referring to the strategy, the government recently commissioned the Swedish Transport Agency to analyse whether a number of traffic rules pertaining to cyclists should be changed with the goal to increase cycling under safe conditions. One of these rules refers to overtaking (Regeringen: Infrastrukturdepartementet, 2021), which is particularly relevant for rural roads. This is one of the reasons why we dedicated an own chapter to the topic (see Chapter 4).

1.2. Roads and regulations in Sweden

The state via the Swedish Transport Administration is responsible for the planning for all road traffic infrastructure as well as for constructing and operating state-owned roads. Most roads in areas outside of towns are state-owned and -operated – the so-called public roads ("allmän väg" in Swedish). The government can rule that municipalities are responsible for the maintenance of roads or road sections within their jurisdiction. Within built-up areas the municipality typically is responsible for streets. Private roads are owned and maintained by private organisations or individuals and can receive support from the state for keeping the roads open to public access. Public roads are, as their name indicates, fully accessible to the public. This means that the basic rule is that cycling is allowed on public roads, except when traffic signs say otherwise. On motorways and express roads ("motortrafikled" in Swedish) cycling is prohibited.

Most cycle paths are found in urban areas and are maintained by the municipality while some are privately owned. Cycle paths adjacent to state-operated roads are operated by the Swedish Road Administration. For longer cycle paths, it is common that several road managers are responsible for different parts of the path. However, in Sweden there is usually no separate dedicated bicycle

infrastructure in rural areas. This can partly be explained by the fact that state-owned roads must be accessible to all types of vehicles, at the same time as the state currently lacks the right of expropriation for the construction of independent cycle paths. This makes it almost impossible to build cycle paths without a direct connection to state-owned roads. The re-design of wider rural roads with high speed limits to the for Sweden typical divided 2+1-roads (three lanes where the middle lane alternates direction every few kilometres, with a physical barrier between directions and on the outer sides, for more detail see Chapter 6.2) made cycling on these roads virtually impossible, because speeds are high, no road shoulders exist and lanes are narrow.

1.3. Death tolls

For the EU27 countries (years 2015-2017) over 40% of all cyclist fatalities occurred on rural roads, with variations from 25% in Romania to almost 70% in Spain (European Transport Safety Council, 2020), but no exposure data are available. In the UK 32% of cycling, but 58% of cyclist fatalities occur on rural roads (Department for Transport, 2015), with a higher fatality risk on major roads than on smaller rural roads. In the US, a similar share of the population (ca. 12-14%) cycles in high-density urban areas and in very low-density rural areas, even though cycling frequency and trip length were not reported (Tribby & Tharp, 2019). NHTSA (2018) states that 30% of all cyclist fatalities in the US in 2010 to 2015 combined occurred outside of urban areas, but without exposure data this information is not helpful. Ferster, Nelson, Laberee, and Winters (2021) demonstrated how exposure data massively change the pattern of crash hotspots in an urban example area.

For Sweden, the official statistics in Strada report 89 cyclist fatalities in rural areas and 150 in urban areas, for 38 the location was unspecified (years 2009-Nov 2021), which implies that 37% of the fatal crashes with known location occur in rural areas. The corresponding percentage for severely injured cyclists is 16% in rural areas, with 6101 cases in total and an additional 648 with unknown location. While the information on location is not very reliable, a trend can be seen that crashes in rural areas have a higher likelihood of ending in death for the cyclist involved. Combining Strada Police[1] and NVDB[2] shows that the absolute number of cyclists injured and killed is higher on roads with a 70 km/h speed limit than on roads with higher speed limits. As stated above, though, without reliable exposure data this is impossible to interpret.

1.4. Exposure

Generally, little is known about the prevalence of cyclists on rural roads, and less is known about the potential for cycling had circumstances been more conducive. Some attempts are made to improve the situation, but typically not by governments or other central organisations. Nelson, Denouden, Jestico, Laberee, and Winters (2015) introduce the crowd-sourcing tool BikeMaps.org, which maps collisions and near misses involving cyclists worldwide by way of volunteer information. So far, exposure data are provided by the sport logging application Strava (Strava Inc., 2021). The available reported data are so far very concentrated on the American continent and to a small extent on some countries in Europe.

Strava provides a “global heat map” for all cycling where the application was used and the rides were not marked as “private”. Via the application “Strava Metro” it also provides access to more detailed statistics, for example whether the trips were marked as or appear to be for leisure or commute

[1] Strada Police (Swedish Traffic Accident Data Acquisition reported by the Police) is an information system for data on accidents and injuries acquired within the road transport system. e. https://www.transportstyrelsen.se/sv/vagtrafik/statistik/olycksstatistik/om-strada/

[2] NVDB (National Road Database) covers a reference road network and a large amount of data connected to that and are used by both public and private actors. https://www.nvdb.se/sv/about-nvdb/

purposes, distributions by age and gender and across different time scales. Data access is granted for maximum one region per user, and trip statistics can in theory be investigated down to the level of single road links, albeit in a time-consuming fashion. Strava claims that the data are representative for cycling in general (Strava Inc., 2020). Jestico, Nelson, and Winters (2016) showed that the relationship between manually counted cyclists and Strava data was linear for the city of Victoria, Canada, with one logged cyclist representing 51 manually counted cyclists in the year 2013. Since then, further studies have found varying correlation coefficients (for a summary see Lee & Sener, 2021), which indicates that logging behaviour is location dependent. Stigell, Michielsen, Segernäs, and Nilsson (2018) showed that trips recorded with Strava in the Gothenburg-area in Sweden were typically longer than those recorded with a travel survey app, with the application Moves or with a traditional travel survey. Similar findings were made by Watkins, Ammanamanchi, LaMondia, and Dantec (2016) in Atlanta, USA. While Strava differentiates between commute and leisure trips, it is highly probable that utilitarian and recreational trips are not logged as frequently as sportive cycling is. Thus, this type of data is likely not representative for all types of cyclists, but it can give an indication of which roads cyclists seek out or avoid. Spot checks from Strava Metro (Strava Inc., 2021) indicate that the prevalence of cyclists on roads with a speed limit of 70 km/h is higher than on roads with higher speed limits, which is the most probable explaining factor of the higher incident rates mentioned above.

In Sweden no year-round measurements of cycling on rural roads are conducted and the data material from available periods is sparse (Berg, 2017). Despite the lack of reliable exposure data, Berg (2017) could conclude that people cycle in rural areas also in locations that are far from the nearest built-up area, and not necessarily only on longer rides from one town to the next. Instead, one might cycle to the nearest bus stop, to visit friends, to the local store, the local training centre and so on (Rosander & Johansson, 2012). Furthermore, the Swedish national travel survey indicates that the share of distance travelled by bicycle, on foot and with public transport combined was second largest in rural municipalities, after major cities, and these statistics do not include cycling with the sole purpose of going out for a ride (Trafikanalys, 2021a). Thus, the potential for cycling in rural areas for utilitarian cycling is high, which is further supported by the fact that the percentage of people who live within 20 minutes of travel by bicycle to the nearest shop, elementary school or health centre is well above 50%, even for remote areas (Trafikanalys, 2021b, p. 57) see also Table 1. Instead of using current cyclist counts as a base for cycling potential, it is recommended to assess the amount of potential origins and destinations around the investigated location (Johansson & Rosander, 2017; Kågeson, 2007).

Table 1. Percentage of the Swedish population living within a 20-minutes trip by bicycle from the nearest grocery store, elementary school or health centre, depending on the type of municipality (from Trafikanalys, 2021b, p. 57).

Type of municipality	Grocery store (%)	Elementary school (%)	Health centre (%)
Major town	99	100	98
Densely populated municipality close to major town	93	96	84
Densely populated municipality, far from major town	88	92	76
Rural municipality, close to major town	85	91	65
Rural municipality, far from major town	82	88	64
Rural municipality, very remote	75	78	59

The same source indicates that, according to the travel survey from 2019, the longest average bicycle commute to work is 6.9 km oneway, for municipalities close to major towns, and the next longest, with 5.3 km oneway, occurs in municipalities close to towns of medium size. In more remote areas, the average bicycle commute is shorter than that. As shown by Stigell et al. (2018), the variance in bicycle trip length varies widely, though, such that a mean trip length can only serve as a rough indicator.

1.5. Who cycles and how – and who does not?

With little being known about the amount of bicycle traffic in rural areas, even less is known about who is cycling there, how one cycles and for what purpose. The heterogeneity of people who cycle is tacitly known and has also been considered in some research, though not specifically related to cycling in rural areas. The numerous typologies of cyclists that have been made can be linked to people's propensity to cycle at all, how frequently, and what environment they prefer or require (Bergström & Magnusson, 2003; Damant-Sirois, Grimsrud, & El-Geneidy, 2014; Dill & McNeil, 2013; Geller, 2006; Hosford, Laberee, Fuller, Kestens, & Winters, 2020), what their socio-economic background is (Sener, Eluru, & Bhat, 2009), or which opinions different groups have about the "typical cyclist" (Gatersleben & Haddad, 2010). When the purpose of the trip is considered, this happens mainly with the aim to sort people into different groups, like "commuter", "sports/weekend", "utilitarians", "leisure cyclists", etc. (Damant-Sirois et al., 2014; Félix, 2012). Kroesen and Handy (2014) acknowledge that the same person can ride for utilitarian and for leisure purposes ("all-around cyclist"), but it is still implicitly assumed that the needs and preferences as a cyclist are manifested in the person. We would argue, however, that needs and preferences are a function of personal characteristics in combination with the purpose of the trip, which includes the type of bicycle used, where both factors modify the relative and absolute needs, preferences and barriers for a specific trip. While we in this report use common terms like "utilitarian" and "leisure" cycling, these are not necessarily strictly separated, as a commute can be used for training, for example (Aldred, 2015; Larsen, 2018).

The national travel survey does not separate between cycling in rural and urban areas, but shows that the average trip length per person and day is one kilometre, with no big difference between genders (Trafikanalys, 2021a). In Great Britain, men cycle about three times as much as women (Department

for Transport, 2020), and it is generally very common to cycle less than once a week, but no numbers were found on how many people do not cycle at all. Generally, it seems like the share of women cycling is larger in high-cycling countries (e. g. the Netherlands, Denmark, Germany), as is the representation of younger age groups (Aldred, Woodcock, & Goodman, 2016). Again, urban and rural cycling were not separated.

Reasons for why people choose to cycle or not, and for which purpose, differ and therefore must be addressed depending on their origin. They can be connected to objective and physical barriers due to natural circumstances or because they have been built as barriers, or they can be consequences of regulations, for example when cycling is prohibited on certain roads. Barriers can be absolute or depend on personal judgement on what is considered “bikeable”. In this latter case, the judgement can be based on factors like actual danger or discomfort, or on perceived danger or discomfort. Barriers can be local, in that they prevent people from cycling in certain areas or under certain conditions, or general, such that people do not cycle at all. They can also be connected to the presence or absence of facilities like a safe place to park the bicycle, or the possibility to shower at the workplace. Furthermore, barriers can also stem from a societal or personal opinion about cycling, which does not have to be related to aspects of safety or comfort. We look more into all these topics below, identifying research findings as well as research gaps.

2. Method

The literature for this review stems from a semi-structured search in Scopus, Google scholar and Web of Science, where references in found articles could be included, too. Also, reports and websites from relevant agencies, organisations and administrative organs were included. We do not claim that the review is exhaustive. Rather, it is meant to provide an overview of available literature concerning several aspects of cycling in rural areas (or results transferable to rural conditions) from different disciplines, with the aim to highlight what is known, and to identify knowledge gaps. Where data were available, or when specific legislation or road designs were concerned, we also highlight findings from Swedish conditions. A common denominator of the studied literature is that it is linked to cycling on the road and path network aimed at transportation in a broader sense, but not at cycling within a distinct, limited area such as a bike park or similar. Organised events like races or sportives are excluded.

For improved readability the report is subdivided into several aspects pertaining to cycling in rural areas. This does not imply, however, that improvements and changes should be made for only one aspect at a time. Instead, it is important to consider interactions and interdependencies.

3. Bikeability

Whether a road is used for cycling depends on its attractiveness for cycling in relation to the availability and attractiveness of alternative routes and likely also some absolute cut-off criteria. According to Reggiani et al. (2021), "bikeability" can be defined as the extent to which an environment is "convenient and safe for cycling". While this definition applies to all areas, the body of research on the topic is mainly focused on urban areas, with exceptions in cycle tourism and overtaking of cyclists, where rural cycling plays a prominent role.

3.1. Connectivity and route choice

Road network connectivity refers to the density of connections in the network and the directness of links (Dill, 2004). A well-connected network has short links, numerous intersections and few dead-ends, leading to decreased travel distance and increased route choice between any two locations in the network[3]. In addition to connectivity, which is computed based on the relationship of links to nodes (intersections or dead ends), accessibility is an important factor. It compares the actually travelled distance with the direct travel distance and thereby provides an indication how much out of the way a person travels to reach the destination. It is common that cyclists choose a different route than the most direct one between two points. A Canadian study showed that 75 per cent of the investigated cyclists on non-recreational trips used routes within 10 per cent of the shortest possible distance, and 90 per cent used a route within 25 per cent of the shortest distance (Winters, Teschke, Grant, Setton, & Brauer, 2010). Lu, Scott, and Dalumpines (2018) found that the typically chosen routes were around 30% longer in distance than the shortest path, but only 10% longer in time. Cyclists are more willing to add distance for decreased stress when not on a commute (Broach, Dill, & Gliebe, 2012).

Figure 1. An example where cyclists are directed to a rough gravel road to circumvent the main road, but a fence is put up where the main road must be crossed. Photo: Katja Kircher.

Aldred, Elliott, Woodcock, and Goodman (2017) conducted a review of 54 studies (including both rural and urban areas). They show that cyclists prefer fully separated cycle paths over cycle lanes and that women's preference for this type of infrastructure is stronger than men's. Some of the reviewed studies showed that older cyclists have a stronger preference for fully separated cycle paths than do younger cyclists. In addition, Wehtje, Andersson, and Niska (2018) showed that separating cyclists from other road users increases cycling safety. These studies are, however, based on the current situation and the results may be different in a traffic environment where all road users share the road on more equal terms.

[3] https://www.vtpi.org/tdm/tdm116.htm

Further, cyclists appreciate low motorised vehicle speeds, wide infrastructure, and the absence of heavy vehicles (Bakogiannis et al., 2020; Rossetti, Saud, & Hurtubia, 2019). The cyclists also appreciate a limited number of intersections and left turns (in right-hand traffic). Furthermore, Jacobsen, Racioppi, and Rutter (2009) showed that higher speeds and a larger traffic volume are correlated with lower levels of cycling. In northern Sweden, a questionnaire study indicated that daylight versus darkness and seasonal differences played a big role for how comfortable people felt cycling on the main road in rural settlements (Rosander & Johansson, 2012). Different types of cyclists have different preferences (Griswold, Yu, Filingeri, Grembek, & Walker, 2018; Misra, Watkins, & Dantec, 2015), such that it can be necessary to offer a range of solutions in the same location to accommodate a large share of cyclists. This becomes especially clear when looking at values and preferences identified for cycle tourism as compared to utilitarian cycling (see Chapter 3.2).

The factors identified for urban route choice are not fully transferable to rural route choice, mainly because the road network is different regarding route choice options (Sorton & Walsh, 1994). Maybe even more for rural than for urban cycling the purpose of the trip needs to be taken into account – for utilitarian cycling direct and efficient routes are likely to be preferred, recreational cycling might benefit especially from a quiet and attractive environment and cycling for training purposes can include actively seeking out inclines and physically challenging conditions.

Also, it is not enough to consider those factors that influence the route choice behaviour of people who already cycle. Fishman, Washington, and Haworth (2012) identified a qualitative difference in perceived barriers to cycling between people who at least occasionally cycle and people who do not cycle at all. Fear of motorised traffic was the most frequently mentioned reason for not cycling at all. Inclement weather as deterrent to cycling ranked higher among cyclists than non-cyclists. A Canadian survey, on the other hand, found icy or snowy road conditions and a high traffic volume to be the strongest deterrents to cycling (Winters, Davidson, Kao, & Teschke, 2011), regardless of predisposition for cycling. Generally, non-cyclists found adversary factors more deterring and positive factors less motivating than cyclists.

As shown, connectivity for cyclists means more than the mere presence of roads, as not all roads are experienced as equally appropriate for cycling. Partially picking up on the points mentioned above, several classification schemes for bicycle facilities were developed (for an overview, see Figliozzi & Blanc, 2015), with two well-known schemes being the Bicycle Level of Service (BLOS; Landis, Vattikuti, & Brannick, 1997; Landis et al., 2003), and the Bicycle Compatibility Index (BCI; Harkey, Reinfurt, & Knuiman, 1998). Both classification schemes are based on ratings on a six-point scale, for the BLOS from 150 cyclists on a real inner-city course and for the BCI from 202 responses to a video-based survey. Infrastructure features like number of lanes, presence and type of bicycle facilities, and potential for cross-traffic and motorised traffic related features like traffic volume and speed were used to model the cyclists' ratings. These models were developed in urban areas and have mainly been used in urban contexts (Kazemzadeh, Laureshyn, Winslott Hiselius, & Ronchi, 2020), but they are briefly referenced here, because analogous models for rural areas should be possible in principle. According to our knowledge, only two attempts were made on the American continent (Jones & Carlson, 2003; Noël, Leclerc, & Lee-Gosselin, 2003).

Using results from a web-based survey, Jones and Carlson (2003) proposed a rural bicycle compatibility index (RBCI). 32 video clips of 30 s length were rated by 101 cyclists on a scale from 1 to 6 for overall comfort, and in relation to the amount of traffic, heavy vehicles, and space for riding. The videos were recorded with a camera mounted on a car travelling at ca. 10 mph (16 km/h) on rural roads in Nebraska, USA, with varying road shoulder width, slightly varying lane width and posted speed limits, varying measured speeds, intersection and driveway density, traffic volumes and heavy vehicle volumes. It can be noted that the mounting position on the left outer edge of the car did not allow any close overtaking from the perspective of the camera representing a cyclist's view. In

addition to rating the videos, cyclists reported on their own cycling behaviour. Based on this information, 56 respondents were classified as “experienced riders”, the remaining 45 as “casual riders”. The “experienced riders” expressed generally higher comfort levels than the “casual riders”. A statistical model was produced analogous to the BCI. The main factors increasing comfort within groups were wider road shoulder width and lower volumes of heavy traffic, while general traffic volumes did not influence comfort ratings much. A comparison with the BCI developed for urban conditions, using the criteria from the BCI to describe the segments, showed that the urban model cannot be directly applied to rural conditions.

Noël et al. (2003) used a survey with 200 participating cyclists to build the CRC Index (Compatibility of Road for Cyclists). On four pre-selected routes cyclists were recruited on-site and asked a few background questions. They then rode the route and were asked to stop at six predetermined sites to provide comfort ratings of 1-6 based on pre-established criteria. At the end of the route the rating cards used were collected and the cyclists were interviewed about the role that different factors played for their perceived comfort. Traffic flow was counted while the ratings were ongoing. Based on the background variables of total kilometres and cycling frequency the cyclists were categorised into “sport cyclists”, “moderate cyclists” and “leisure cyclists”. Analyses showed that road shoulder pavement and width, interpreted as space available for cyclists, was most important for cycling comfort, regardless of cyclist type, but that other factors varied between types, supporting the notion that different cyclists or trip purposes have different needs.

These statistical models have been criticised for several reasons. By averaging cyclists’ ratings, the heterogeneity between cyclists is not acknowledged (Griswold et al., 2018; Noël et al., 2003). Also, the models are described as essentially being “black box”-approaches, which do not allow a direct classification of a street based on its visible features (Mekuria, Furth, & Nixon, 2012). Carter, Hunter, Zegeer, Stewart, and Huang (2007) discuss the advantages and disadvantages with using crashes, behavioural data like conflicts, and safety ratings and choose a combination of them all for their (urban oriented) bicycle intersection safety index (Bike ISI).

Mekuria et al. (2012) suggest a non-statistical classification of the (urban) road network based on what they call “level of traffic stress” (LTS), somewhat similar to an initiative by Sorton and Walsh (1994), where stress was modelled for different types of cyclists. Mekuria et al.’s categorisation is centred around four types of cyclists described by Geller (2006), thereby connecting the bikeability of a section to a certain prototype of cyclist, and is loosely based on the Dutch design manual for bicycle traffic (CROW, 2016). A combination of factors like speed of motorised vehicles, traffic density, vehicle parking, road width, separated infrastructure or not determine for which types of cyclists the segment should be suitable. Four levels are described, with LTS1 inducing least stress and being suitable for children, LTS2 being “suitable to most adult cyclists” and corresponding to Dutch design standards for bicycle facilities, LTS3 inducing more traffic stress, but still markedly less than on LTS4 (detailed description in Mekuria et al., 2012, p. 14). Connectivity on a certain LTS is based on the “weakest-link” method, identifying whether it is possible to cycle between two points only using segments at or below a certain level of stress, and how much longer this route is compared to the most direct route. For urban areas, the detour should not become longer than 125% of the most direct route (Crist et al., 2019; Mekuria et al., 2012). While different cyclist types are acknowledged via the four levels, they are assumed to be on “an ordinal scale of skill and comfort”, which is criticised by Griswold et al. (2018), who suggests that the picture is more complex than that.

Crist et al. (2019) used the LTS method to classify all roads in San Diego County, including rural areas. They found that the rural road network mainly consisted of LTS4-roads, thereby creating islands of lower stress levels that are not interconnected. This means that rides between those islands are not possible without riding on high-stress roads. GPS-data collected from actual cycling trips showed that cyclists were forced to include high-stress segments in more than 25% of the registered trips, as no

other (reasonable) alternatives were available. An additional analysis showed that for more than half of the actual routes, no alternative on exclusively LTS2 or lower existed.

Making an effort to incorporate cyclist heterogeneity on a nominal level, Griswold et al. (2018) suggest the usage of a Latent Class Choice Model to identify which infrastructure is suitable for a certain type of cyclist. They used both urban and rural material for their model and found qualitative differences in preference for the three cyclist types that they identified in their sample. They did not consider, however, that the same cyclist might have different preferences depending on the purpose of the trip.

Yet a different approach to classify infrastructure for bicycle usage was taken by the iRAP group with the innovation project CycleRAP[4]. It is an extension of the bicycle model of euroRAP and is meant to be used either as standalone method or in combination with other road assessment tools. By categorising infrastructure used by cyclists and other users of micromobility its intention is to predict high-risk locations. Instead of modelling cyclists' ratings, crash risk for four crash types is modelled, with the risk factors being based on findings from the scientific literature. The model is still under development, with a current application case in the SABRINA project[5].

Wahlgren, Stigell, and Schantz (2010) developed the Active Commuting Route Environment Scale (ACRES) based on Swedish conditions by letting commuters in the centre and outskirts of Stockholm assess their route with regard to different variables, including the presence of bicycle infrastructure, route characteristics like sharp turns, red lights etc., traffic density and speed of both motorised vehicles and other cyclists, the level of exhaust fumes and noise, the perceived frequency of conflicts with other road users, and environmental factors like the presence of greenery, the pleasantness of the route, hilliness, route length etc. In addition, experts consisting of civil servants working with bicycle related questions, assessed the cycling environment in Stockholm with respect to similar factors. An application of the ACRES model to data collected from around 2000 respondents showed that the factors "ugly or beautiful" and "presence of greenery" had a substantial positive correlation with an environment perceived as stimulating for cycling, whereas noise, density of motorised vehicle traffic and exhaust fumes were perceived as hindrances. In contrast to most models with a background in traffic engineering, this model, which has its base in the health domain, works with two somewhat independent outcome variables, showing that more factors than (perceived) safety determine cycling propensity on a route. Further multifactorial indices for bikeability exist in the public health domain, but they are mainly focused on urban areas (Hardinghaus, Nieland, Lehne, & Weschke, 2021; Pikora, Giles-Corti, Bull, Jamrozik, & Donovan, 2003; Porter et al., 2019) or Kellstedt, Spengler, Foster, Lee, and Maddock (2021) for an overview. It will have to be explored to which extent these models can be applied to rural areas.

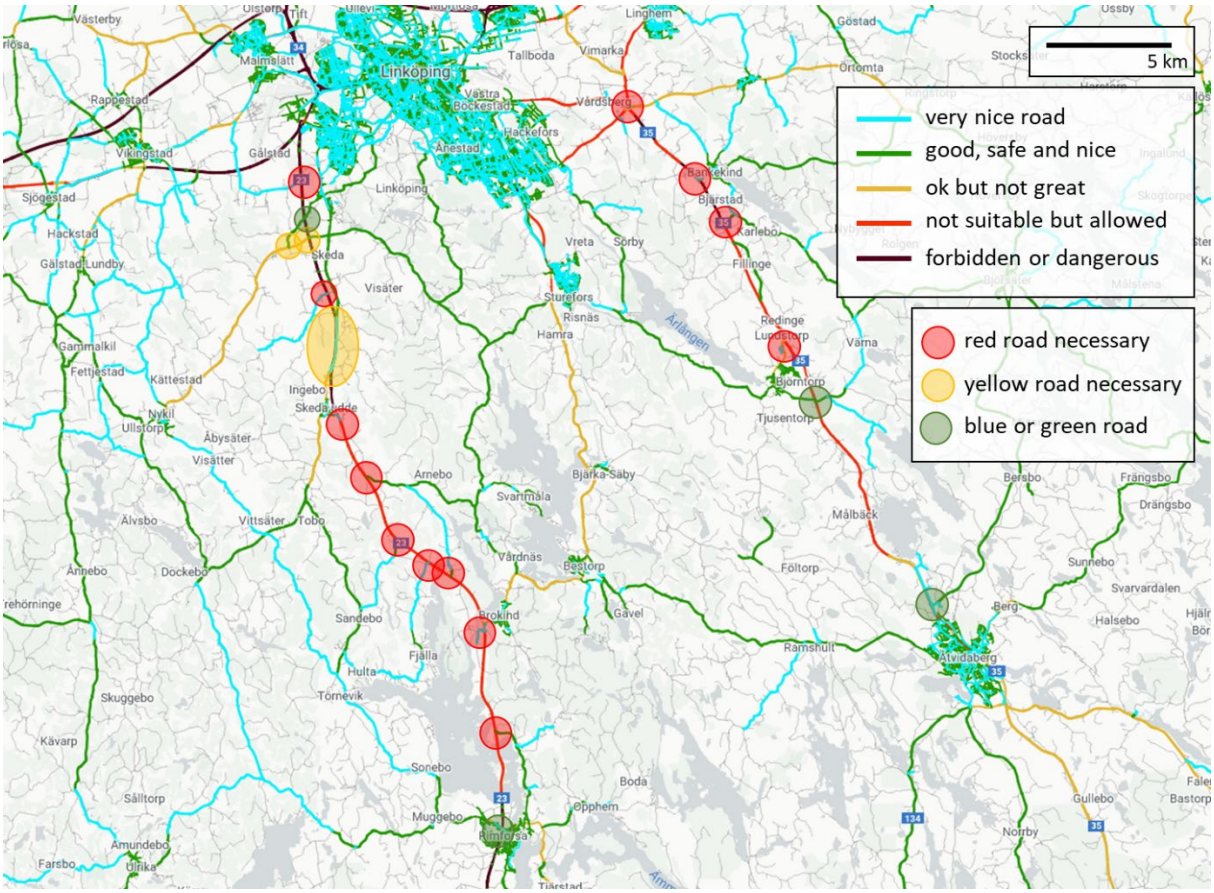
The Swedish Road Administration prepared a classification to indicate how well-suited the rural roads in the country are deemed to be for tourist cycling routes (Wirsenius, Liljehov, Pettersson, & Mattsson, 2021). The classification criteria include the posted speed limit, the average daily count of traffic (AADT) and the presence and type of dedicated bicycle infrastructure (p. 26). Three levels for cycling suitability were identified and described. This classification is the basis for the identification of national cycle routes for tourism, which are described further in Chapter 3.2. A similar map, using road width, traffic volume and posted speed limit to calculate bikeability, can be found on Roadfinder[6]. This site focuses on tarmac roads and has not been updated since March 2018. The map section in Figure 2 shows how the implementation of two divided 2+1-roads (mainly the roads marked red) render it difficult for cyclist to travel both from east to west and southward while avoiding roads

[4] https://irap.org/2021/05/innovation-project-in-focus-cyclerap/

[5] http://www.interreg-danube.eu/approved-projects/SABRINA

[6] www.roadfinder.se

that are classed as unsuitable for cycling. This is due to the fact that many side roads end on the main road and do not continue on its other side, which would necessitate cycling on the main road for at least a short distance.


5 km
very nice road
good, safe and nice
ok but not great
not suitable but allowed
forbidden or dangerous
red road necessary
yellow road necessary
blue or green road
Linköping
Skeda
Visåter
Ingebo
Arnebo
Bjärka-Säby
Svartmåla
Vårdnäs
Bestorp
Brokind
Gävel
Sandebo
Fjälla
Hulta
Törnevik
Sonebo
Boda
Öpphem
Muggebo
Rimforsa
Tjärstad
Vreta
Sörby
Sturefors
Risnäs
Hamra
Fillinge
Redinge
Lundstorp
Björntorp
Tjusentorp
Värna
Mölbäck
Föltorp
Ramshult
Atvidaberg
Berg
Sunnebo
Svarvardalen
Halsebo
Bersbo
Frängsbo
Drängsbo
Gullebo
Norrby
Bastorp
Ljungsbro
Ödeshög
Ingelstad
Linghem
Vimarka
Tallboda
Vårdsberg
Bankekind
Bjärstad
Karlebo
Göstad
Örtomta
Stocksund
Ussby
Malmslätt
Rappestad
Vikingstad
Gålstad
Ånestad
Hackefors
Västra Bockestad
Sjögestad
Hackstad
Gålstad
Lundby
Garnimalkil
Fettjestad
Kättestad
Nykil
Ullstorp
Åbysäter
Visätter
Älvsbo
Vittsäter
Tobo
Annebo
Dockebo
Skuggebo
Kävarp
Sälltorp
Amundebo
Farsbo
Ulrika
Hällestad
Mjölby
Åtvidaberg
Hjältevad
Kisa
Vadstena
Motala
Skänninge
Borensberg
Norrköping
Söderköping
Finspång
Valdemarsvik
Åtvidaberg
Kinda
Boxholm
Ydre
Kinda
Åtvidaberg
Motala
Vadstena
Mjölby
Linköping
Norrköping
Finspång
Ödeshög

through road accidents. Traffic environment, on the other hand, is based on the cyclists' presumed perception as described below.

As a first step, the assessment of the traffic environment is based on the mean number of motorised vehicles during a 24 hour period (AADT), the posted speed limit, and the type of bicycle infrastructure available (Table 2 shows the assessment of the traffic environment on different stretches of road outside built-up areas). The cyclists' perception of the traffic environment is largely in line with previous research (Bakogiannis et al., 2020; Rossetti et al., 2019) which shows that cyclists prefer the absence (or low density) of cars and high-speed roads.

Table 2. Assessment of traffic environment on different stretches of road outside built-up areas (after Wirsenius et al., 2021).

Bicycle infrastructure	**ÅDT**	**Posted speed limit**						
		30	**40**	**50**	**60**	**70**	**80**	**≥ 90**
Separate cycle path								
Cycle lane, 2-1-roads[7], wide road shoulder >1 meter	<250							
	250-1000							
	1000-2000							
	2000-4000							
	>4000							
Mixed traffic, narrow road shoulder ≤ 1 meter	<250							
	250-1000							
	1000-2000							
	2000-4000							
	>4000							

Green standard: good, desirable, attractive

Cyclists feel that it is a very safe traffic environment and that it is possible to cycle with children under 12 years. This includes separate cycle paths, summer cycle paths and roads with little traffic.

Yellow standard: Less good, pleadable, acceptable

Cyclists feel that it is a fairly safe traffic environment and that it is possible to cycle along the route as an adult. This includes cycling in mixed traffic with little traffic and wide road shoulders, or on cycle lanes.

Red standard: Low, deficient, should be avoided

The traffic environment is perceived as unsecure and unsafe. This includes cycling in mixed traffic with larger traffic volumes and higher speeds.

The colour coding in Table 2 is supposed to mirror cyclists' perception of the traffic environment. As far as we know, these assessments have been made by looking at examples from other countries in combination with in-house discussions at the Swedish Transport Administration. Site visits are

[7] See Chapter 6.1 for a further description.

recommended only when stretches are on the border between yellow and red standards. No questionnaire- or interview-studies mapping cyclists' actual experience of cycling on these routes have been conducted.

As a second step, only stretches which are on the border between yellow and red standard are further assessed. This assessment is based on the mean number of motorised vehicles during 24 hours during the cycling season, actual vehicle speeds, classification of road safety[8], the width of the road and the road shoulder, visibility, share of heavy traffic, length of the stretch, possible alternative routes and expected target groups (e.g., families with children).

As a third step, the whole cycle route is assessed aiming for mostly green standard. A total of ten percent of the total length of the cycle route can be red standard but this must be divided into several shorter segments. Even though the Swedish Transport Administration only accepts shorter segments of red standard, we believe that these segments will still be perceived as unsafe by cyclists, constituting a barrier especially for more vulnerable groups such as families with children, older cyclists or cyclists who are new to cycling holidays (see Chapter 3.1 for more details).

For red segments with a posted speed limit of > 70 km/h there should be a plan for improvement to yellow standard. In contrast to previous recommendations (Trafikverket, 2017) no time limit for the improvement was found in Wirsenius et al. (2021). Furthermore, no cycling in mixed traffic with a posted speed limit >70 km/h and traffic volumes > 4000 and above should be included. This is also a relaxation in requirements compared to (Trafikverket, 2017) which did not accept cycling in mixed traffic with a posted speed limit of 80 km/h and traffic volumes > 1000 or any cycling in mixed with a posted speed limit of 90 km/h, regardless of the traffic volume. It is well known that collisions between motorised vehicles and vulnerable road users at speeds above 30 km/h often result in serious injury and death. It could therefore be questioned if national cycle routes for tourism really meet the criteria for traffic safety when cycling in mixed traffic with a posted speed limit up to 80 km/h is accepted.

From these criteria for national cycle routes follows that a route could be approved with substantial parts of the route being located on cycle lanes along roads and/or in mixed traffic without any cycle infrastructure. Downward and Lumsdon (2001) have shown that recreational cyclists find roads with mixed traffic acceptable if the level of traffic is very low. Even if these roads are accepted, Deenihan and Caulfield (2015) showed that tourists prefer separated cycle paths over cycle lanes along the roads as well as over roads with no cycle infrastructure at all. Especially, older female tourists are more likely to choose fully separated cycle paths or cycle lanes along the roads while younger men are more likely to choose roads with no cycle infrastructure at all.

Looking farther afield, the European Cyclists' Federation (ECF) has developed a route classification system for the EuroVelo European Cycle Route Network (ECF and EuroVelo, 2018) for the categorisation of the quality of its long-distance bicycle routes. The routes are intended to target any type of cycling including cycle tourism, commuting and sportive cycling. Three levels of demand are described, and route segments are then classified according to the extent to which they meet the demands of the three groups. The evaluated criteria refer to infrastructure, services along the route and route promotion. "Essential" criteria must be met along the entire route, "important" criteria are assumed to cater to occasional bicycle tourists and must be met along 70% of the route, whereas "additional" criteria cater to demanding bicycle tourists and are optional on the routes. An example from the infrastructure sector is that routes must be non-disrupted, that is, there should be adequate infrastructure for cycling and no segments where cycling is prohibited (essential criterion). Should there be stairs on the route, then they must have a gentle incline and ramps (important criterion). The absence of obstacles that could prevent the demanding group of cyclists from being able to use the

[8] www.nvdb.se

infrastructure is an additional criterion. Essentially, to meet this criterion, cyclists should not be required to dismount (additional criterion; paraphrased from p. 8).

Importantly, the ECF classification does not only consider infrastructure and traffic volume, but also attractiveness of the surroundings, the quality of route signage, the possibility to use public transport with the bicycle in its assembled state as alternative mode of transportation, various services and accommodation along the route and easily accessible information about the route on the internet.

In terms of accessibility, the Swedish Transport Administration (Wirsenius et al., 2021) acknowledge the large difficulties in bringing bicycles on public transport. Basically, no public transport operator allows cargo bikes or bike trailers, which are popular among bicycle tourists. In addition, SJ (the market-leading train operator in Sweden) and most bus operators do not allow standard bicycles either (unless they are folded and packed). Many regional train operators do allow standard bicycles, but only subject to availability and without any option to pre-book. At the time of writing, FlixTrain, connecting Stockholm and Gothenburg, seems to be the only train operator which allows pre-booking of space for standard bicycles. This is not in total agreement with EU regulations which state that: “Railway undertakings shall enable passengers to bring bicycles on to the train, where appropriate for a fee, if they are easy to handle, if this does not adversely affect the specific rail service, and if the rolling-stock so permits” (EU, 2007). The Swedish Government further elaborated on this and stated that it can be restricted by the railway company if it has a negative effect on the traffic service or if the carriages do not allow it (Regeringskansliet, 2017). However, they add that the government is positive to solutions that support transport companies to offer the possibility of taking a bicycle on a train when this is realistic, mainly from a "whole trip perspective", but also as support for increasing tourist and recreational cycling.

3.3. Discussion: Bikeability

Connectivity is essential for the functionality of a transport network, and a single barrier in the network can render an otherwise fine route unusable. Therefore, it is advisable to investigate network connectivity and identify barriers, because a strategic removal of sometimes small barriers can lead to a vast improvement in connectivity (Lowry & Loh, 2017; Natera Orozco, Battiston, Iñiguez, & Szell, 2020). Most road classification approaches in the traffic engineering domain are uni-dimensional, focusing on either a subjective rating or a safety index like crash likelihood, and the predictor variables typically consist of traffic and infrastructure related features in the narrower sense, similar to variables considered in route choice modelling. In the Swedish classification system for cycle routes for tourism two out of the eight criteria concern traffic safety and presumed perceived traffic environment. However, as far as we know, no one has asked any cyclists how they actually perceive these routes. We therefore recommend studies mapping different cyclists’ actual experience.

While route choice models have been shown to be predictive of actual route choice (e. g. Broach et al., 2012; Casello & Usyukov, 2014; Crist et al., 2019), the variables included in these models typically do not represent all relevant factors, and they can only model the behaviour of people who already cycle. Route choice modelling tends to focus on urban or suburban networks where there are numerous alternatives, and where features may differ from the rural network. When no suitable routes are available, cyclists either need to ride on unsuitable routes or refrain from cycling, thus, a lack of comfortable alternatives may increase cycling on unsuitable routes. A detour in a rural area can add several hours of travel time, which may lead to a different weighting of options than in urban areas.

In addition to considering infrastructure related factors, changes of regulations or innovative technical solutions might help increase connectivity for cyclists. These factors are lacking in all reviewed road classification models, even though for example an effective implementation of a minimum passing distance law could change cyclists’ perception of a route without changing the infrastructure itself (see also Chapter 4).

To sum up, to increase cycling, including cycle tourism in rural areas the network must become more attractive and accessible to cyclists, at the same time as measures should be taken that prevent cyclists from getting hurt. While there certainly is a correlation between the two, more than physical safety is needed for an environment to be considered bikeable, and the needs vary with cyclist type and likely with trip purpose.

4. Overtaking of cyclists

When cycling in rural areas it is a very common occurrence to be overtaken by motor vehicles. As elaborated further in Chapter 7, close overtaking can constitute a stressful experience for cyclists. The current Swedish legislation requires cyclists to keep as close as possible to the right edge of the road shoulder or the currently used lane. Cyclists should also ride in single file, except if riding abreast can be done without danger or disturbance for traffic. Overtaking traffic must keep an appropriate lateral safety margin for reasons of safety and comfort, but no absolute distance or other interpretation advice is given. Motorised vehicles overtaking cyclists constitute a safety risk; in the US, 36% of all crashes including a cyclist fatality occurred when a motorised vehicle overtook a cyclist (Feizi, Mastali, Van Houten, Kwigizile, & Oh, 2021).

Cyclists may swerve due to potholes, debris on the road or side winds. Other reasons for swerving can be looking over their shoulder towards an approaching vehicle, or simply because it is natural not to ride in a completely straight line (Kaparias et al., 2021; Westerhuis, Jelijs, Fuermaier, & de Waard, 2017). Also, given the relatively smaller size and lower speed, the aerodynamic effects of motorised vehicles on cyclists are much larger than the other way round (Ferrara, 2001; Gromke & Ruck, 2021; Khan & Bacchus, 1995), which is another important factor that needs to be considered especially for large vehicles.

Research on motorised vehicles overtaking cyclists has increased substantially in the last decade. Measurement methods differ but are typically made either from the bicycle or from stationary devices, only in rare cases they are made from the overtaking vehicle. Cameras, ultrasound sensors and radar/lidar are common measuring technologies, either on their own or in combination. In most cases, single cyclists are observed, but a few studies from a research group in Spain also consider groups of up to ten cyclists (e. g., Garcia, Llorca, & Serra-Planelles, 2020; López, Pérez-Zuriaga, Moll, & García, 2020; Moll, López, Rasch, Dozza, & García, 2021; Pérez-Zuriaga, Moll, López, & García, 2021). Typical measurements are the lateral distance during the overtaking manoeuvre in an absolute number, the type of overtaking manoeuvre performed (accelerating: the driver slows down and waits for an opportunity to pass, accelerating in the overtaking process; or flying: the driver does not slow down prior to overtaking). In some cases, additional variables are collected, like speed during overtaking and how the vehicle is positioned relative to the road markings present.

Legislation, the presence of cyclists on the road and their within-group variation with respect to numerous factors, as well as traffic culture vary between regions. Therefore, generalisability of results should not be assumed without considering the specific circumstances.

Close overtaking is relatively frequent in many countries, with estimates ranging from 2% to 16%, (Beck et al., 2019; Debnath, Haworth, Schramm, Heesch, & Somoray, 2018; Kay, Savolainen, Gates, & Datta, 2014; Love et al., 2012; Mackenzie, Dutschke, & Ponte, 2021), to as high as 36% (Llorca, Angel-Domenech, Agustin-Gomez, & Garcia, 2017). Walker, Garrard, and Jowitt (2014) found that one to two percent of overtaking manoeuvres come within 0.5 metres. Depending on how the lateral clearance is measured (from the bicycle frame to the vehicle body vs. from the outer edge of the handlebars to the outer edge of the car mirror) the same data set has been shown to yield very different shares of close passing (9% vs. 36%, Llorca et al., 2017).

It should be noted that the definitions of "close" differ and are often linked to the legislation in the country where the study was conducted. In most US states the minimum lateral overtaking distance is 3 ft (ca. 0.9 m). Other countries prescribe at least 1.5 m (e. g. F, P, B, ES, UK), in Spain from March 2022 drivers will have to change lanes on roads with more than one lane per direction. In Germany the minimum lateral overtaking distance is 1.5 m in built-up areas and 2 m outside of built-up areas. In Queensland, AUS, the minimum lateral distance is 1 m for speed limits of up to 60 km/h and 1.5 m above. Here, Nolan, Sinclair, and Savage (2021) found 6.1% respectively 31.8% of the passing events to be below the legal limit. Oregon and Rhode Island belong to the few US states that do not require a

specific minimum distance, but demand that the overtaking vehicle must pass at “a distance that is sufficient to prevent contact with the person operating the bicycle if the person were to fall into the driver's lane of traffic” (Oregon Department of Transportation, 2019)[9].

4.1. Infrastructure

The lateral distance during overtaking has been found to decrease with the presence of a central rumble strip (Kay et al., 2014; Savolainen, Gates, Todd, Datta, & Morena, 2012), when the centre line is solid (Feng, Bao, Hampshire, & Delp, 2018), when no road shoulder is available (Chapman & Noyce, 2012, 2014), and for narrower roads (Love et al., 2012). For other factors results were not consistent. Especially the results for the presence or absence of painted cycle lanes or symbols like sharrows range from findings of increased to decreased lateral distances (Beck et al., 2019; Chuang, Hsu, Lai, Doong, & Jeng, 2013; Debnath et al., 2018; Love et al., 2012; Mehta, Mehran, & Hellinga, 2015; Nolan et al., 2021; Parkin & Meyers, 2010; Richter, Beyer, Ortlepp, & Schreiber, 2019; Shackel & Parkin, 2014; Stewart & McHale, 2014), and the explained variance is often small. However, Nolan et al. (2021) claim that methodological shortcomings are the reason behind the inconclusiveness of the results related to cycle lanes. Their data set of more than 45.000 overtaking manoeuvres logged by 162 participants with well-calibrated sensors and video footage to enhance data quality was analysed with four different types of statistical models. One of those models specifically considered that differences in lateral distance matter more for small clearances. The authors differentiate between several types of cycle lanes and conclude that after controlling for other factors, overtaking distances were larger for cycle lanes with wide painted buffers and larger still for physically protected cycle lanes. Simple painted cycle lanes did not have a large effect on lateral overtaking distances and parked cars reduce the effect of cycle lanes. The share of trips with at least one overtaking event with a lateral clearance below 1 m was around 90% when at least 50 overtaking events were recorded during the trip, and 100% for more than 200 overtaking events in the trip, which means that a cyclist can basically be certain to experience at least one close overtaking when going out on such a trip.

The study by Nolan et al. (2021) does not consider the lateral positioning of the cyclist with respect to the infrastructural demarcations (e. g. painted lines). This was done by Kay et al. (2014) in a controlled study, who found that the absolute lateral clearance was larger, if the cyclist travelled farther to the right on the road shoulder, but that the overtaking vehicle tended to execute a larger lateral shift to the left when the cyclist was positioned on the right edge of the lane instead of on the road shoulder.

Figure 3. Two overtaking manoeuvres on the same road. In the case on the left-hand side, the car driver adheres to the double solid lines thereby passing much closer to the cyclist than the driver in the picture on the right-hand side, who crosses the dashed lines. Photo: Katja Kircher.

[9] For a compilation of all law texts pertaining to the overtaking of cyclists in the USA see https://www.ncsl.org/research/transportation/safely-passing-bicyclists.aspx

4.2. Other traffic

One major factor leading to a decrease of lateral distance to the overtaken cyclist is the presence of oncoming traffic (Dozza, Schindler, Bianchi-Piccinini, & Karlsson, 2016; Feng et al., 2018; Kay et al., 2014; Mehta et al., 2015; Shackel & Parkin, 2014). Also, there are some indications that the lateral clearance is smaller for larger overtaking vehicles (De Ceunynck et al., 2017; Haworth & Schramm, 2014; Kay et al., 2014; Walker, 2007), which might be related to available space.

Analysing the duration of the overtaking manoeuvre, Moll et al. (2021) found, not surprisingly, that accelerating manoeuvres take longer time than "flying" manoeuvres. They also found that the overtaking duration was shorter in the presence of oncoming traffic and when the lateral clearance was smaller, leading to the assumption that the overtaking speed was higher in these cases.

4.3. Cyclist related factors

The fact that cyclists are a heterogeneous group is important to remember. Novice cyclists, children who cycle for fun, families on bicycle holidays, cyclists commuting to school/work, experienced cyclists training for the next race and older people cycling for leisure are all examples of cyclists with different needs and preferences. These can even vary within the same person, depending on the purpose of the trip, and whether riding alone or in company. Unfortunately, there is a lack of knowledge of these differences at the same time as research has shown that car drivers tend to treat most cyclists in the same way. While several studies (Chuang et al., 2013; Sando & Moses, 2011; Walker, 2007; Walker et al., 2014) found indications that car drivers keep a larger distance when passing a cyclist with a female appearance, this was not confirmed by Haworth, Heesch, Schramm, and Debnath (2018), and no differences have been found for apparent skill and experience of the cyclist. In one field experiment in the south-east of England seven different appearances were tested (Walker et al., 2014). Four of the appearances signalled different levels of skill and experience ranging from an inexperienced cyclist wearing a vest with 'Novice Cyclist Pass Slowly' printed on the back to an experienced cyclist with a stereotypical sportive outfit. In addition, two safety vests were used. One of the safety vests resembled a police officer's jacket with 'POLITE PLEASE SLOW DOWN' printed on the back while the other safety vest featured the word 'POLICE' together with a warning that the cyclist was video recording the ride. The only outfit resulting in a significantly larger mean passing distance was the police attire. It can be speculated that the increased overtaking distance for the alleged police cyclist is related to a fear of being fined, though almost 25% of the overtaking manoeuvres were still performed at below one metre of lateral clearance. Ampe et al. (2020) identified increased overtaking distances for cyclists who appeared to transport a child, for example when the bicycle had a child trailer or child's seat (in an urban setting).

Studies focusing on groups of cyclists found that the lateral clearance was lower for cyclists riding in parallel than in single file, but that the overtaking motorised vehicles more often moved over to the oncoming lane (López et al., 2020; Pérez-Zuriaga et al., 2021). Garcia et al. (2020) found that motorised vehicles overtaking cyclist riding in a group (in pairs of two or single file) on two-lane Spanish rural roads had a lower speed than when passing cyclists riding alone. On the other hand, the motorised vehicles, especially trucks, also had a lower lateral distance to cyclists riding two abreast than to cyclists riding single file or alone. "Accelerative" overtaking manoeuvres were more frequent when the cyclists rode two abreast than when they rode in a single file, regardless of the group size (Pérez-Zuriaga et al., 2021).

4.4. Subjective experiences

Questionnaire studies show that close overtaking is named as prominent stress inducer, which even prevents people from cycling (Fernández-Heredia, Monzón, & Jara-Díaz, 2014; Heesch, Garrard, & Sahlqvist, 2011; Heesch, Sahlqvist, & Garrard, 2011). Still, much research focuses on lateral clearance

when motorised vehicles overtake cyclists, while the overtaken cyclists' subjective experiences, needs and preferences gain much less attention. To complicate things further, data is missing from individuals who are not cycling at present, but who might have chosen to cycle if higher levels of safety and comfort were provided. This is probably a substantial number, given that the British National Travel Survey indicates that roughly two thirds of adults indicate that it is "too dangerous to cycle on the roads" (Department for Transport, 2020). Reasons cited for not cycling were, apart from no interest in cycling, "road safety concerns" and "too much traffic/traffic too fast".

Garcia et al. (2020) found that the cyclists' experience of risk when overtaken in real traffic is correlated with the aerodynamic effect created by a combination of distance, speed and size of the overtaking vehicle. Looking at different constellations of cyclists riding individually or in groups, Garcia et al. (2020) and López et al. (2020) established that the risk perception of single cyclists was higher than in groups of two or three for the same overtaking distance. The risk was also perceived as higher for "flying" overtaking manoeuvres as compared to accelerative manoeuvres, and in a group of ten experienced cyclists, the positions on the outer edges were experienced to carry the highest risk, both for riding in parallel lines and in a single file.

4.5. Driver related factors

There is a striking scarcity of studies investigating the driver as a potentially contributing factor to explaining the variance in overtaking related variables with only a few studies investigating this question. This is likely due to the predominant measuring technique of using instrumented bicycles or on-site cameras, which in most cases does not log more than one overtaking manoeuvre per driver nor identifies the driver. A simulator study indicates that drivers with a negative attitude towards cyclists pass significantly faster, but also that people who claim that they identify with being a cyclist and who cycle regularly themselves perform more close passes, but at a lower speed (Goddard, McDonald, Alambeigi, Kim, & Anderson, 2020). People who reported feeling concerned around cyclists generally passed at slightly lower speeds and greater distances than those who did not report such a concern. Generally, the results of the study were complex and not easily interpretable. Using a picture-based questionnaire study, Saxton and Thorp (2021, submitted) also found that a negative attitude towards cyclists, but also not cycling oneself and a higher score on "driving anger", lead to a higher acceptance of close passes. Rasch et al. (2020) found that drivers overtaking a robot cyclist on a test track experienced situations with a short time gap to oncoming traffic and a small lateral distance to the cyclist as "uncomfortable", but this did not prevent all drivers from refraining from overtaking in this situation. Female drivers were more likely to wait behind the cyclist and execute an "accelerative" overtaking manoeuvre. Based on data from a naturalistic driving study, Feng et al. (2018) report that during or before 8% of identified manoeuvres where a cyclist is overtaken, the driver operated a mobile phone. Unfortunately, the driver was not considered as a factor in the paper, even though it would have been possible given the data collection method. This is a research gap that should be addressed, as it may have consequences for potential mitigation strategies. Emotional factors in a broader sense are discussed further in Chapter 7.

4.6. Evaluation of minimum passing distance laws

So far, no scientific before/after comparison of overtaking distances have been made in relation to the adoption of a minimum passing distance law. A simulator study comparing drivers who were aware of the 3 ft-passing law (ca. 0.9 m) in place in the state with drivers who were not, did not find any differences in measured overtaking distance (Herrera, Parr, & Wolshon, 2020). A comparison of American cities with different minimum passing distance laws showed that a 5-ft-law (ca. 1.5 m) led to larger distances than no law or a 3-ft-law, but the effect of a third lane was larger than the effect of the passing law (Feizi et al., 2021). It has also been speculated that a prescribed minimum distance can be interpreted as target distance, which could lead to the undesirable effect that overtaking distances

become smaller, especially when the prescribed distance is small (Lamb et al., 2020; Nehiba, 2018). Feizi et al. (2021) found that 70% of the respondents on a questionnaire did not know whether a minimum passing distance law was in place in their city. An Australian questionnaire study revealed that more than 30% of the respondents claimed not to follow the 1.5 m distance law (Haworth, Heesch, & Schramm, 2018), and the above-mentioned frequency of narrow passings, which are prevalent both in places with and without minimum distance passing laws, indicate that other measures may be required.

Lamb et al. (2020) used videotaped overtaking manoeuvres to obtain risk ratings by participants recruited from the public and enforcement decisions by police officers, which were then compared to different minimum passing distance laws. They found that the subjective judgement by the police officers reflected the participants' opinion more closely. Due to this fact, in combination with other discussed disadvantages of laws prescribing an absolute minimum distance, they favour a so-called "performance-based law" allowing for police officer discretion. Interestingly, in Ireland a law proposal prescribing 1 m for speeds below 50 km/h and 1.5 m for higher speeds was abandoned due to concerns voiced by the Attorney General about enforceability[10].

Given the available research and the fact that drivers find it difficult to estimate absolute distances (Black et al., 2020; Haworth & Schramm, 2014; Schramm, Haworth, Heesch, Watson, & Debnath, 2016) VTI proposed an alternative to passing a law based on absolute values (Kircher, 2021). This alternative uses infrastructural features as guidance for how to overtake, which reflects research results better and is easier to understand and enforce. The concept behind the proposal is to treat bicycles like motorised vehicles, such that they should not be overtaken in the same lane. Implications for narrow lanes and the Swedish type of divided 2+1-roads are considered specifically. It is recommended to evaluate whether this type of regulation is easier to understand and implement, and to conduct before/after evaluations of actual overtaking behaviour, including the subjective experience of cyclists.

4.7. Discussion: Overtaking of cyclists

As presented above, numerous situational factors are associated with the absolute lateral clearance between an overtaking vehicle and a cyclist, and for the most part, the direction of the effect can easily be explained. A rough simplification could be that the (experienced) available space is related to lateral clearance, which could explain that narrower roads, parked cars, the presence of centre rumble strips, larger vehicles and oncoming traffic are correlated with a reduced lateral clearance. However, notwithstanding the recent results from Nolan et al. (2021), we hypothesise that the presence and type of road markings and the cyclist's lateral positioning in relation to them affect overtaking behaviour. We argue further that the absolute lateral clearance is not necessarily the main factor that determines how an overtaking manoeuvre is experienced by the cyclist. Rather, we would speculate that cyclists, with their different needs and preferences, weighs in factors like the availability of space, the speed and size of the overtaking vehicle, and possibly factors like visibility, side wind and predictability, which all contribute to a feeling of how considerate the manoeuvre is experienced to be executed. In a situation like in a protected cycle lane, where cyclists can choose their lateral position with relative certainty that an overtaking vehicle will not enter their space, a smaller lateral clearance may feel equally acceptable or even safer than a somewhat larger lateral clearance, where the cyclist has no control over the choice. As reported above, some first attempts have been made to relate the cyclists' subjective perception of the overtaking manoeuvre to measurable variables, but we claim that variables of more complex type need to be considered, too. Just like for the statistical models of

[10] https://www.irishtimes.com/news/ireland/irish-news/new-law-on-drivers-overtaking-cyclists-abandoned-1.3745451

infrastructure classification, the subjective ratings of "perceived risk" for overtaking manoeuvres was given on a unidimensional linear scale, which effectively prevents a multidimensional assessment.

Related to the difficulties associated with the usage of absolute lateral clearance measures is the problem of absolute distance estimation, both from the driver's and the cyclist's point of view. More systematic studies should be conducted that investigate how accurately drivers can place themselves at a given lateral distance, depending on the surrounding circumstances, and also how consistent cyclists are in estimating the distance with which they were overtaken. As indicated above, it is doubtful that there is a linear relationship between lateral clearance and how comfortable or safe an overtaking manoeuvre is experienced by a cyclist. Factors like the speed, size and shape of the overtaking vehicle play a role for objective safety, and additional factors influence subjective safety. Therefore, the absolute lateral clearance is probably not the best dependent variable when modelling risk or experienced risk.

We would also welcome studies that investigate how much variance in how the overtaking manoeuvre is performed is explained by the driver as a factor – will the same people make close passes time and again, or is the lateral clearance more dependent on situational conditions? Furthermore, drivers' reasoning about their behaviour when overtaking cyclists is an important question. Which factors influence their decision to overtake or not in a given situation, and are these even conscious decisions? How could they be influenced to increase cyclist safety? How do a driver and a cyclist experience the same situation, and are there any discrepancies? All these questions can have implications for potential countermeasures to ensure that the overtaken cyclists' experience will not constitute a barrier to cycle on rural roads.

5. Cycling as a social activity

Cycling abreast is treated differently across countries. As mentioned, current Swedish legislation requires cyclists to keep to the right and ride in single file as a basic rule, where cycling abreast is only allowed if it does not hinder "traffic". In Germany, the law was changed in 2020 to make cycling abreast the basic form but requiring cyclists to use the so-called single file formation to allow overtaking traffic to pass. Keeping to the right is required by law. In the UK, the legislation was recently changed from requiring that cyclists should "never ride more than two abreast, and ride in single file on narrow or busy roads and when riding round bends" (old Highway Code Rule 66). The new text aims at strengthening the cyclists' position and reads: "[cyclists' should] ride in single file when drivers wish to overtake and it is safe to let them do so. When riding in larger groups on narrow lanes, it is sometimes safer to ride two abreast"[11]. There is no specific law on keeping to the left kerb (in left-hand traffic). Instead, the position in the middle of the lane is called the "primary position" whereas a position further to the edge is named the "secondary position". The updated Rule 72 focuses on safe road positioning and recommends for cyclists to ride in the centre of their lane in several situations where this positioning is seen to increase safety. In other European countries the phrasing varies, generally requiring that either cyclists specifically or road users in general keep to the right, and none of them are allowed to ride abreast outside of built-up areas (Italy) to viewing cycling two abreast as fully acceptable (The Netherlands). In the US, six states do not have laws requiring cyclists to keep to the right[12]. Riding abreast is not restricted at all in six states, riding two abreast is allowed in most states, for around half of those with the addition that traffic should not be impeded (which implies more than a delay). In two states single file riding is required at all times (ibid.).

Independent of skill and experience, cycling is seen by many as a social undertaking constituting a chance to share the experience with others (McIlvenny, 2015). Cycling abreast gives the cyclists a better opportunity to talk to each other at the same time as it offers a possibility for experienced cyclists (i.e., adults) to form a barrier between inexperienced cyclists (i.e., children) and passing traffic. In a broader sense, cyclists also interact with other road users and with their environment to a larger extent than motorists, which leads to a tighter connection with their surroundings (te Brömmelstroet, Nikolaeva, Glaser, Nicolaisen, & Chan, 2017). Aldred (2015) describes the conflict experienced by cyclists as wanting to socialise and chat while cycling, while at the same time feeling that cycling abreast is not appropriate for the reason of being "in the way" for motorists. So, what would be a social experience for cyclists is at the same time perceived as anti-social behaviour towards others.

In addition to direct social aspects, cyclists riding in a peloton also experience much less wind resistance than individual cyclists (Blocken et al., 2018), which creates a sense of community and helping each other out in addition to performance benefits.

5.1. Discussion: Cycling as a social activity

Most motorised vehicles are built such that they can carry several passengers at a time, usually allowing at least two people to sit side by side. Their common space is often well isolated from surrounding noise, making communication simple. Thus, the conceptualisation of motorised vehicles as capable of carrying several people together acknowledges the fact that humans are social beings who want to communicate with each other. The potential of socialising in a vehicle even takes precedence over being frugal with occupied space, even though average car occupancy rates usually are well below two (Politis et al., 2021). Similarly, for group rides, cycling holidays in groups of

[11] 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

[12] https://iamtraffic.org/advocacy-focus-areas/equality/u-s-bicycle-laws-by-state/

several people, but also during shorter trips, for example when children ride to school together in a rural area, the social component is an important aspect of undertaking the ride together. Still, research on the topic is very limited, and it is a general perception that each bicycle, also in a group, should be seen as an individual vehicle. One exception is the German traffic rule (StVO §27) stating that more than 15 cyclists who ride together in a group can form a convoy, where the group is then treated as a single vehicle. This has several implications, for example that the convoy should not be split in the sense that if the first riders have passed a traffic light or an intersection where other traffic has priority, all following riders in the group can pass, too, even though the traffic light might turn red or traffic with priority may appear in the meanwhile. This can prevent confusion both within the group and for other road users.

Future research on cycling in rural areas should include the social aspects of cycling and how current regulations are compatible with them. It should also be investigated whether an implementation of a convoy regulation already for smaller groups could be beneficial for group riding with respect to comfort, pleasantness, and safety and how other road users would interpret such a rule and adapt their behaviour.

6. Swedish infrastructure solutions

While not completely exclusive for the country, Sweden has implemented a few infrastructure designs that are not used widely elsewhere. Here, we provide a short description and discussion of those that affect cycling in rural areas.

6.1. 2-1-roads

To facilitate for cyclists and pedestrians, so-called 2-1-roads (see Figure 4) have recently been introduced to the Swedish transport system. These roads consist of a carriageway for motorised vehicles in the middle with wide road shoulders on both sides where cyclists and pedestrians can travel. These road shoulders may also be used by motorised vehicles, which is necessary as the carriageway in the middle is too narrow for the motorised vehicles to meet. Using the road shoulders may, however, only be done under consideration of any unprotected road users who travel there. The road design is most common in urban areas but has also been tried on local rural roads with limited traffic. An interview study (Patten, Wallén Warner, & Sörensen, 2017) with 19 respondents showed that the introduction of 2-1-roads on some stretches of local rural roads in the southern part of Sweden resulted in a reduced perception of safety and a reduced sense of security. In addition, the participants felt that the behaviour of the car drivers became more difficult to predict. This was confirmed by drivers' responses, with about a third of the respondents stating that they often drove with the whole car in the middle of the carriageway except when they met other cars while about as many drivers said they often drove with the car straddling the dashed line even when there was no on-coming traffic.

Figure 4. A 2-1-road in the southern part of Sweden. Photo: Svante Berg, Movea.

A follow up interview study (Wallén Warner & Patten, 2017) showed that many of the participants liked the idea of 2-1-roads as it gave them, as cyclists, a clear right to exist on the road. At the same time, they felt that the design created a false sense of security due to the car drivers' increased unpredictability. The introduction of 2-1-roads did not result in substantially lower speeds, but the average distance between cyclists and passing cars decreased, which could constitute an increased risk of incidents and collisions (van der Meulen & Berg, 2018). Wallén Warner and Patten (2017) found that a slight majority of the participants preferred the 2-1-design over rural roads with mixed traffic. Many did, however, point out that a cycling and walking path fully separated from motorised traffic

was the best solution. Erke and Sørensen (2008) conducted an overview of the Swedish 2-1-design together with similar infrastructure solutions in Denmark, the Netherlands, the UK and four other countries with less similar designs. The results showed that the speeds did not decrease as much as expected, the overtaking motorised vehicles kept smaller distances to the cyclists and there was confusion among road users as to what rules apply. This is in line with the Swedish results presented above.

6.2. Divided 2+1-roads

As a low-cost alternative to decrease the number of head-on collisions, so-called divided 2+1-roads (see Figure 5) were introduced to the Swedish transport system in the mid-90s. This type of road is typically a re-designed 13 metres wide rural road, which previously consisted of one lane in each direction with a wide road shoulder. The new layout consists of three lanes, where the centre lane alternates direction every few kilometres. The driving directions are usually divided by a steel cable barrier. There is no road shoulder, and the lanes are slightly narrower than on other roads with the same posted speed limit. There can be a steel cable barrier on the outer sides of the road. By the year 2018 more than 3000 km of divided 2+1-roads had been build in Sweden[13] (Forsman, Vadeby, Bjørnskau, & Larsson, 2020). While some other countries implemented the road type in some locations, it is not very widely spread, especially not outside Europe.

Figure 5. A divided 2+1-road divided by a central steel cable barrier and a small rural road running in parallel. Photo: Katja Kircher, VTI.

There is no general rule denying non-motorised travellers access to this type of road, likely because in many cases there is no acceptable alternative routing. When the divided 2+1-roads are constructed, it is normally not considered economically efficient to build separate cycle paths as cycling, in most cases, is permitted. Given the narrow lanes with physical barriers and the high speeds (the posted speed limit is commonly 100 km/h), cyclists tend to avoid these roads (Liljehov, Sandberg, & Singh, 2021). As described above in Chapter 3.1, this creates functional barriers for cycling, not only

[13] Map showing motorways, expressways and divided 2+1-roads in Sweden: https://www.trafikverket.se/contentassets/7fb4b042b7224f82850e3ae2c78e0f52/motesfriavagar20211201.pdf

preventing cyclists from using the road, but also from crossing it. Not much research is available that investigates the effects of this road design on cycling, except for documents evaluating the road layout and coming to the conclusion that it is a dangerous environment for cycling (e. g. Kirby, Wilmshurst, & Koorey, 2014). It is desirable and important to investigate divided 2+1-roads from a cyclist perspective, considering the national strategy to increase cycling, and the fact that data on cycling activity and potential cycling activity especially in rural areas is very scarce.

6.3. Summer cycle paths

As the functional barriers for cycling increased, not least with the increasing number of divided 2+1-roads, so-called "summer cycle paths" (see Figure 6) were introduced as a potentially viable solution (Hedström, 2008). These paths are normally not paved, illumination is not provided, and maintenance is very limited with a complete lack of winter maintenance. The recommended width is 2 meters, and the alignment should be adapted to the existing landscape (Berg, 2019), which can lead to additional inclines compared to the main road. In most cases, cyclists have a positive experience of summer cycle paths, even though they think that the maintenance is insufficient and neglected.

Figure 6. A summer cycle path in Sweden. Photo: Svante Berg, Movea.

6.4. Discussion: Swedish infrastructure solutions

While the Swedish divided 2+1-roads constitute a functional barrier for cycling, 2-1-roads and summer cycle paths are two recent infrastructure solutions intended to facilitate for cyclists and pedestrians. While 2-1-roads consist of a narrow carriageway for motorised vehicles in the middle with wide road shoulders for cyclists and pedestrians, summer cycle paths are basic separate paths for mainly cyclists and pedestrians. Even if the aim of these infrastructure solutions is to facilitate for cyclists, they still constitute a barrier for many cyclists due to the reduced perception of safety and sense of security (2-1-roads) and deficient surface and maintenance (summer cycle paths), which only

makes them accessible for a subset of bicycle types and in many cases not year-round. Today, infrastructure decisions are often based on the number of cyclists (Trafikverket, 2022) but to increase safe cycling this is not enough. Instead, it is important to investigate which types of infrastructure are needed to create a well-connected network for various types of cyclists and trips year-round. This includes involving cyclists as well people who do not cycle but would like to and considering their opinions and needs.

7. The emotional experience of “sharing” the road

Recent years have witnessed a growing interest in non-motorised modes of transport, due in large part to concerns about the negative side effects of car usage but also societal benefits, such as increased health, social inclusion and accessibility (e. g. Oja et al., 2011; Tainio et al., 2016). However, cyclists on rural roads often find themselves in situations where they occupy the same space as motorised traffic, which is often referred to as “sharing the road”, even though it does not occur on equal terms. This can be stressful, inducing a negative experience which can become a main barrier preventing a more widescale use of the bicycle as a mode of transport (e. g. Heesch, Sahlqvist, et al., 2011; Joshi, Senior, & Smith, 2001; O'Connor & Brown, 2010; Rissel, Campbell, Ashley, & Jackson, 2002). It could therefore be argued that a greater understanding of factors that trigger emotional stress and how this is dealt with are very important to support a more pleasant interaction between cyclists and drivers.

Also in this field, most research has been conducted on cyclists in urban areas, but many of the findings can be transferred to cycling in a rural environment. For instance, motorised vehicles overtaking cyclists, which has already been discussed above, is the most frequent reported cause of stress, fear and anger reported by cyclists (Bjørnskau, Sørensen, & Amundsen, 2012; Fyhri, Bjørnskau, & Sørensen, 2012; Heesch, Sahlqvist, et al., 2011; O’Connor & Brown, 2010; Sørensen & Mosslemi, 2009; Walker et al., 2014). Analysing the intensity of anger, Huemer, Oehl, and Brandenburg (2018) asked cyclists to rate 208 unique anger events. The results showed that the interaction with cars led to the highest cycling anger intensity ratings. Similar results were also presented by O'Hern, Stephens, Young, and Koppel (2019). They discovered that the interaction with car drivers was much more anger provoking than interaction with pedestrians and other cyclists. To understand this, we need to look at what trigger anger and how it is expressed.

7.1. Stressful encounters and the link between anger and aggression

First, when a person is exposed to a threat (real or imaginary) a fight, flight or freeze response is triggered. This is an involuntary physiological response to danger activating several physiological functions. These functions help the person to react quickly to the threatening situation (for example, increased heart- and respiratory rate)[14] which in turn mobilises the person to act in one way or another. Basically, it is designed to help us to survive stressful and life-threating situations. When the signal reaches the brain, a secondary psychological response becomes activated. That is when the person tries to understand the meaning of the perceived threat. For instance, is the threat dangerous, is it likely to inflict pain? Fyhri et al. (2012) found that car drivers who perceived that the cyclists behaved in an aggressive way towards themselves were more likely to display agression than others. Similar results was presented by Huemer et al. (2018), although this time it was about cyclists who perceived the driver to act in a careless way.

When a cyclist is involved in a near collision with a motor vehicle the most likely first response is of fear and if the situation is interpreted as an intended attack, then the same reaction might turn into anger. Indeed, Golden (2021) among others has found that feelings of fear are closely related to anger, both can arise when we perceive a threat to our safety.

The assessment of the situation is usually based on previous experiences of the same or similar situations. Cyclists who, more often than others, have been subject to a behaviour which was perceived as aggressive also behaved more aggressively towards the car driver (Fyhri et al., 2012).This also explain why the reaction can be violent in some situation, whereas in others no sign of any outward reaction at all.

[14] See https://www.simplypsychology.org/fight-flight-freeze-fawn.html.

Thus, anger may or may not be linked to aggression and it is therefore important to differentiate between angry feelings and how and if that anger is expressed (Moscoso & Spielberger, 2011). Anger can be defined as an emotional state or as Lakoff (1987) describes it: "Anger is the heat of liquid in a container". It can vary in frequency, intensity and duration and can be experienced as anything from mild irritation to intense fury and rage (Kassinove & Sukhodolsky, 1995). Therefore, if anger is an emotional state, then aggression can be described as its response, immediate or planned, intending to harm, hurt or injure another person or object (Berkowitz & Harmon-Jones, 2004).

As discussed above "sharing" the road with other road users can generate anger and, in some circumstances, also result in acts of aggression (Høye, Fyhri, & Bjørnskau, 2016). From a car driver´s perspective sharing the road with cyclists can generate anger if they regard the cyclist as a hindrance and an obstacle on the road (Fyhri et al., 2012; Huemer et al., 2018). Aggressive behaviours by both drivers and cyclists can therefore be explained by a form of 'retaliation' (Wickens, Wiesenthal, Hall, & Roseborough, 2013).

The likelihood that anger shall translate into an act of aggression also depends on the perceived outcome of the attack. If the person believes that it will results in something which will be of benefit to themselves then they are more likely to attack, than if they believe that they will be punished. For instance, regaining control over a situation, or simply getting an outlet of negative emotions can be seen as beneficial. On the other hand, aggressive behaviour does not always include some physical component, it can also be expressed verbally, for instance shouting and swearing. Another form of aggression has also been described, which is not linked to anger, that is instrumental aggression (Kassinove & Sukhodolsky, 1995). This can be described as proactive, rather than reactive, involving some degree of planning to achieve a goal and can be carried out in a cold and calculating manner (Stangor, Jhangiani, & Hammond, 2014).

When trying to understand the expression of anger it is important to point out the many ways which separate cyclists from car drivers. A cyclist is more vulnerable and therefore at risk of being injured in a collision is much greater. It can therefore be argued that a cyclist has more to fear from an aggressive encounter than the car driver (Marín Puchades et al., 2017). This is also supported by McGarva and Steiner (2000), who found that cyclists expressed less anger due to their perceived vulnerability. Furthermore, since a cyclist is more exposed and not as anonymous as the car driver this can, according to Ellison-Potter, Bell, and Deffenbacher (2001), also explain a lower level of anger expression among cyclists than drivers.

7.2. Coping strategies

According to Kaplan and Prato (2016) the coping strategies of drivers could be divided into three main courses of action. The first one was confrontational including getting into a vocal or physical argument with the cyclist. The second course of action was described as a problem-solving strategy related to feelings of fear. This was less frequently mentioned and could result in the driver trying to maintain a safe distance from the cyclist when overtaking. The third course of action was not as usual as the other two. It meant that the driver was seeking some form of social support, for instance, to call the police and ask them to intervene if they felt that the cyclist acted in an unsafe way.

Although the coping strategies of cyclists also consisted of three main courses of action, they were rather different from the drivers. The first one was described as an avoidance strategy with feelings of fear. This meant that the cyclist stopped using the bicycle altogether or stayed away from some roads to avoid, as they described it, being 'bullied' by drivers. The second strategy was confrontational when the cyclists tried to reclaim the road. However, this was not a very common strategy (Kaplan & Prato, 2016). Instead, the anger experienced by the cyclist could be directed towards another road user who does not elicit the same fear of retaliation (Marín Puchades et al., 2017). According to the same authors this can be seen as a consequence of a large power imbalance between cyclists and car drivers and has been described as 'displaced aggression'. The third course of action was closely linked to the

cyclists' own behaviour. This meant that they accepted their own responsibility and tried to increase their own safety. For instance, using the cycle path but it could also be related to using front and rear lights and a bicycle helmet.

It can therefore be concluded that the most important coping strategy by drivers was confrontation whereas for cyclists it was avoidance. This can also explain why cyclists have experienced more aggression from drivers than the other way around. In a study with the members of a cyclist federation (SLF) the results showed that as many as 70 percent of the cyclists had experienced that car drivers have been driving in an aggressive and threatening manner (Fyhri et al., 2012). Similar results were also presented by Heesch, Sahlqvist, et al. (2011) who found that 63 percent of the cyclists had been verbally abused by car drivers. Cyclists who bike for training appear to be more likely to be exposed to harassment than others (Fyhri et al., 2012; Heesch, Sahlqvist, et al., 2011).

The power imbalance between cyclists and drivers is not only a reflection of the cyclist's greater vulnerability but also, according to Prati, Marín Puchades, and Pietrantoni (2017) of the social climate. According to them cyclists in a car-oriented culture are regarded as "second class" road user who has not got the same right to the road space as the car driver. This is also in line with an Australian study which showed that 50 percent of car drivers argued that cyclists should not be allowed to ride on main roads (Heesch, Sahlqvist, et al., 2011), and a study indicating that cyclists tend to be dehumanised (Delbosc, Naznin, Haslam, & Haworth, 2019). This would then produce mutual stress which could be translated into anger and fear and sometimes lead to aggressive behaviour and an unwillingness to share the road (Kaplan, Luria, & Prato, 2019; Kaplan & Prato, 2016; Møller & Haustein, 2017). Others have described this as a "territorial conflict" (Huemer et al., 2018).

7.3. Expression of anger and its links to risk-taking

Studies have found that drivers' expression of anger has been related to violations (e. g. Precht, Keinath, & Krems, 2017; Sarma, Carey, Kervick, & Bimpeh, 2013) and crash involvement (Nesbit, Conger, & Conger, 2007). The same relationship has also been found among cyclists, although this is less well researched (Møller & Haustein, 2017).

According to the appraisal-tendency framework (Lerner & Keltner, 2000, 2001), anger leads individuals to perceive less risk and to make risk-seeking choices (Marín Puchades et al., 2017). The likelihood of adopting a risky behaviour is also greater if they feel that they have more control over the situation and therefore feel more able to avoid a crash (Chaurand & Delhomme, 2013). This would also be in agreement with Delhomme, Verlhiac, and Martha (2009) who found that both car drivers and cyclists perceived less risk when they were the person breaking the law, not because of a mistake but because they believed that they had more control over the situation.

7.4. How to encourage a more peaceful interaction between drivers and cyclists

Evidence exists that drivers who also cycle exhibit more considerate behaviour towards cyclists. An Australian survey with almost 2000 drivers compared responses from people who also cycle (cyclist-drivers) to those from people who do not cycle (drivers). The cyclist-drivers reported safer driving behaviour, were somewhat more aware of rules related to cycling infrastructure and had a more positive attitude towards cyclists than drivers (Johnson, Oxley, Newstead, & Charlton, 2014). According to Nixon (2014) car drivers who also used other forms of transport expressed more empathy for other road users. This has also been supported by a study which found that cyclist-drivers regarded the shared road environment more positively and therefore were more willing to share (Kaplan, Mikolasek, Bruhova Foltynova, Janstrup, & Prato, 2019).

Campaigns have been used to encourage greater cooperation on common roads. A campaign called "Share the road" was launched in Norway. The results from the evaluation showed that the behaviour

of both cyclists and drivers improved. Cyclists also reported fewer close overtaking from cars and a decrease in the number of car drivers who drove in a reckless manner (Høye et al., 2016).

7.5. Discussion: The emotional experience of “sharing” the road

“Sharing” the road can create a great deal of stress and anger amongst both car drivers and cyclists, with the cyclists clearly having less power. From a cyclist´s perspective a stressful encounter can become a key barrier to cycling. To encourage a more pleasant interaction between cyclists and drivers it is important to understand what triggers emotional stress and what can be done to reduce it.

In this chapter literature from both urban and rural areas was used, since only very few studies have focused on rural areas. However, an event which triggers aggression in an urban setting can also occur in rural areas, although perhaps with a different frequency. If it occurs in rural areas the consequences could be more severe considering the higher speed of motorised vehicles. When discussing aggressive behaviour, it is important to differentiate between anger and aggression. Both cyclists and drivers can feel anger without expressing it verbally or physically. It is also possible to behave in an aggressive way without being angry. If the person will act on his/her feelings depends very much on how the situation is interpreted, who is to blame and if the person has the resources needed to take up a “fight”.

When looking at coping strategies it is therefore not surprising that car drivers are more willing to express their feelings since the car provides some protection and anonymity, putting drivers less at risk and making them less restrained. Cyclists are more exposed and therefore more at risk if they are getting involved in an encounter with a driver. This can also explain why the most important coping strategy for drivers are confrontational and for cyclists’ avoidance-related, which can be linked to their greater vulnerability but also less power and status.

It could therefore be argued that a car not only provides the driver with power but also status (Steg, 2005) and drivers could become provoked by cyclists if they view the road as a space for cars. In this case the cyclist can be perceived as an intruder who blocks the driver’s movement. Indeed, if the other person is to blame, then the experience is more likely to generate frustration and anger than if not. Therefore, the perception of others helps us to understand why the same event can trigger anger in one person but not in another. The perception of responsibility does not necessarily rest on facts. It is quite likely that one road user (cyclist or car driver) perceives that the other is at fault even if that is not the case.

Control over the situation has also been found to explain the expression of anger since it can be linked to the consequences of the act. If the person feels that he/she has something to gain from an expression of anger, then chances are greater that anger is expressed than if it is believed to result in some form of loss. Loss does not necessarily mean injury; it could also be loss of control and self-esteem.

It could therefore be argued that car drivers and cyclists need to start to interact in a more considerate way. One way to increase car drivers’ understanding of cyclists is to encourage them to also use a bicycle. Another important aspect is to start regarding cyclists as a legitimate road users (Heesch, Sahlqvist, et al., 2011) who have the same rights as car drivers to use the road. This could create an atmosphere of cooperation rather than power struggle and territorial conflicts:

> “// the importance of creating an inclusive road social climate that makes mixed traffic more acceptable. Accordingly, policy measures should aim at not only providing bicycle facilities and infrastructure, but also creating a positive social climate where drivers and cyclists accept to be integral parts of the same ecosystem and develop positive self-concepts and emotions for the whole experience” (Kaplan, Luria, et al., 2019, p. 56).

8. General discussion

Cycling is marginalised in the prevailing discourse on transport and mobility (see e. g. Aldred, 2015; Fevyer & Aldred, 2022; Koglin, 2020; Whitelegg, 2020). Being structurally disadvantaged in a systematic fashion creates a vicious circle where both planners and users of the system accept this as a matter of fact. As a consequence, the marginalised user group will not make demands for the better, and if demands are made, they are not always implemented.

Given the pronounced declaration that cycling shall increase and be safe, structural issues that disadvantage and marginalise cycling as a means of transportation in relation to motorised traffic must be identified and addressed. The nature of these structural issues varies and ranges from public financing over regulations to the provision of facilities, to generation of knowledge and generally accepted "truths", like the focus on speed as a means to "save time" (see e. g. van der Meulen & Mukhtar-Landgren, 2021). Also, the language used in the public domain when reporting on and discussing cycling in relation to car driving is biased (Fevyer & Aldred, 2022; Goddard, Ralph, Thigpen, & Iacobucci, 2019; Ralph & Girardeau, 2020). Here, we briefly touch upon some of these issues as examples of levers that can be used in the toolbox for increased safe cycling, especially in rural areas.

An increased share of trips on bicycles requires larger investments in infrastructure catering to cyclists, and in cycling as mode of transportation in general. On the other hand, it has been shown that cycling and walking are profitable for the society, while car driving incurs costs (Gössling, Choi, Dekker, & Metzler, 2019; Gössling, Kees, & Litman, 2022), such that an increased share of active mobility can be expected to repay its initial costs. To achieve maximum benefit from the invested funding, existing knowledge needs to be exploited and knowledge gaps need to be identified and filled. This includes questioning current regulations and customs. There is a risk that implementing suboptimal solutions for cyclists can be worse than not implementing anything at all. A solution that is not perceived as safe, that is perceived as cumbersome, or a path of poor quality is not used. This can lead to additional conflicts between cyclists still using the road and drivers of motorised vehicles who do not understand why the cyclists do not use the dedicated path. It can also lead to inertia on the side of the administration, arguing that investments for cycling have already been made, but to no avail.

The goal of increased cycling cannot only mean that those people who already cycle should cycle more, but also that more people take up cycling. It is important to understand that a change of habits and behaviours can take time, such that implemented measures may not see immediate consequences. There is evidence that people tend to take up (or stop) cycling in connection to "life events", and that this change is facilitated by a suitable environment (Chatterjee, Sherwin, & Jain, 2013). Hence, offering an environment conducive to cycling is necessary, but it may not be sufficient in itself to generate change. Here, additional measures may be needed. Larsen (2018) found that colleagues could inspire others to take up long-distance commuting by bicycle and Pucher, Dill, and Handy (2010) stress the importance of public policy in combination with physical interventions. In urban areas, the scarceness and pricing of parking or increasing congestion may be arguments enough to make people take up cycling, simply because it is more efficient and cheaper. In rural areas these factors are less likely to be critical, and in combination with the often greater distances that can be covered faster by motorised vehicles, the bicycle is rarely an efficient competitor. If not forced financially, a genuine interest in cycling as a mode of transport or for other reasons such as training, environmental factors, the image, or simply for its own sake, is needed. Thus, a shift to cycling is complicated by the fact that people who do not yet cycle, but could imagine doing so, tend to have higher demands on the surrounding situation than people have who already cycle (Winters & Teschke, 2010). Thus, it does not suffice to extend what we already have to more places, but we also need to improve what we have.

The aforementioned acceptance of a detour of 25 percent, compared with the shortest route for connectivity indicates that a cyclist's time is valued less than a car driver's time. With cycling already

being inherently slower, but with all the health and environmental advantages over motorised traffic, it can be argued that no detours compared to the closest path for motorised traffic should be acceptable, such that rerouting of motorised traffic would become the accepted norm. Also, when planning for cycling, instead of applying the same benchmarks as for motorised traffic, which include putting saved travel time central stage, a valuation procedure appropriate for the mode of travel should be used.

Reliability and foreseeability are important factors when planning a trip, therefore uncertainty can be perceived as a barrier. This can apply to issues like not knowing whether the bicycle can be brought on the train or not or whether the summer cycle path is in a rideable condition or not.

Separation of road user groups, at least into motorised and non-motorised traffic/micro-mobility, seems to be a widely accepted strategy when aiming for increased traffic safety. The idea is to prevent collisions with high relative speeds where the mass and physical protection of the involved road users differ substantially. In urban areas, the many intersections make full separation a challenge. Also, it is not self-evident how to separate different road user groups. Already today there are conflicts between cyclists and pedestrians who are often required to share the same infrastructure in spite of their differences. Recently, e-scooters were added to the mix, and chances are that the micromobility sector will diversify more, which is bound to lead to efficiency issues and conflicts within and between groups. In rural areas, a fully separated infrastructure would be easier to provide technically, as more space is available. However, full separation would require huge investments in infrastructure, emission of greenhouse gases and an intrusion into natural resources, which can be difficult to justify especially in areas with low traffic density.

In practice, the separation approach often leads to well-connected and well-maintained infrastructure for motorised traffic, while the remaining traffic often is disadvantaged in several respects, for example regarding connectivity, efficiency, maintenance, and available space. Therefore, a different approach, with the goal of a mixed traffic situation that caters to all road users equally, can be worth considering. In line with the sustainability goals, this would mean that the needs connected to active travel must be identified, prioritised, and implemented. If it becomes a matter of course for drivers of motorised vehicles to expect and accept non-motorised traffic on most roads and if we see an end of the present trend of increasing road rage and aggression towards active road users, connectivity and accessibility could be increased markedly for many groups of road users without the need to build new infrastructure. To achieve this, a combination of regulations, education, information, and technological solutions is likely to be required.

A larger share of cyclists and other active travellers on the roads has been shown to decrease the risk to which each individual is exposed to, as per the safety-in-numbers effect (Aldred, Goel, Woodcock, & Goodman, 2019; Elvik & Goel, 2019; Jacobsen, 2003). It is important to emphasise, however, that the safety-in-numbers effect is not enough if no additional measures are being implemented. Removing threats and barriers to active travellers could also aid in normalising active travel, increasing its status, making it more visible, and thereby attracting more people to sustainable mobility.

Not only most of the infrastructure is built to mainly meet motorists' needs but current rules, regulations and assumptions are often a consequence of optimised system efficiency for motorists rather than oriented at cyclists' needs. To name a few examples, the regulation prevailing in most countries that cyclists must take a lateral position on the right edge of the road (in right-hand traffic) is the result of the notion that this provides motorists with an easy opportunity to overtake cyclists without losing momentum and time. However, for cyclists this means having to ride where most debris accumulates and where the road surface quality often is worse. It also means that cyclists are less visible to traffic approaching from behind, and where they easily end up in a position where they are crowded by motorists overtaking too closely. Valuing the potential efficiency of motorised travel higher than the safety of cyclists, and for that matter, valuing cycling with transport models built for motorised traffic, is a structural disadvantage (Freudendal-Pedersen, Kesselring, & Servou, 2019; van

der Meulen & Mukhtar-Landgren, 2021). The underlying theme can be found in many other aspects of how cycling as a means of transport, is treated compared to motorised traffic.

8.1. Knowledge gaps

Compared to the body of research on cycling in urban areas, there are larger knowledge gaps regarding cycling in rural areas, and especially for the specific situation in Sweden. Given the particular Swedish infrastructure features, the climate and the low population density, we cannot assume that results from other countries automatically apply to Sweden.

Little is known about who cycles, where people cycle and the purpose of cycling trips. Even less is known about who would like to cycle, but does not, because one's needs are not met. We do not know whether certain roads are used voluntarily or because there is no feasible alternative, and how many more cyclists would use the road if conditions were different. From research conducted abroad we know that cyclists refrain from cycling in rural areas because of stressful encounters with motorists but we do not know how prevalent this is in Sweden. The whole picture is probably complex and can include psychological and practical aspects both on the strategical and the tactical level. The social norm regarding cycling is also important. To perceive cycling as low status can prevent people from even considering cycling in the first place (Daley & Rissel, 2011; Sarrica, Alecci, Passafaro, Rimano, & Mazzara, 2019). For this group, improved cycling conditions would not help without changing the image of cycling itself. People who do not cycle in rural areas, because they do not perceive their environment as conducive to cycling are likely to be more responsive to interventions that remove more tangible barriers. People who already cycle but refrain from cycling under certain circumstances or avoid certain areas may benefit from additional sets of measures to increase their cycling.

Furthermore, we found almost no literature at all with a specific focus on cycling in small settlements or villages in an urban area. Map-based services indicating connectivity, like the mentioned Roadfinder, suggest that in many cases cycling will not be perceived as a viable solution, even though distances to service points of different kinds often are not large. Research into improved connectivity within rural settlements could aid in promoting the bicycle as a solution for utilitarian cycling in those areas.

A large-scale, representative investigation of actual and desired cycling behaviour could shed light on these questions, providing important input to analyses of the cycling potential on our roads and which modifications might be needed to increase the potential and its status (see also Misra et al., 2015; Winters & Teschke, 2010). With the goal of increased cycling in mind, it is especially important not only to consider the trips that are already made today, but also those that would be made given the right preconditions.

Another often overlooked issue regarding cycling in rural areas is the complexity of planning a route. A driver of a motorised vehicle can basically just follow the route that is provided by any navigation application, which today exist in abundance for every smartphone. This does not apply to route planning for cycling. While several routing applications exist, their reliability differs between countries, and cyclists still need to make sure that their specific needs are catered to. When on the road, cyclists need to make sure that they have their routing aid available and charged, as road signs usually do not provide information for cyclists but are mainly catering to motorised traffic that is directed to major roads. For increased cycling, reliable routing which can be adapted to individual cyclist's needs should be readily available and user friendly. Filling the research gaps indicated above on cyclist types, trip purposes and other needs and preferences is a precondition for developing functional and informative routing aids. In addition to this, it can be considered whether physical road signage can be updated and adapted to cyclist needs, such that the same service is provided to active road users as to motorists.

A related topic is a lack of research on innovative solutions for the removal of barriers in the rural network. Regulations and technological solutions could be implemented in addition to modifications and extending the infrastructure. As an example, the potential of temporary speed limits when cyclists are present could be investigated for their acceptance and feasibility.

Most research dealing with cycling on rural roads is based on individual cyclists, either when riding alone, or considering their individual perceptions of interactions with other road user types. However, cycling in groups is not uncommon on rural roads, either in strict formations, like when riding in a peloton, or more loosely, when on tour with friends or family. Compared to cycling alone, the dynamics of a group are different, and the social interaction within the group is relevant for how the group behaves. This is also important given that other road users are likely to perceive a group of cyclists differently from how they perceive a single cyclist.

"Sharing" the road can many times be stressful for cyclists but also for drivers. Although the number of studies exploring emotional factors are growing, it tends to be an overlooked subject, and we could not find any published studies from Sweden. Therefore, several issues need to be explored. One important point is increasing our understanding of drivers' attitudes towards cyclists and when a negative attitude is translated into aggressive behaviour. Another is if perceived norms shape driver' of motorised vehicles behaviour towards cyclists. We also need to evaluate studies aimed at behavioural change. One example could be campaigns which encourage greater cooperation on common roads. Campaigns can also be used in combination with infrastructure measures and rule changes, creating a positive image of cyclists and increasing their status. This can be augmented with awareness training for politicians and the media in what language is used when talking about cycling.

8.2. Limitations and reflections

While our ambition was to review a broad range of topics concerning cycling in rural areas, we do not claim that the coverage is exhaustive, as we may have missed relevant literature. We decided to exclude cycling in bike parks or on dedicated trails. We also excluded sports cycling in the form of organised events, for competition or as sportives, and we excluded research on the potential of cycle sport events as incentive for increasing active mobility in everyday life, but we would like to point out that this is an area worth considering for the promotion of cycling (see e. g. Bursa & Mailer, 2021),.

Generally, the body of available research is much larger for cycling in urban areas, and it appears that cycling is mainly only viewed as a realistic alternative to motorised transport for short trips up to around 5 km in length, with longer trips mainly seen as either not feasible or as "unnecessary" leisure or sports cycling. Therefore, cycling in rural areas does not receive the same attention and status as cycling in urban areas. This can be a factor preventing a larger public interest in increasing knowledge about the peculiarities and diverseness of rural cycling, such that it remains largely marginalised and under the radar. It is also worth pointing out the need for making multimodal trips easier. A bicycle could then form one part of the trip and be combined with public transport.

As pointed out above, the differences between urban and rural areas entail that result from urban cycling cannot unreservedly be transferred to rural circumstances, and we have already named a number of areas where further research efforts could bring more clarity. The mentioned knowledge gaps should, however, not be taken as excuse to remain passive. There is enough accumulated knowledge, not least on the policy and societal discourse level, to start implementing measures that have the potential to increase cycling also in rural areas, while at the same time initiating additional research in areas that need to be developed and investigated further. What is currently missing is a political commitment to take decisive and rigorous action for a step-change in mobility and transportation strategies, promoting and supporting cycling as one representative of sustainable travel throughout the country while at the same time cutting back on unsustainable travel.

Concretely, we suggest launching large-scale pilot projects where combinations of measures are implemented and evaluated over time. Ideally, several measures are combined at such sites in conjunction with a clear communication strategy. The pilot projects should be large and long enough to have a potential to lead to a change in public perception and "culture of mobility". It is important to not only measure the effect of a first encounter with a change, but to monitor if behaviours and attitudes change over time when the users get used to the new implementation.

9. Conclusion

The prevailing transport system creates a power imbalance where cycling as a means of transport is marginalised in relation to motorised traffic. This power imbalance reflects the cyclist's greater vulnerability relative to drivers of motorised vehicles, but also to the construction of the transport infrastructure, current rules and regulations, and the social climate. As shown, cyclists in a car-oriented culture are regarded as "second class" road users who do not have the same rights to the road space as drivers of motorised vehicles. In addition to having to deal with physical barriers, cyclists' experience of "sharing" the road with other road users can be very stressful and become a psychological barrier preventing a more widescale use of the bicycle as a means of transportation.

Despite the knowledge gaps identified above, the available knowledge is sufficient for taking immediate action to increase cycling in a safe way at a national level including rural areas. To succeed, it is certainly not enough with 'quick fixes' in random spots. Instead, a system perspective must be taken with the goal of a future traffic scenario that caters to all road users, considering and incorporating everybody's special needs, where sustainable travel is systematically prioritised. This requires a remaking from the beginning, with changed priorities, policies, societal norms, and attitudes, based on a road user hierarchy, which consistently puts the needs of the most sustainable and relatively most vulnerable road users highest.

In this remaking, it is important to remember that cyclists are a heterogenous group, including different ages and constellations, with different purposes and levels of skill, education, and competence. The needs and preferences of all these cyclists, as well as of those who have not yet chosen the bicycle, must be taken into consideration. These are the preconditions for increased and safe cycling, and for creating a sustainable transport system which promotes safe and healthy travelling for all road users on equal terms.

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The Swedish National Road and Transport Research Institute (VTI), is an independent and internationally prominent research institute in the transport sector. Our principal task is to conduct research and development related to infrastructure, traffic and transport. We are dedicated to the continuous development of knowledge pertaining to the transport sector, and in this way contribute actively to the attainment of the goals of Swedish transport policy.

Our operations cover all modes of transport, and the subjects of pavement technology, infrastructure maintenance, vehicle technology, traffic safety, traffic analysis, users of the transport system, the environment, the planning and decision making processes, transport economics and transport systems. Knowledge that the institute develops provides a basis for decisions made by stakeholders in the transport sector. In many cases our findings lead to direct applications in both national and international transport policies.

VTI conducts commissioned research in an interdisciplinary organisation. Employees also conduct investigations, provide counseling and perform various services in measurement and testing. The institute has a wide range of advanced research equipment and world-class driving simulators. There are also laboratories for road material testing and crash safety testing.

In Sweden VTI cooperates with universities engaged in related research and education. We also participate continuously in international research projects, networks and alliances.

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