TØI Report 1466/2016

Aslak Fyhri
Torkel Bjørnskau
Aliaksei Laureshyn
Hanne Beate Sundfør
Rikke Ingebrigtsen

Institute of Transport Economics
Norwegian Centre for Transport Research

# Safety in Numbers - uncovering the mechanisms of interplay in urban transport

TØI Report
1466/2016

# Safety in Numbers - uncovering the mechanisms of interplay in urban transport

Aslak Fyhri, Torkel Bjørnskau, Aliaksei Laureshyn, Hanne Beate Sundfør & Rikke Ingebrigtsen

ISSN 0808-1190
ISBN 978-82-480-1256-6 Electronic version

Oslo, May 2016

**Title:** Safety in Numbers - uncovering the mechanisms of interplay in urban transport

**Tittel:** Safety in Numbers - en studie av mekanismer for samhandling mellom trafikanter

**Author(s):** Aslak Fyhri
Torkel Bjørnskau
Aliaksei Laureshyn
Hanne Beate Sundfør
Rikke Ingebrigtsen

**Forfattere:** Aslak Fyhri
Torkel Bjørnskau
Aliaksei Laureshyn
Hanne Beate Sundfør
Rikke Ingebrigtsen

| | | | |
|---|---|---|---|
| **Date:** | 05.2016 | **Dato:** | 05.2016 |
| **TØI report:** | 1466/2016 | **TØI rapport:** | 1466/2016 |
| **Pages** | 55 | **Sider** | 55 |
| **ISBN Electronic:** | 978-82-480-1256-6 | **ISBN Elektronisk:** | 978-82-480-1256-6 |
| **ISSN** | 0808-1190 | **ISSN** | 0808-1190 |
| **Financed by:** | The Research Council of Norway | **Finansieringskilde:** | Norges forskningsråd |
| **Project:** | 3886 - Safety in Numbers | **Prosjekt:** | 3886 - Safety in Numbers |
| **Project manager:** | Aslak Fyhri | **Prosjektleder:** | Aslak Fyhri |
| **Quality manager:** | Rune Elvik | **Kvalitetsansvarlig:** | Rune Elvik |
| **Key words:** | Accidents<br>Bicycle<br>Conflict<br>Risk | **Emneord:** | Konflikt<br>risiko<br>Sykkel<br>Ulykker |

**Summary:**

When more cyclists turn to the roads in Oslo each spring, the risk for each cyclist of being involved in a conflict or near miss is reduced. In other words, there is proof of a Safety in Numbers effect. Comparing Norwegian road users with their Danish and Swedish counterparts shows that this effect can either be accentuated or reduced by differences in infrastructure quality and traffic culture (norms about how to behave to each other).

**Sammendrag:**

Når flere syklister dukker opp på veiene i Oslo hver vår, reduseres risikoen for hver syklist for å bli involvert i en konflikt eller nestenulykker. Med andre ord finner vi et bevis på Safety in Numbers effekten i denne studien. Sammenligner vi norske trafikanter med sine danske og svenske motparter, ser vi at denne effekten kan både forsterkes og reduseres med forskjeller i infrastrukturkvalitet og trafikkultur (normer om hvordan man skal oppføre seg mot hverandre).

Language of report: English

*This report is available only in electronic version.*

*Rapporten utgis kun i elektronisk utgave.*

*Institute of Transport Economics*
*Gaustadalleen 21, 0349 Oslo, Norway*
*Telefon 22 57 38 00 - www.toi.no*

*Transportøkonomisk Institutt*
*Gaustadalleen 21, 0349 Oslo*
*Telefon 22 57 38 00 - www.toi.no*

# Preface

An important goal of the National Transport Plan of Norway is that all future growth in transport in cities should happen with sustainable transport modes. There has been a concern that an increase in walking and cycling will create more accidents. This has been countered by the argument of a Safety in Numbers (SiN) effect. According to SiN an increase in the number of pedestrians / cyclists in traffic does not provide a corresponding increase in the number of accidents and injuries and thus lead to a lower risk for each pedestrian / cyclist.

This report summarizes a three-year project under the Norwegian Research Council TRANSIKK program (project number 224821), which has aimed partly to prove the SiN-effect empirically through controlled studies, and partly to clarify the mechanisms that contribute to the effect. The report is a summary of all publications within the project. It attempts to answer 15 specific hypotheses about SiN-effect. More detailed results can be found in other publications, listed at the end. The report is written in English but has a Norwegian summary.

Project manager for the project has been Senior Researcher Aslak Fyhri, who has also been responsible for putting together this report. Chief Research Officer Torkel Bjørnskau has helped in the planning and design of data collection, as well as provided comments to the various publications. Senior Researcher Aliaksei Laureshyn has been responsible for collecting video data, and analysis and reporting this. Researcher Rikke Ingebrigtsen has analyzed and reported survey material, and has contributed to the statistical analysis of video data. Researcher Hanne Beate Sundfør has been responsible for the study of tram drivers and also helped with preparation and completion of the survey data.

Oslo, May 2016
Transportøkonomisk institutt

| | |
|---|---|
| *Gunnar Lindberg* | *Michael Wøhlk Jæger Sørensen* |
| *Managing Director* | *Research Director* |

# Content

Summary:

# Safety in Numbers - uncovering the mechanisms of interplay in urban transport

*TØI Report 1466/2016*
*Authors:*
*Aslak Fyhri*
*Torkel Bjørnskau*
*Aliaksei Laureshyn*
*Hanne Beate Sundfør*
*Rikke Ingebrigtsen*
*Oslo 2016, 55 pages*

*When more cyclists turn to the roads in Oslo each spring, the risk for each cyclist of being involved in a conflict or near miss is reduced. In other words there is proof of a Safety in Numbers effect. Comparing Norwegian road users with their Danish and Swedish counterparts shows that this effect can either be accentuated or reduced by differences in infrastructure quality and traffic culture (norms about how to behave to each other).*

Bicycle advocates and other stakeholders with an interest in arguing for a shift from motorized to non-motorized travel often rite the concept of "Safety in numbers" (SiN) as an argument against the concern about a potential increase in numbers of accidents resulting from such a policy. The concept of SiN is used to explain the non-linear statistical relationships between the number of pedestrians or bicyclists and the number of injuries for the same group (Elvik, 2009; Geyer, Raford, Ragland, & Pham, 2006; Jacobsen, 2003). The mechanism has been proven in a number of cross sectional and longitudinal studies, summarised in a quite recent meta-analysis (Elvik & Bjørnskau, in press). The concept has been subject to debate, regarding its existence (Bhatia & Wier, 2011), its mathematical characteristics (Brindle, 1994; Elvik, 2013; Knowles et al., 2009) and also related to this, regarding a clear understanding of *the mechanism* behind the safety in numbers effect.

The Scandinavian countries, and in particular Norway are interesting cases to test the SiN effect, as there is a substantial seasonal variation in bicycle use. The seasonal variation is substantial, meaning that every spring there is a dramatic increase in the number of bicycles other road users are exposed to each subsequent week. By studying conflicts and interactions at the same study sites, it is possible to keep a close control with any other potential influencing factors, and only look at the effect of changes in the share of one of the road user groups. In other words, this situation can be used as an experiment of the SiN effect. In the current study, we exploit this variation in cycling levels and infrastructure design in order to give a better explanation of the mechanisms involved in the SiN effect. The same interviews and video recordings that were conducted in Norway were also conducted in Denmark and Sweden.

The current report summarizes a three-year research program carried out at the Institute of Transport Economics (*Safety in Numbers - uncovering the mechanisms of interplay in urban transport*). The project consisted of several work packages, all aiming to either test the existence of the SiN mechanism or to the unravel mechanisms behind it. The report is structured around 15 different hypotheses regarding SiN. In addition potential contributions from infrastructure and traffic culture in explaining the SiN phenomenon are discussed.

Specifically we hypothesize that from April to June and from June to September, there is a reduction in number of …

1. … times bicyclists are not seen by car drivers
2. … times bicyclists are not seen by pedestrians
3. … times car drivers are surprised by a bicyclist
4. … times pedestrians are surprised by a bicyclist
5. … times cyclists are involved in near-misses with car drivers
6. … times cyclists are involved in near-misses with pedestrians
7. … traffic conflicts between car drivers and bicyclists[1]

Regarding the cross national differences we expect that Norwegian …

8. … bicyclists are more often overlooked by cars …
9. … bicyclists are more often overlooked by pedestrians …
10. … bicyclists are more involved in near-misses with car drivers
11. … bicyclists are more involved in near-misses with pedestrians …
12. … car drivers are more often surprised by a bicyclist …
13. … pedestrians are more often surprised by a bicyclist …
14. … bicyclists are more often involved in traffic conflicts with car drivers[1]…

…than their Danish and Swedish counterparts.

In addition, we have conducted a separate survey of tram drivers, who are interviewed at three different time points. For these data we have the following hypothesis:

15. The number of times tram drivers are surprised by bicyclists is reduced, from April to June and from June to September

The data collection procedure was quite complex and extensive and provided several sources of information for answering the hypotheses:

- Survey data with car drivers, cyclists and pedestrians from April, June and September collected in the field, in order to study the seasonal effects
- Survey data with car drivers, cyclists and pedestrians from April, June and September collected in a home survey, in order to study the seasonal effects and get more background information
- Video data from four intersections in Oslo from April, June and September collected in the field, in order to study conflicts between cyclists and cars

[1] As measured by video observations

- Video and survey data (like above) from Aalborg (Denmark) and Gothenburg (Sweden) in order to capture longer term effects of differences in cycling levels, and differences in traffic culture and infrastructure
- A survey of tram drivers from April, June and September collected in the field, in order to study the seasonal effects

We have summarised the results of the analyses in one table for the seasonal data and one for the cross national comparisons below.

*Table S1 Summary of hypotheses 1-7 and 12 (seasonal effects). The arrows indicate increase, decrease or no change between different periods. Green colour indicates confirmation of hypothesis, yellow indicates that it is not confirmed and red indicates that change is opposite of what is hypothesised.*

| | | April to June | June to September |
|---|---|---|---|
| H1 | Cyclists overlooks by cars | ↘ | ↘ |
| H2 | Cyclists overlooks by pedestrians | → | ↘ |
| H3 | Car drivers surprise by cyclists | → | → |
| H4 | Pedestrians' surprise by cyclists | → | → |
| H5 | Cyclists near-misses with cars | ↘ | → |
| H6 | Cyclists near misses with pedestrians | ↘ | ↗ |
| H7 | Conflicts with cars (video) | → | ↘ |
| H15 | Tram drivers' surprise by cyclists | ↘ | → |

Regarding seasonal variation, only the first hypothesis is fully confirmed, in the sense that overlooks drops both from April to June and from June to September. H2, H5, H6 and H7 are all partly confirmed since overlooks and near misses drops at one point in the season. H3 and H4, regarding other road users' surprises are not confirmed. However, H15 regarding tram drivers' surprises is partly confirmed.

The results suggest that bicyclists experience a short term Safety in Numbers effect through the season. Each individual cyclist experiences fewer occasions of being overlooked by cars and fewer safety critical situations (near-misses). Video observation data confirm this pattern. However, the SiN effect seems to be countered by another mechanism taking place at the same time: The influx of inexperienced and risk-taking cyclists through the season. Thus car drivers and pedestrians also report to find themselves being surprised by cyclists in traffic late in the season.

As a separate task, accident data were collected from a prospective population-based study, during 2014 at the Oslo Emergency Clinic. The analysis of cycle flow and accident data can be used to illustrate the SiN effect. We found that both collisions and single accidents are closely related to the number of cyclists on the road. However, when we look at the relative difference between single accidents and collisions (the ratio), we see that collisions decrease relative to single accidents when cyclist numbers increase. In December 28 percent of all cyclist accidents are collisions, a figure that drops to 10 percent in July.

The table below summarizes the cross national comparisons in the report, as gold, silver and bronze medals.

*Table S2 Summary of hypotheses 8-11. Ranks from 1st (gold) via 2nd (silver) to 3rd (bronze) place.*

| | | Denmark | Sweden | Norway |
|---|---|---|---|---|
| H8 | Overlooks by cars | 1 | 3 | 2 |
| H9 | Overlooks by pedestrians | 1 | 3 | 2 |
| H10 | Near miss with car | 1 | 1 | 1 |
| H11 | Near miss with pedestrian | 1 | 3 | 1 |
| H12 | Car drivers' surprise by cyclists | 1 | 2 | 3 |
| H13 | Pedestrians' surprise by cyclists | 1 | 2 | 3 |
| H14 | Conflicts between cars and cyclists | 1 | | 2 |

Our hypotheses regarding cross national differences are partly confirmed. For all of the hypotheses, except number 10 (near misses with cars), Denmark (Aalborg) comes out as the sole winner. This was as expected. When comparing Sweden (Gothenburg) and Norway (Oslo), the results are mixed. Depending on the data, we find that interplay between cyclists and other roads users sometimes is worse, sometimes the same, and some times better in Norway. Hence there seems to be certain difference in how cyclists interact with other road users, that has evolved over time, a long term SiN effect.

One explanation for the not-expected poor level of interplay in Sweden compared to Norway, is the particular infrastructure design used in many central pars of Gothenburg, where there are designated marked cycle paths either on pavements, or in the central part of bidirectional boulevards, where also pedestrian are supposed to walk.

Our discussions regarding the role infrastructure and traffic plays in explaining this long term effect is a bit inconclusive. We see that infrastructure does play a role, the badly designed Danish solutions (such as marked cycle paths in roundabouts) give *more* conflicts than the average Norwegian. Also, the Swedish solution mentioned above, seems to be conflict inducing. But, including infrastructure as a variable in multivariate models does not explain away national differences, which can be seen as indicative of a SiN effect regardless of different infrastructure quality. Further we find that road users are far more rule obedient and considerate in Denmark than in Sweden and Norway. But again, including a measure of traffic culture into the multivariate models does not explain any differences in near misses or surprises.

**Sammendrag:**

# Safety in Numbers - en studie av mekanismer for samhandling mellom trafikanter

*TØI rapport 1466/2016*
*Forfattere:*
*Aslak Fyhri*
*Torkel Bjørnskau*
*Aliaksei Laureshyn*
*Hanne Beate Sundfør*
*Rikke Ingebrigtsen*
*Oslo 2016 55 sider*

*Når flere syklister dukker opp på veiene i Oslo hver vår, reduseres risikoen for hver syklist for å bli involvert i en konflikt eller nestenulykker. Med andre ord finner vi bevis på Safety in Numbers effekten i denne studien. Sammenligner vi norske trafikanter med sine danske og svenske motparter, ser vi at denne effekten kan enten bli både forsterket eller redusert med forskjeller i infrastrukturkvalitet og trafikkultur (normer om hvordan man skal oppføre seg mot hverandre).*

Det er et politisk mål at fremtidig transportvekst i byer skal skje med bærekraftige transportformer. Det har vært en bekymring for at økt omfang av gange og sykling vil skape flere ulykker. Dette er blitt imøtegått av argumentet om en Safety in Numbers (SiN) effekt. Ifølge SiN vil en økning i antallet på fotgjengere/syklister i trafikken ikke gi en tilsvarende økning i antall ulykker og skader og dermed føre til en lavere risiko for hver enkelt fotgjenger/syklist.

SiN-effekten har tidligere blitt vist i tverrsnittstudier, og i noen få tidsseriestudier, men det er ingen som hittil har kartlagt *mekanismene* bak effekten. Dette prosjektet har hatt som formål a) å påvise denne effekten på en kontrollert måte, ved bruk av observasjonsstudier av konflikter mellom trafikantgrupper, og b) å avdekke de mekanismer som er i virksomhet. I prosjektet har vi forsøkt å isolere de foreslåtte mekanismene bak SiN. I oppsummeringen av funnene har vi pekt på implikasjoner for utforming av infrastruktur.

En mulig forklaring på SiN-effekten er at den reduserte risikoen skyldes *økt synlighet*. I Norge har vi en naturlig sesongvariasjon i sykkelbruken, som kan brukes som et nesten perfekt naturlig eksperiment for å teste denne hypotesen. Ved å kartlegge samspillet mellom syklister og andre trafikanter på tre tidspunkter, i april, juni og september, kan vi se om dette blir bedre etter hvert som man blir mer vant til hverandre. Vi kan med andre ord se om bilistenes *forventning* om å møte syklister forandres jo flere syklister som er der.

For å måle kvaliteten på samspillet bruker vi antall konflikter (nestenulykker) som mål, og ikke ulykker. For å registrere konflikter har vi benyttet videoobservasjoner. I tillegg til disse observasjonene har vi gjennomført intervjuer i de samme tidsperiodene.

Andre forklaringer på SiN-effekten er at det er kulturelle forskjeller mellom land i hvor godt man samspiller med andre trafikantgrupper, eller at forskjeller mellom land i hvor godt utbygd infrastrukturen er. Disse forskjellene kan skyldes mange forhold, og har gjerne satt seg over lang tid. Vi har derfor også samlet inn data i Sverige og Danmark. Vi vil kontrollere for hva slags type løsninger som er valgt ut, hvordan trafikantene blir tvunget sammen eller holdt fra hverandre, for å se om dette kan påvirke samspillet dem imellom.

Vi har i sykkelsesongen 2014 også gjennomført intervjuer med trikkeførere. Dette er en spesielt interessant gruppe å studere, siden de kjører de samme rutene hele tiden, og er bedre i stand enn andre til å observere hvordan samhandlingen med andre evt. endrer seg gjennom sesongen.

I rapporten tester vi ut 15 spesifikke hypoteser om SiN effekten.

Mer spesifikt antar vi at fra april til juni, og fra juni til september, er det en reduksjon i antall ...

1. ... ganger syklister ikke blir sett av bilførere

2. ... ganger syklister ikke blir sett av fotgjengere

3. ... ganger bilførere blir overrasket av en syklist

4. ... ganger fotgjengere blir overrasket av en syklist

5. ... ganger syklister er involvert i nestenulykker med bilførere

6. ... ganger syklister er involvert i nestenulykker med fotgjengere

7. ... trafikkonflikter mellom bilister og syklister

Når det gjelder nasjonale forskjeller forventer vi at norske ...

8. ... syklister er oftere oversett av biler ...

9. ... syklister er oftere oversett av fotgjengere ...

10. ... syklister er mer involvert i nestenulykker med bilførere

11. ... syklister er mer involvert i nestenulykker med fotgjengere ...

12. ... bilførere er oftere overrasket av en syklist ...

13. ... fotgjengere er oftere overrasket av en syklist ...

14. ... syklister er oftere involvert i trafikkonflikter med bil førere ...

...enn sine danske og svenske motparter

I tillegg har vi gjennomført en egen undersøkelse av trikkeførere , som er intervjuet på tre forskjellige tidspunkter . For disse dataene har vi følgende hypotese :

15. Antall ganger trikkeførere er overrasket over syklister er redusert , fra april til juni og fra juni til september

Tabellene nedenfor oppsummerer disse funnene.

*Tabell S1 Sammendrag av hypoteser 1 til 7 og 15 om sesongeffekter. Pilene indikere økning, ingen endring eller reduksjon. Grønn farge betyr at hypotesen er bekreftet, gul at den ikke er det og rød betyr endring i motsatt retning av hypotesen.*

| | | April til Juni | Juni til September |
|---|---|---|---|
| H1 | Syklister oversett av biler | ↘ | ↘ |
| H2 | Syklister oversett av fotgjengere | → | ↘ |
| H3 | Bilister overrasket av syklister | → | → |
| H4 | Fotgjengere overrasket av syklister | → | → |
| H5 | Syklisters nestenulykker med bil | ↘ | → |
| H6 | Syklisters nestenulykker med fotgjengere | ↘ | ↗ |
| H7 | Konflikter med bil (video) | → | ↘ |
| H15 | Trikkeførere overrasket av syklister | ↘ | → |

De endelige funnene fra spørreskjema-dataene viser at syklistene i Oslo opplever å bli oversett oftere i starten av sykkelsesongen, enn mot slutten. Denne forskjellen finner vi også når vi kontrollerer for at populasjonene i hver periode ikke er helt sammenlignbare (ved bruk av paneldata). Vi finner derimot *ikke* at bilister og fotgjengere blir mindre overrasket av syklister gjennom sesongen, slik vi hadde ventet. Videodataene viser imidlertid også at det blir færre konflikter mellom biler og sykler gjennom sesongen. Blant trikkeførerne finner vi at det rapporteres om færre hendelser der syklister dukker opp overraskende utover i sesongen.

En interessant observasjon som ble gjort var at det var flere som syklet på rødt lys mot slutten av sesongen enn før. Dette kan bidra til å forklare at ikke alle hypotesene ble fullt ut bekreftet. Muligens ser vi her to effekter som virker mot hverandre: På den ene siden blir bilistene mer oppmerksomme på syklister, jo flere det er av dem. På den annen side er sykkelpopulasjonen mer forsiktig og regel-etterlevende i starten av sesongen (når det er få syklister) enn mot slutten.

En analyse av sesongvariasjonen i sykkelulykker, basert på Oslo skadelegevakts rapporter, viser at kollisjoner som andel av *alle ulykker* henger tett sammen med antall syklister. I gjennomsnitt er 18 prosent av alle sykkelulykker en kollisjon med en annen trafikant. Denne andelen er høyest (28 prosent i desember), og lavest (10 prosent i juli).

Tabellen nedenfor oppsummerer krysser nasjonale sammenligninger i rapporten, som gull-, sølv- og bronsemedaljer .

*Tabell S2 Sammendrag av hypoteser 8-14. Rangering fra første (gull) via andre (sølv) til tredje (bronse) plass.*

| | | Danmark | Sverige | Norge |
|---|---|---|---|---|
| H8 | Oversett av bil | 1 | 3 | 2 |
| H9 | Oversett av fotgjenger | 1 | 3 | 2 |
| H10 | Nesten ulykke med bil | 1 | 1 | 1 |
| H11 | Nestenulykke med fotgjenger | 1 | 3 | 1 |
| H12 | Bilister overrasket av syklister | 1 | 2 | 3 |
| H13 | Fotgjengere overrasket av syklister | 1 | 2 | 3 |
| H14 | Konflikter med bil (video) | 1 | | 2 |

Når vi sammenligner surveydata fra Norge og Danmark får vi støtte for at norske syklister blir oftere oversett enn danske. Vi finner også at norske bilister blir oftere overrasket av syklister enn danske. Videoanalyser av norske og danske kryss viser at det er høyere risiko for konflikter mellom syklister og bilister i Norge. Interessant nok fant vi at risikoen for konflikter var høyest i kryss med få syklister, uavhengig av land, noe som støtter opp under antagelsen om SiN-effekten.

Men vi fant også at risikoen for konflikt hang sammen med kvaliteten på infrastruktur. Generelt oppleves denne som bedre i Danmark. Et interessant tilfelle er imidlertid rundkjøringer. Disse oppleves som tryggere i Danmark enn i Norge, men når vi sammenligner andelen konflikter finner vi at den er høyest i de danske rundkjøringene. Den danske løsningen, med stor grad av separering mellom biler og syklister, kan synes tiltalende, men er altså mer risikabel enn den «utrygge» norske. Dette er også noe av grunnen til at man nå går vekk fra oppmalte sykkelfelt i rundkjøringer i Danmark. På den annen side oppleves de separate danske sykkelveier som tryggere enn norske sykkelfelt, og er det.

Vi finner at svenske syklister rapporterer om å bli oversett flere ganger enn de norske. Dette kan henge sammen med den løsningen for sykkelfelt som brukes flere steder i sentrale områder i Gøteborg, hvor markerte sykkelfelt enten er på fortauet eller plassert i midtrabatten på store alleer, hvor syklister og fotgjengere må dele på arealet.

Det er også en klar forskjell mellom landenes trafikkultur. De danske trafikantene er langt mer regeltro enn norske og svenske, og opptrer også mer hensynsfullt. Andelen som sykler på rødt lys var høyere i Norge. Dette kan tolkes som at dårlig infrastruktur bidro til å skape en dårligere trafikkultur, men det er vanskelig å konkludere noe sikkert om årsaksretning med våre data. Det kan like gjerne være slik at trafikantene gjennom økt eksponering for hverandre blir flinkere til å samhandle.

# 1 Introduction

## 1.1 Background

Bicycle advocates and other stakeholders with an interest in arguing for a shift from motorized to non-motorized travel often rite the concept of "Safety in numbers" (SiN) as an argument against the concern about a potential increase in numbers of accidents resulting from such a policy. The concept of SiN is used to explain the non-linear statistical relationships between the number of pedestrians or bicyclists and the number of injuries for the same group (Elvik, 2009; Geyer, Raford, Ragland, & Pham, 2006; Jacobsen, 2003). The mechanism has been proven in a number of cross sectional and longitudinal studies, summarised in a quite recent meta-analysis (Elvik & Bjørnskau, in press). The concept has been subject to debate, regarding its existence (Bhatia & Wier, 2011), its mathematical characteristics (Brindle, 1994; Elvik, 2013; Knowles et al., 2009) and also related to this, regarding a clear understanding of *the mechanism* behind the SiN effect.

The mechanism that has most frequently been proposed, is that motorists become more attentive, and change their behaviour, when exposed to higher numbers of pedestrians and cyclists (Jacobsen, 2003). Another possible mechanism is improved interplay between road users groups when road users acquire experience with each other, and develop more correct expectations (Phillips, Bjørnskau, Hagman, & Sagberg, 2011). Still another suggested mechanism is that the cyclists and pedestrians entering the population at a later stage may be more risk averse and cautious (Fyhri, Bjørnskau, & Backer-Grøndahl, 2012). It has also been suggested that the effect can be a result of safer environmental conditions, including engineering countermeasures or differences in pedestrian norms and behaviours (Bhatia & Wier, 2011). However, these hypotheses have yet to be tested. Knowledge about these mechanisms is essential (Bhatia & Wier, 2011) and is necessary to adopt a safe active transport policy aiming at a shift to increased use of sustainable urban transport.

The Scandinavian countries, and in particular Norway are interesting cases to test the SiN effect, as there is a substantial seasonal variation in bicycle use. The cycle share in winter is in the range of 1 to 2 % of all trips, and rises to 8 % in summer (Hjorthol, Uteng, & Engebretsen, 2014). Pedestrians are a more steady presence in traffic. In fact, the share of pedestrians is somewhat *higher* in winter, around 22 %, and drops to around 18 % in summer (probably due to some bicyclists shifting to walking when conditions are not good enough for cycling). Thus, looking at interplay in traffic as a function of seasonal variation in bicycle use can provide useful insights into the mechanisms involved in the safety in numbers effect.

The seasonal variations is substantial, meaning that every spring there is a dramatic increase in the number of bicycles other road users are exposed to each subsequent week. By studying conflicts and interactions at the same study sites, it is possible to keep a close control with any other potential influencing factors, and only look at the effect of changes in the share of one of the road user groups. In other words, this situation can be used as an experiment of the SiN effect.

Although the Scandinavian countries (Norway, Sweden and Denmark) are similar in many respects, much is also different. Cycling levels, but also infrastructure design as well as legal contexts differ between these countries. In the current study, we exploit this variation in cycling levels and infrastructure design in order to give a better explanation of the mechanisms involved in the SiN effect. The same interviews that were conducted in Norway were also conducted in Denmark and Sweden and similar video registrations of road traffic were carried out in Norway and Denmark.

A major difference between the countries is the modal shares for different road user groups; in Denmark, the modal share for cyclists is 17 %, compared to 4 % in Norway and 12 % in Sweden. The countries are also characterised by different traditions for transport planning, road design and use of infrastructural measures for pedestrians and cyclists. For pedestrians, relevant measures may be pavements, crossings, raised crosswalks and walkways, whereas for cyclists measures such as bikeways, cycle lanes, cycle boxes and coloured cycle lanes will be important. A principal distinguishing factor is the relative use of separation between groups of road users. In Norway, mixed traffic is widely used, while separated lanes or tracks are the norm in Denmark. Sweden employs a combination of planning measures, and also novel planning concepts such as shared space. As a consequence, framework conditions for vulnerable road users (pedestrians and cyclists) differ widely between the three countries. The purported SIN effect could therefore be an effect of different road design and city layout in different cities.

Traffic accidents are often a result of inadequate road user interaction, but research on the importance of road user interaction for accidents is rather limited. The importance of correct expectations and the ability to predict other road users' behaviour has not been studied much, despite the fact that such abilities are vital in order to avoid accidents (Bjørnskau, 1994; Bjørnskau, 1996; Rothengatter, 1991).

When the proportions of different road user groups change, for instance through an increase in soft transport modes, interaction patterns may also change. Bjørnskau (in press) has documented how road user interaction can change over time as a result of dynamic interplay. One example is pedestrian crossings, where cars yield to cyclists contrary to the traffic rules (Bjørnskau, in press). Another is how novice drivers change their use of the headlights and adapt to the dominant practice of dipping, contrary to what is prescribed in driver education (Bjørnskau, 1994).

Studying interaction among road users, rather than behaviour from one single road user group, creates substantial methodological challenges, which might be one reason for the scarcity of previous controlled experimental studies. In the context of Safety in Numbers, a relevant experience from a bicyclist's point of view is that of being overlooked by other road users. However, whether a bicyclist is overlooked in a given situation will depend on the bicyclists' own behaviour in that situation as well as the behaviour from the surrounding road users.

In order to overcome these challenges a multidisciplinary approach is needed. Traditional surveys function quite well to provide valid descriptions of different road users perceptions and own experiences and can also to a certain extent describe interaction patterns (Bjørnskau & Fyhri, 2012). Observational techniques can function well to supplement the picture. One promising approach that has gained a renewed interest in later years is to use surrogate accident measures, such as conflicts and to record these with video. The Swedish Traffic Conflict Technique (TCT) is one among several such methods (Hydén, 1996; Laureshyn, 2010), but is the only one that has been validated with strong relation found to the number of police-reported accidents (Svensson, 1992). The method also exhibits strong *process validity* (similarity in how conflicts to accidents develop), and is especially valuable for the studies of vulnerable road users' safety since this group is under-represented in the accident statistics (Juhra et al., 2012). We therefore use video observations to study the seasonal change of road user interaction, and to compare across countries.

When the project was planned, no reliable accident data existed for cyclists in Oslo. Police records were available, but since these are known to underreport cyclist accidents dramatically, we decided not to use these. During 2014, a project was initiated where all patients who contacted the Oslo Emergency Clinic after a bicycle accident were asked to fill out a bicycle injury form. These data were therefore utilized to provide a description of seasonal variations on bicycle accidents.

## 1.2 Objectives

The objective of the current report is to investigate if bicyclists experience an increased quality of interplay with cars when more bicyclists enter the streets throughout the cycling season. Further, we expect that there will be differences between Norway, Sweden and Denmark in interplay and number of conflicts.

Specifically we hypothesize that from April to June and from June to September, there is a reduction in number of …

1. … times bicyclists are not seen by car drivers
2. … times bicyclists are not seen by pedestrians
3. … times car drivers are surprised by a bicyclist
4. … times pedestrians are surprised by a bicyclist
5. … times cyclists are involved in near-misses with car drivers
6. … times cyclists are involved in near-misses with pedestrians
7. … traffic conflicts between car drivers and bicyclists[1]

Regarding the cross national differences we expect that Norwegian …

8. … bicyclists are more often overlooked by cars …
9. … bicyclists are more often overlooked by pedestrians …
10. … bicyclists are more involved in near-misses with car drivers
11. … bicyclists are more involved in near-misses with pedestrians …
12. … car drivers are more often surprised by a bicyclist …
13. … pedestrians are more often surprised by a bicyclist …
14. … bicyclists are more often involved in traffic conflicts with car drivers[1]…

…than their Danish and Swedish counterparts.

Regarding the cross national differences we further aim to investigate whether potential differences are best explained by 1) individual factors such as age, gender or aspects of the personality, 2) infrastructure design, or 3) modal share.

In addition, we have conducted a separate survey of tram drivers, who are interviewed at three different time points. For these data we have the following hypothesis:

[1] As measured by video observations

15. The number of times tram drivers are surprised by bicyclists is reduced, from April to June and from June to September

## 1.3 How to read this report

This report is a summary of a three- year research program carried out at the Institute of Transport Economics (Norwegian Research Council project nr 224821: *Safety in Numbers - uncovering the mechanisms of interplay in urban transport*). The project ran from January, 2013 to December, 2015. The project consisted of several work packages, all aiming to either test the existence of the SiN mechanism or to unravel the mechanisms behind it. Results from the different work packages in the project have previously been documented in separate publications, as listed in the table in appendix 1.

In chapter 2 we give an outline of the methods used to collect the survey data from road users and tram drivers. In chapter 3 we give an outline of the methods used to collect video data. In chapter 4 we answer the hypotheses about seasonal variation with the survey results from Norway. In chapter 5 we answer the hypotheses about seasonal variation with video data from Norway. In chapter 6 we answer to the hypotheses about cross national differences with survey data. In chapter 7 we answer to the hypotheses about cross national differences with video data. In chapter 8 we give a brief outline of results from the study of tram drivers, also answering to the hypothesis about seasonal variation. In chapter 9 we discuss if the observed differences in behaviour between Norway, Sweden and Denmark can be explained by differences in infrastructure quality. In chapter 10 we discuss if the observed differences can be ascribed to differing traffic cultures.

In chapter 11 the accident record data from Oslo are presented and discussed in light of the SiN effect. Finally, in chapter 12 all the results are summarized and discussed in light of the Safety in Numbers phenomenon. All the results presented here are collected from other publications, and will only be presented as summaries. Further details about methods and analysis procedures can be found in the original documents referred to in each chapter.

# 2 Survey methodology

## 2.1 Seasonal data (Norway)

Data were collected in a series of field surveys among road users in some preselected streets and parking lots in Oslo, Norway. The surveys were conducted at three time-points in 2013: April (15$^{th}$ to 29$^{th}$), June (10$^{th}$ to 21$^{st}$) and September (02$^{nd}$ to 13$^{th}$). The data collection period spanned over two weeks at each time point. Interviews were conducted on weekdays, and during daytime. Most interviews were conducted in the morning and afternoon, during rush hours, in order to recruit enough respondents at each location.

Pedestrians and bicyclists were interviewed at three different locations in Oslo. The locations were selected so that we would recruit "average" road users, have enough traffic, and to ensure that those interviewed would have had sufficiently long travels so that they could have experienced interactions with other road users on the current trip. The interviewers were in principle asked to stop any pedestrian or bicyclist approaching them. However, as we were mostly interested in bicyclists' perceptions, on some days the interviewers were asked to recruit twice as many bicyclists as pedestrians. The interview took approximately 4-5 minutes to complete, and data were registered using tablet PCs. All who participated were promised a ticket in draw for a prize worth 5000 NOK (approx. 600 €). Interviews were only conducted on days with no rain.

Respondents were asked a range of questions, all regarding the trip they just had made (or were in the process of undertaking):

- Trip length in minutes
- Number of times they had experienced specific situations with poor interplay
- Assessment of interplay with cars and pedestrians (bicyclists for pedestrians)
- Experiences of near-misses
- Feeling of safety

In addition, background questions about amount of cycling, seasonal variation in cycling and age were asked. The interviewers registered gender, bicycle type and type of equipment.

Car drivers were interviewed at parking lots outside commercial centres and at street side parking lots in the city centre.

Respondents (bicyclists, pedestrians, and car drivers) who completed the interview were asked if we could contact them anew, and those who said yes, were asked to leave their email address. One week after the field interviews the respondents received a survey at home where they were asked some further questions about their experiences with being in traffic during the last week, and about interplay with other road users. They also answered questions about their attitudes and moral obligations in traffic and about their personality. In order to establish a panel survey design, those who completed this survey in Oslo, were asked if we could contact them again at the next phase of the survey (In June and September).

Data collected through roadside interviews will be referred to as the *field survey*. The questionnaire they filled out at home, will be referred to as the *home survey*.

For car drivers and pedestrians, only the field data are analysed in this paper. Sample size for the three field samples and for the three panel samples of bicyclists are presented in Table 1.

*Table 1 Sample size for field and panel surveys for cyclists and for field samples for car drivers and pedestrians.*

<table>
<tr><th></th><th>Car drivers</th><th>Pedestrians</th><th>Cyclists</th><th></th><th></th><th></th></tr>
<tr><th></th><th>Field</th><th>Field</th><th>Field</th><th>Panel 1<br>April and June</th><th>Panel 2<br>June and September</th><th>Panel 3<br>April, June and September</th></tr>
<tr><td>April</td><td>222</td><td>232</td><td>327</td><td rowspan="2">152</td><td></td><td rowspan="3">109</td></tr>
<tr><td>June</td><td>246</td><td>139</td><td>284</td><td rowspan="2">196</td></tr>
<tr><td>September</td><td>203</td><td>247</td><td>463</td><td></td></tr>
<tr><td>Total</td><td>671</td><td>618</td><td>1074</td><td>152</td><td>196</td><td>109</td></tr>
</table>

### 2.1.1 Sample

Table 2 shows the sample characteristics of the Norwegian bicyclists recruited in the field in April, June and September.

*Table 2 Sample characteristics of bicyclists. Percent (except for age).*

| | April | June | September |
|---|---|---|---|
| Mountain bike | 44 | 34 | 37 |
| “Hybrid bike” (city bike) | 39 | 38 | 33 |
| Racer bike | 5 | 7 | 9 |
| Rented bike | 1 | 1 | 1 |
| Classical bike | 10 | 19 | 19 |
| Other types | 1 | 1 | 1 |
| 5 days / week or more | 73 | 72 | 73 |
| 2-4 days /week | 24 | 26 | 25 |
| 1 day/week | 2 | 1 | 1 |
| 1-3 days /month | 0 | 0 | 0 |
| Rarely | 0 | 0 | 1 |
| Whole year bicyclist | 46 | 33 | 36 |
| Male | 57 | 58 | 53 |
| Mean age | 44.6 | 43.8 | 43.1 |
| N | 327 | 284 | 463 |

Notably, many of the respondents use mountain bikes. This share is as high as 44 % in spring, and falls to 34 % in mid-summer. This is typical of the Norwegian cycling population where mountain bikes for a while has been the most popular cycle type, even for urban cyclists. In addition, we can see that many of those who are interviewed are quite accustomed bicycle users. As many as 73 % cycle “every day” (i.e. five or more days a week). This share is quite stable throughout the season. Still, the April sample probably contains more experienced cyclists than the others, as there is a higher share (46 %) who cycle all year than in the other samples. The samples have a somewhat higher share of males than females, and are biased towards middle-aged participants (mean age ranges from 43.1 to 44.6; approximately 4 % are under 25 years and 3 % are above 65 years).

## 2.2 Cross national comparison (Norway, Sweden and Denmark)

The survey procedures in Aalborg (Denmark) and Gothenburg (Sweden) were similar to the Norwegian approach, with some exceptions:

- In Denmark the data collection (both interviews and video registrations) took place in October/ November 2013.
- In Sweden the interviews took place in September/October 2014.
- Money rewards in Denmark were 1000 DKK, and 5000 SEK in Sweden

Since data was only collected during autumn in Denmark and Sweden, the spring and summer data from Norway is not used in the cross national comparison.

The following sections compares background characteristics of the samples of the cyclists in these three surveys. Background characteristics of pedestrians and car drivers can be found in publications 13 and 14 in the publication list (appendix 1).

### 2.2.1 Demography of bicyclists

The field survey data contains answers from 1016 bicyclists, of these 44% (449) are from Norway, 30% (302) are from Sweden, and 26% (265) are from Denmark. Table 3 gives an overview of the number of respondents and the gender balance.

*Table 3 The number of respondents and gender distribution for the field survey bicyclists.*

| Bicyclists (field) | Norway | Sweden | Denmark | Total |
|---|---|---|---|---|
| Female | 47% (210) | 69% (207) | 56% (149) | 56% (566) |
| Male | 53% (239) | 31% (95) | 44% (116) | 44% (450) |
| N | 449 | 302 | 265 | 1016 |

As much as 69 % of the bicyclists recruited to roadside interviews in Sweden were women. The gender balance is much more equal for the respondents from Norway (47 % women) and Denmark (56 % women).

Figure 1 show the age distribution for female and male bicyclists in Norway, Denmark and Sweden.

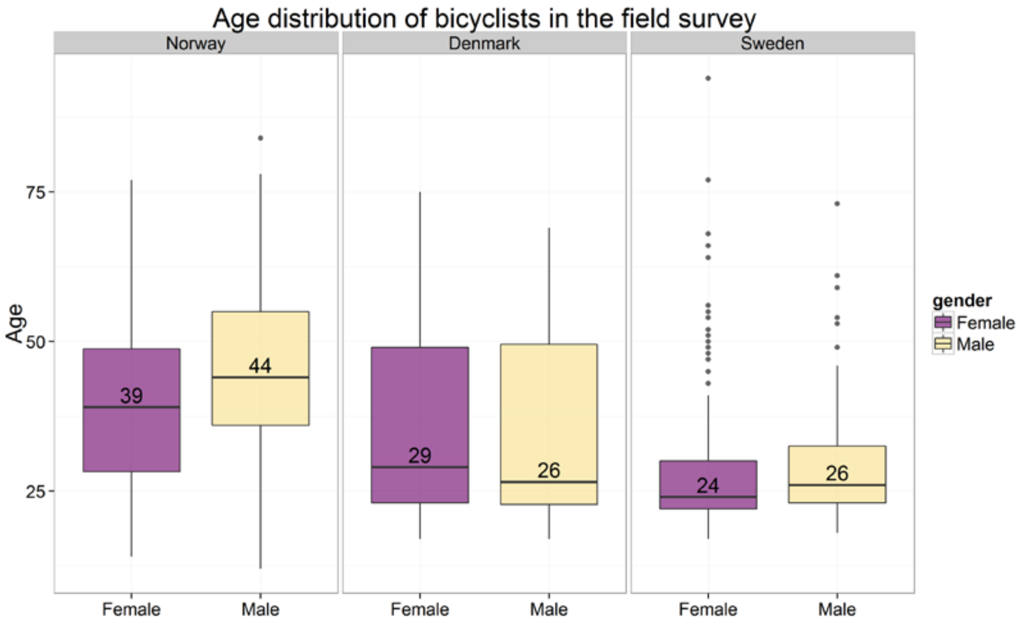


*Figure 1 Box plots showing the age distribution of female and male field survey bicyclists in Norway , Denmark and Sweden. The median age is indicated in the figure. The number of respondents are 449 from Norway, 302 from Sweden, and 265 from Denmark.*

The bicyclists from Sweden are much younger than those from Norway. The median (mean) age for the Norwegian bicyclists are 39 (40) for women and 44 (44.2) for men. For the Danish bicyclists it is 29 (35.7) for women and 26 (35) for men. For the Swedish bicyclists it is 24 (28.5) for women and 26 (29.9) for men. If gender is disregarded, the median age for the Norwegian bicyclists is 41 years, 27 years for the Danish bicyclists and 24 years for the Swedish bicyclists.

There are clearly some differences between the respondent groups. The Norwegian bicyclists recruited to the survey are "on average" in their fourties while the Swedish bicyclists that were recruited are "on average" in their twenties. The Danish bicyclists falls in between these two groups. Figure 2 illustrates the age distribution of the respondents with density plots.

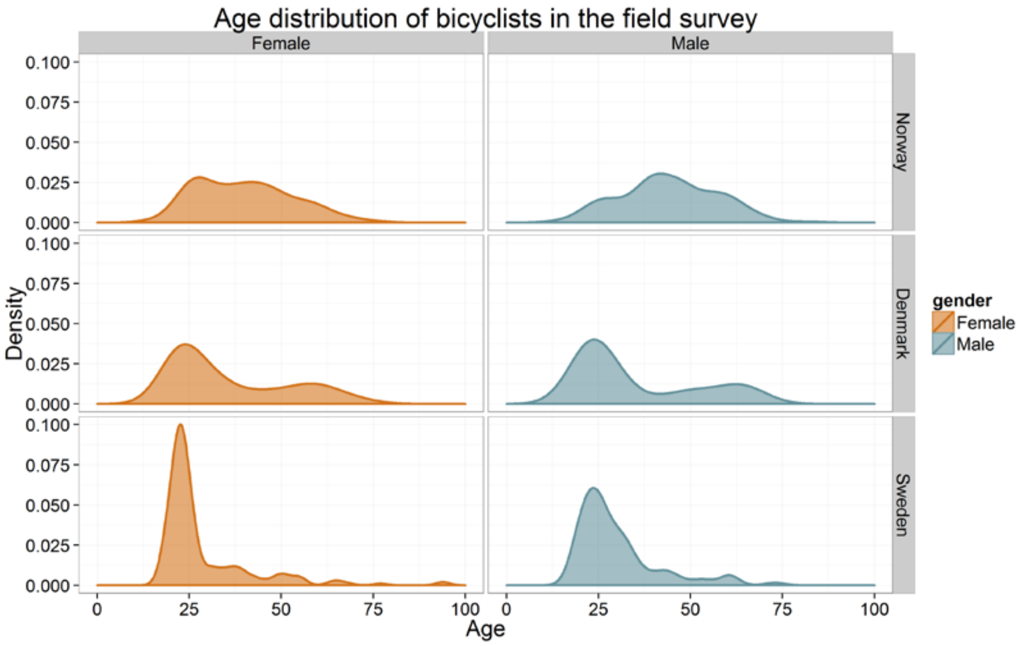


*Figure 2 Density plots of the age distribution among fields survey bicyclists. The number of respondents are 449 from Norway, 302 from Sweden, and 265 from Denmark.*

The density plots show that a majority on the Swedish bicyclists in our sample are around 25 years old. For the Danish bicyclists there are two "bumps", one around 25 and one around 60. The Norwegian bicyclists' age varies more.

The Swedish bicyclists recruited to the survey stands out in terms of both age and gender: they are young and a majority of them are women. The reason can partly be related to the interviewing locations, which were located more in the city centre in Gothenburg than in Aalborg and Oslo. Young people are typically over-represented in the population in inner city areas in Scandinavian countries.

### 2.2.2 Personality

In order to measure personality, we used selected items from a Norwegian version of The Big Five Inventory, called the BFI-20 (Engvik & Clausen, 2011). This inventory consists of 20 items measuring five personality traits, and is increasingly used in research where space and time limit the use of longer tests, such as the NEO-PI R (240 items) (John, Srivastava, & Pervin, 1999). The 20 item version is a tested and validated shortened version of a previous 44-item version (Engvik & Føllesdal, 2005). The short versions do not provide an optimal description of the five personality traits, but provide a practical assessment in situations like ours, where personality only is used a control variable. The inventory measures the five traits extraversion, neuroticism, openness, agreeableness and conscientiousness. Respondents were to indicate on 7 point Likert scales to what degree they agreed with the various statements (i.e. items), from *1 not suitable* to *7 very suitable.*

Figure 3 shows the distribution of the scores on the five personality variables for bicyclists (similar comparisons for car drivers and pedestrians can be found in reports 13 and 14 in the publication list (appendix 1).

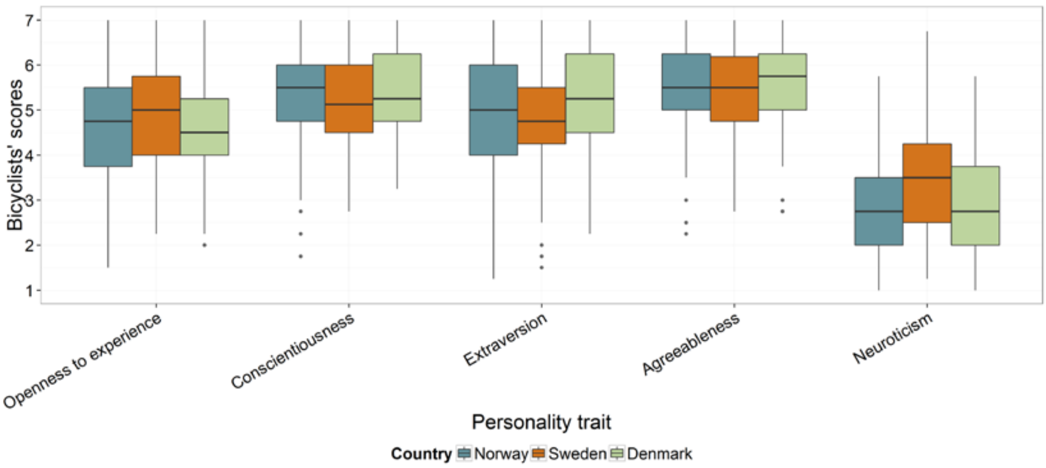


*Figure 3 Comparison of personality test scores for the bicyclists from Oslo (N=384), Gothenburg (N=106), and Aalborg (N=117). In total 20 questions, 4 related to each personality trait, were asked in the home survey. A score for each trait is computed as the average of the 4 related items. The scale is from 1 to 7, and higher scores indicate more agreement with the trait.*

One-way ANOVA shows that there is a significant difference between the mean values of the countries for the personality traits extraversion and neuroticism. This also holds when controlling for age and gender. There is no theoretical reason for differences between the three Scandinavian countries, so the observed differences has to be due to systematic variations in the sampling procedure, for instance the types of places were interviews were conducted. To control for this bias, personality variables are included in the multivariate analyses comparing countries using the home survey data.

## 2.3 Tram survey

A sample file consisting of phone numbers (N=250) to all drivers was delivered by the company. These were used as a basis for the field survey. In the survey periods (on Monday Tuesday and Wednesday) each number received an SMS with a prompt to respond about how it was to drive on that particular day. In all each participant received 9 such prompts and could theoretically have provided 12 responses.
In total we received 225 responses from 123 participants (90 in April, 63 in June and 53 in September).

The home survey was carried out as a web survey in October 2014. In total 83 tram drivers responded (18 females and 55 males). The survey was carried out as a general survey about safety culture and experience of the work environment. These results are reported in publication 17 in the publication list (appendix 1).

# 3 Video observation methodology

## 3.1 Video observations

Behavioural and conflict analyses were done based on video observations. At each intersection, a video was recorded with relatively low resolution (640x480 pixels), which did not allow recognising individual persons or reading number plates on cars, but was sufficient to see and interpret the road user actions.

First, a pre-screening of the footage by students took place, in which every possible violation and conflict was registered. The students' instructions were to mark any "unusual" situation such as strange route, congestion, "narrow coming", powerful braking, etc. Generally, the number of pre-selected situations was about ten times higher than the final conflict count and therefore the risk of missing a relevant conflict at this stage is judged to be low. Afterwards the selected events were reviewed, analysed and categorized by a person trained in using the Swedish traffic conflict technique. Since we used objective speeds and trajectories extracted from video, the subjective component of judging a conflict by a human observer was further minimised. Further details can be found in publications 7 and 15 in the publication list (appendix 1).

## 3.2 Study sites - Norway

The study is based on observations done at four intersections in Norway (*Figure* 4):
**Site I. Toftes gate – Seilduksgata.** A small intersection in central part of the city with one lane in each direction for motor traffic and cycle lanes on both side on one of the streets. Estimated ADT 10,000 vehicles.
**Site II. Suhms gate – Kirkeveien.** A large intersection on a main arterial street (a part of the second city ring). Three lanes for motor traffic and cycle lane on the main street in each direction. Advanced stop lines for the cyclists. Estimated ADT 28,000 vehicles.
**Site III. Vogts gate – Marcus Thranes gate.** Another intersection on the second city ring. Cycle lanes on the main street, but only on one side of the intersection. Tram line going through the intersection on the minor street. Estimated ADT 29,000 vehicles.
**Site IV. Mogata – Jutuveien – Stavangergata**. A roundabout in residential part of the city. One incoming lane for motor traffic in each leg, cycling lanes at two legs merging with the motor traffic just before the intersection. Estimated ADT 15,000 vehicles.


*Figure 4 The views of the studied intersections in Oslo: a) Toftes gate - Seilduksgata; b) Suhms gate – Kirkeveien; c) Vogts gate - Marcus Thranes gate; d) Mogata - Jutuveien – Stavangergata.*

### 3.2.1 Video recordings

The original plan was to observe each site during 5 working days between 6:00 and 21:00 in spring, summer and autumn. The main bulk of the video recordings were done in 2013, but some complementary recordings were done during the spring of 2014. No video was collected at Mogata (Site IV) for the spring period. Due to a technical failure, autumn period at Suhms gate (Site II) contained only video between 6:00 and 11:00. To extend the observation time, the number of days analysed was doubled.

## 3.3 Study sites – Denmark and Sweden

Four sites in Denmark (cities of Ålborg and Viborg) were studied in autumn period. The sites included (Figure 5):

**Site D1. Kastetvej – Poul Paghs Gade.** A small priority-regulated intersection in the central part of Ålborg. The design is comparable with the Norwegian Site N1. Estimated ADT 7,000 vehicles.

**Site D2. Kong Christian Allé – Hasserisvej.** A signalised intersection in Ålborg, relatively similar in to the Site N2. Estimated ADT 16,000 vehicles.

**Site D3. Hjørringvej – Sundsholmen.** A signalised intersection in Ålborg possessing the best features of a Danish cycling infrastructure like raised cycling path at all the approaches and clearly colour-marked cycle passages through the intersection. In its function, the intersection is very similar to the Site N3, but the design implementation is very different. Estimated ADT 26,000 vehicles.

**Site D4. Gammel Skivevej – Rødevej - N. F. S. Grundtvigs Vej (Viborg).** A roundabout in Viborg with a separate colour-marked cycle lane in the middle ring. Again, it is a very different design solution compared to the Site N4, even though the function of the intersections are similar. Estimated ADT 11,000 vehicles.


*Figure 5 The views of the studied intersections in Ålborg and Viborg, Denmark: a) Kastetvej – Poul Paghs Gade; b) Kong Christian Allé – Hasserisvej; c) Hjørringvej – Sundsholmen; d) Gammel Skivevej – Rødevej - N. F. S. Grundtvigs Vej.*

Originally, two sites corresponding to the Norwegian sites N2 and N4 were selected for studying in Sweden (Gothenburg city). However, due to a technical failure data from only one site was usable (Figure 6):

**Site S2. Sten Sturegatan - Egelbrektsgatan.** A signalised intersection in the central part of the city. It is similar to the Site N2, but has some design differences, for example, marking of the cyclist passage through the intersection. Estimated ADT 14,000 vehicles.

*Figure 6 The views of the studied intersection Sten Sturegatan - Egelbrektsgatan in Gothenburg, Sweden (Site S2).*

### 3.3.1 Video recordings

In Denmark, the recordings at all site was done in autumn period. Similarly to Norway, 5 working days between 6:00 to 21:00 were analysed.

In Sweden, due to a failure of a hard drive, most of the recorded material got lost. Some parts of the footage remained for the Site S2.

## 3.4 Exposure counts

The exposure counts were performed during 8 half-hour periods: 7:00-7:30, 8:00-8:30, 9:00-9:30, 10:00-10:30 in the morning and 14:00-14:30, 15:00-15:30, 16:00-16:30, 17:00-17:30 in the afternoon. Motor vehicle were counted on Wednesday and cyclists on Tuesday, Wednesday and Thursday in order to compensate for the higher variation of the cyclist numbers due to, for example, weather conditions. To estimate the total number of cyclists and motor vehicles during the observation period, the daily variation profiles for both categories (available from earlier studies at the same or similar locations) were used.

As a combined measure of exposure it was decided to use the sum of the products of the hourly cyclist and motor vehicle flows. Again, to estimate the flows for the hours in which no counts were done, the daily variation profiles were used.

For the signalised intersections, encounters were counted for the types of interactions corresponding to the most frequent conflict types (e.g. motor vehicle turning left and a cyclist going straight from the opposite direction). An encounter was defined as a situation in which the two road users were heading towards the same area (“conflict area”) sufficiently close in time to affect each other’s actions. This was done during the same half-hour periods as the motor vehicle counts. For the remaining intersection types it was either difficult to make an operational definition for an encounter, or the frequency of all conflicts was too low and further disaggregation by types was not reasonable.

# 4 Results of seasonal survey data

In the following, we summarize the analyses and results concerning hypotheses 1 to 6. These results are an excerpt from publication 7 in publication list (appendix 1).

## 4.1 H1: Bicyclists not being seen by cars

In the field survey, the respondents were asked to think about the trip they had made today, and about their encounters with cars in various situations, at intersections etc. Then they were asked about how many times they had experienced four concrete situations of poor interplay with cars. Figure 7 shows the mean number of times bicyclists have experienced situations with poor interplay on the current trip in April, June and September.

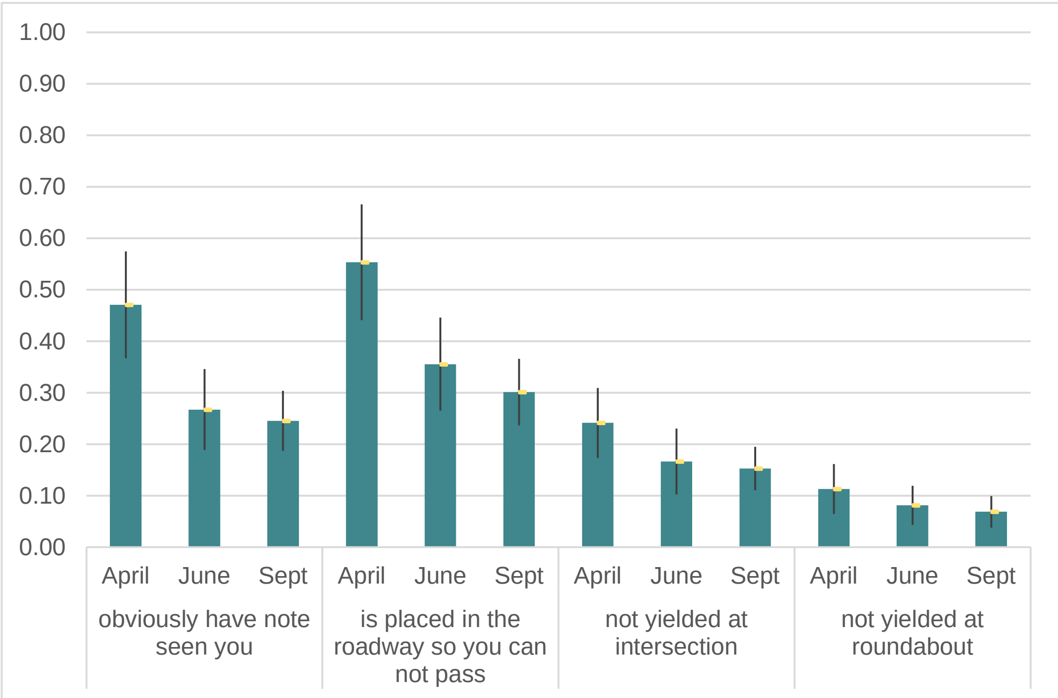


*Figure 7 Mean number of times (with upper and lower confidence intervals) bicyclists have experienced poor interplay on the current trip with car drivers in April, June and September.*

A one-way between groups ANOVA was conducted in order to explore the effect of season on different types of interplay with cars. The number of times the cyclists experience overlookings by a car falls from an average of 0.47 in April to 0.27 in June and to 0.25 in September ($F(2, 1070)=9,3$, $p<.001$). Post hoc tests (Tukey HSD) revealed that only the fall from April to June was statistically significant. The number of times bicyclists experience that cars block their roadway is also significantly influenced by season ($F(2, 1070)=8,9$, $p<.001$). The post hoc tests (Tukey HSD) again showed that only the fall from April ($M$=0.55, $SD$=1.03) to June ($M$=0.36, $SD$=0.77)) was statistically significant ($p$=0.01). There is no statistically significant change in the number of times bicyclists are seen but not respected (i.e. that cars have not yielded at intersections or roundabouts).

In order to control for any seasonal variation that may exist in the sample population, we conducted a multiple regression analysis. In this analysis, we included number of times bicyclists have experienced to be unnoticed by cars on current trip as a dependent variable, and age, gender, interview location, time of day, distance cycled, knowledge of present cycling route and season (month as a linear variable, with three values) as predictor variables (Table 4).

| | **Bicyclists** |
|---|---|
| Gender | |
| Age | -0.82* |
| Interview place | |
| Time of day | |
| Distance | 0.16*** |
| Accustomed to route | |
| Mountain bike | |
| Month | -0.88** |
| Adj $R_2$ | 0.03 |

*Table 4 Linear regression analysis of number of times bicyclists are not seen by cars on current trip. Standardized parameter estimates (β-values)*

*** p < 0,001
** p < 0,01
* p < 0,1

The results of the analysis show that both age and travel distance predict whether bicyclists are overlooked. The effect of season (month) is quite substantial (β=-0.88).

In the panel survey, the respondents were asked to think back to their last week in traffic. They were asked: "Think back to your encounters with cars last week. Imagine that you have met 100 such car drivers during the past week. Approximately how many of these will have…." "not yielded for you at an intersection" etc. (five items). Responses were to be given on a sliding scale with 11 intervals ranging from "none" via 10, 20 etc. to "all". The means and standard deviations are presented below (Table 5).

*Table 5 Descriptive statistics for cyclists being overlooked by cars in April, June and September.*

| | **Mean** | **SD** | **N** |
|---|---|---|---|
| April | 16.86 | 17.91 | 86 |
| June | 13.60 | 19.40 | 86 |
| September | 11.40 | 13.30 | 86 |

In order to test seasonal effect of bicyclists' reported number of overlooks from car drivers, a one-way repeated measures ANOVA was conducted. The sample for the analysis were 86 out of the 109 bicyclists (some were left out due to missing data) who had responded to all three of the home surveys (Panel 3). The number of overlooks drops from 16.9 in April to 13.6 in June and further to 11.4 in September. There was a statistically significant effect for season (Wilks' Lambda=0.851, F(2, 84)=7.36, p<.001, multivariate partial eta squared=0.15.

## 4.2 H2: Bicyclists not being seen by pedestrians

In order to test the seasonal effect of bicyclists' reported number of overlooks from pedestrians, a one-way repeated measures ANOVA was conducted. The analysis revealed no effect of season (Wilks' Lambda=0.986, F(2, 84)=0.581, p=0.56). Upon closer inspection, there seemed to be a tendency for a non-linear change in the number of overlooks. A paired-samples t-test was therefore conducted to compare overlooks in April and June, and in June and September, respectively. Respondents are cyclists who responded to the questionnaire in both of the months April and June or in both of the months June and September.

Table 6 shows the mean number of times during the last week bicyclists have experienced not being seen by a pedestrian, and that a pedestrian has behaved unpredictably in April, as well as the change from April to June, and from June to September.

*Table 6 Number of times bicyclists during the last week have experienced not being seen by a pedestrian in April, and mean change from April to June, and from June to September.*

| | April | Mean change from April to June | Change from June to September |
|---|---|---|---|
| Not seen by pedestrian | 22.33 | 0.37 | -2.97* |
| N | | 136 | 172 |

* p<0.05

There is no change in the number of overlooks from April to June. There is a statistically significant drop in the number of times bicyclists are not seen by pedestrians from June to September, $t(172)=2.1$, $p=0.04$).

## 4.3 H3 and H4: Car drivers and pedestrians being surprised by bicyclists

The pedestrians and car drivers were asked how many bicyclists they thought they had seen on the current trip and how many of those that had appeared surprising on them (Table 7).

*Table 7 Number of cyclists encountered on current trip, number of times being surprised by a cyclist for pedestrians and car drivers. Mean.*

| | Pedestrians | | Car Drivers | |
|---|---|---|---|---|
| | Number of bicyclists | Number of times surprised | Number of bicyclists | Number of times surprised |
| April | 6.4 | 0.44 | 4.8 | 0.34 |
| June | 7.2 | 0.49 | 6.3 | 0.31 |
| September | 9.1 | 0.77 | 5.9 | 0.42 |

For pedestrians, the number of bicyclists encountered are as expected, increasing through the season. The number of times pedestrians are surprised is also increasing from June to September. For car drivers, there is an increase in the number of bicyclists they encounter from April to June. From June to September the number of bicycles encountered drops. The number of surprises is rather steady with a small increase from June to September.

A linear regression was conducted using number of surprises as dependent variable, and among other things month as a dummy variable (Table 8). Exposure (number of cyclists met on the current trip) was included as independent variables.

*Table 8 Linear Regression, number of times pedestrians and car drivers are surprised by a bicyclist, baseline April.*

| | Pedestrians | Car drivers |
|---|---|---|
| June | -0.02 | -0.04 |
| Sept | 0.05 | 0.03 |
| Gender | -0.06 | -0.05 |
| Age | -0.01 | 0.15** |
| Number of encounters with cyclists | 0.38*** | 0.16*** |
| Adj $R_2$ | 0.128 | 0.049 |

*** $p < 0.001$
** $p < 0.01$
* $p < 0.1$

The regression model shows that, when controlling for exposure (number of encounters with cyclists), age and gender, the monthly change in number of surprises is not statistically significant.

## 4.4 H5 and H6: Near-misses between bicyclists and other road users

The bicyclists were asked if they had been involved in near-misses with a car or a pedestrian on the current trip. Figure 8 shows the percentage of bicyclists who have near-misses with cars/pedestrians for each of the three months.

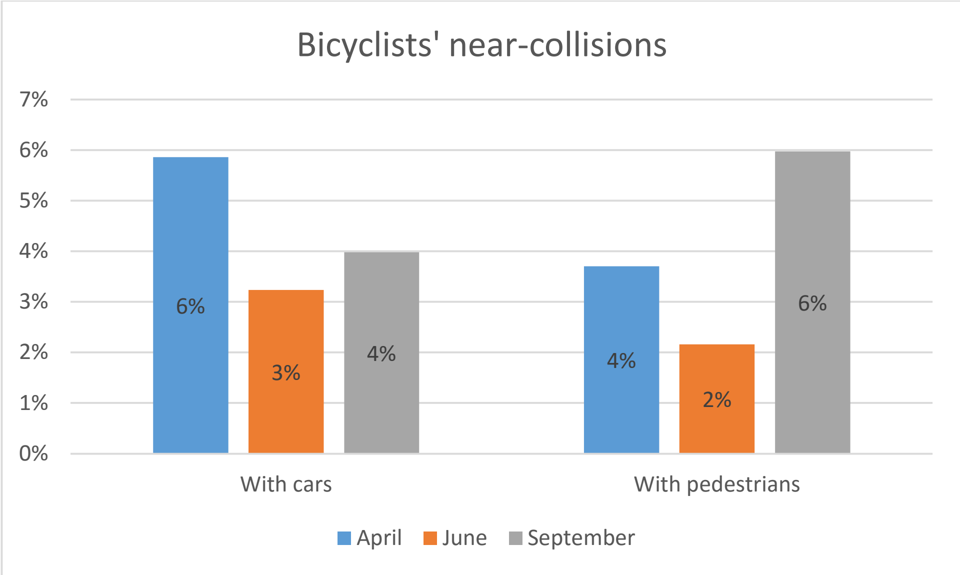


*Figure 8 Bicyclists having had near-misses with cars and pedestrians on current trip in April, June and September. Percent.*

The share of bicyclists who have had near-misses drops from April to June, and then increases from June to September. This holds for both cars and pedestrians as counterparts.

In order to control for changes in the bicyclist population between each interview period, we have conducted two logistic regression analyses (stepwise). Prior to analyses, we tested and confirmed that all the independent variables were well below acceptable levels of multicollinearity (bivariate correlations were in the range 0 to 0.2). Bivariate correlations with the dependent variable were also tested. The highest correlation was between being overlooked and experiencing near misses (r= 0.2 for cars and r=0.21 for pedestrians). Some variables had lower than normally recommended bivariate correlations with the dependent variable, but were included due to theoretical considerations about their potential contribution to explaining near-misses. At step 1 month, gender, age, time of day and distance cycled was included. At step 2 number of times being overlooked by cars/pedestrians on current trip was added.

*Table 9 Logistic regression analyses of near-misses on current trip with cars and pedestrians as counterparts. Exp(b)*

| | ***Cars*** | | ***Pedestrians*** | |
|---|---|---|---|---|
| | **Step 1** | **Step 2** | **Step 1** | **Step 2** |
| Month | | | | |
| June | 0.38** | 0.46 | 0.36 | 0.43 |
| September | 0.65 | 0.85 | 1.89* | 2.17* |
| Gender | 1.19 | 1.29 | 0.90 | 1.00 |
| Age | 0.99 | 1.00 | 0.96** | 0.96** |
| Time of day | | | | |
| Mid day | 0.75 | 0.74 | 0.85 | 0.65 |
| Afternoon | 0.27** | 0.25** | 1.18 | 1.19 |
| Distance cycled | 1.17 | 1.05 | 1.09 | 0.91 |
| # overlooks | | 1.99*** | | 1.88*** |
| **Adj $R_2$ (Nagelkerke)** | 0.06 | 0.13 | 0.07 | 0.18 |

*** p < 0.01
** p < 0.05
* p < 0.1

For near-misses with car drivers there is a statistically significant reduction from April to June, but no change to September at step 1. Time of day (afternoon having a lower likelihood of near-misses) is also statistically significant. When number of overlooks is entered at step 2, the seasonal effect is not statistically significant any more.

For near-misses with pedestrians there is a substantial reduction from April to June, but this change is not statistically significant. The increase in near-misses from April (and from June) to September is statistically significant. Age is also statistically significant (decreased risk of near-misses with increasing age). These effects hold even when we control for number of overlooks at step 2.

Having been overlooked by cars results in an increased likelihood of also being involved in near-misses with cars (Exp(B)=1.99). In the same manner, having been overlooked by pedestrians results in an increased likelihood of also being involved in near-misses with pedestrians (Exp(B)=1.88).

Thus, for both types of near-misses, there is a clear and statistically significant relationship between being overlooked by the opposing road user group and being involved in a near-miss.

The car drivers and pedestrians were also asked if they had experienced a near-miss during the last week in the panel survey. Panel 1 (April to June) and panel 2 (June to September) were used as units of analysis. In order to calculate exposure we used number of trips reported during last week and multiplied with an index figure of estimated number of cyclists (April=1, June=1.5, September=1.4). The index figure for number of cyclists is derived from two sources: 1) The National Travel Behaviour Survey data (Hjorthol et al., 2014), subsample drawn from southeast Norway, mean number of trips per person/day (N=3158) and 2) Bicycle counters (inductive loop) placed at four different locations in Oslo (N=28725). Risk was calculated as occurrence of near-misses/exposure to cyclists.

Figure 9 shows the risk of near-collisions with a cyclist for pedestrians/car drivers interviewed in April and June on the left side, and in June and September on the right side. Note that the mean numbers for the left side June and the right side June differs somewhat, since they represent different, but slightly overlapping, population samples (Panel 1 and Panel 2, as presented in table 1).

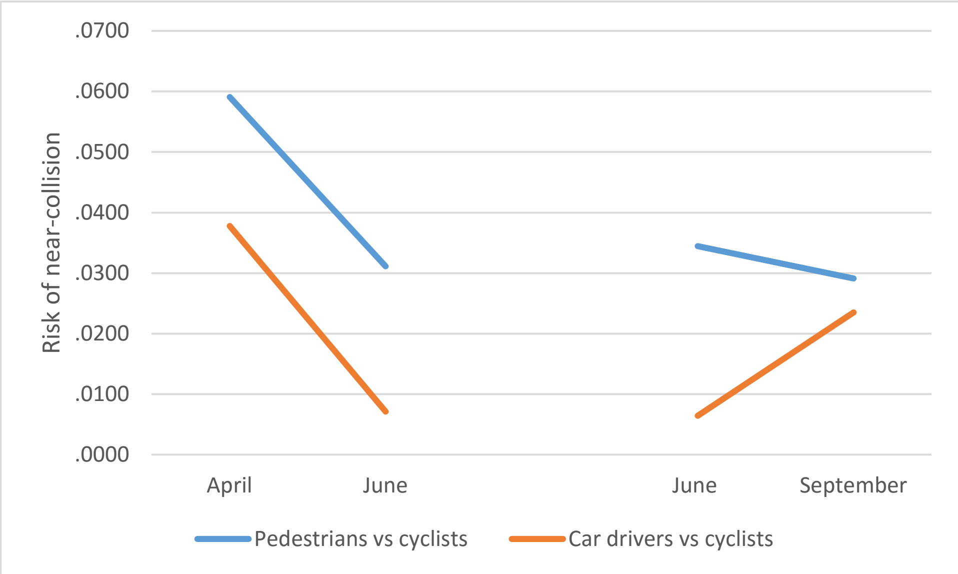


*Figure 9 Risk of near-misses with cyclists during the last week for pedestrians and car drivers. Percent.*

A paired-samples t-test was conducted to compare risk of near-misses in April and June, and in June and September, respectively. Data were first transformed using the Freeman-Tukey transform for Poisson data (Bisgaard & Fuller, 1994).

The drop in risk for near-misses with cyclists is statistically significant for both car drivers $t(30)=2.1$, $p=0.04$) and pedestrians $t(46)=1.8$, $p=0.07$) from April to June. From June to September there is an increased risk for car drivers $t(44)=-1.9$, $p=0.06$), and no change for pedestrians.

# 5 Results of seasonal video observations data

In the following, we summarize the analyses and results concerning hypothesis 7. These results are an excerpt from publication 7 in publication list (appendix 1).

## 5.1 H7: The number of traffic conflicts between car drivers and bicyclists are reduced from April to June and from June to September (video observations)

For each individual intersection, the number of conflicts were too low to produce any statistically significant differences, even though the pattern of change was the same. Table 10 summarizes the exposure, number of conflicts and risk of conflict for all of the four intersections. Data from each individual intersection are presented in the Appendix. The number of conflicts per cyclist does not change much from April to June, but falls towards September. The decrease in risk from June to September is statistically significant at $\alpha = 0.05$ level (two-proportion Z-test).

A similar pattern can be seen even if the motor vehicle x cyclist-measure is used as the exposure. It is not possible, however, to test statistically the risk change since one unit of such exposure (1 motor vehicle x cyclist) is not strictly speaking a trial in statistical terms.

*Table 10 Exposure (number of cyclists), conflicts, and risk of conflict at all four intersections in April, June and September.*

| | | April | June | September |
|---|---|---|---|---|
| **Exposure** | Sites observed | I-III | I-IV | I-IV |
| | Hours | 180 | 300 | 275 |
| | Cyclists (C) | 15060 | 38770 | 46513 |
| | Motor vehicles (MV) | 225198 | 413459 | 390422 |
| | $\Sigma(^{C}/_{h} \cdot {}^{MV}/_{h}) / 10^6$ | 23.68 | 63.18 | 77.52 |
| **Conflicts** | all types | 19 | 51 | 37 |
| **Risk** | Conflicts $\cdot\ 10^3$ / cyclists | 1.26* | 1.32* | 0.80* |
| | Conflicts $\cdot\ 10^6 / \Sigma(^{C}/_{h} \cdot {}^{MV}/_{h})$ | 0.80 | 0.81 | 0.48 |

* difference in risk (conflicts per cyclist) is not statistically significant from spring to summer, but statistically significant at 95% from summer to autumn (two proportion Z-test).

Figure 10 shows the relative change in the number of cyclists, motor vehicles, combined (motor vehicle x cyclist) measure and the risks based on different exposure definitions.

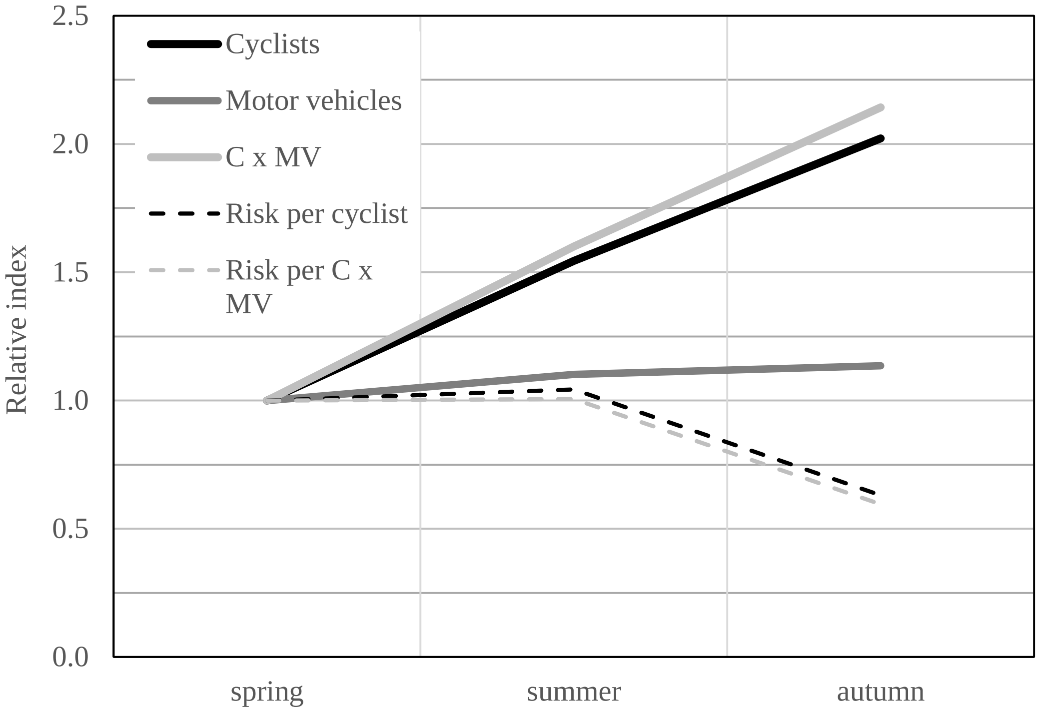


*Figure 10 Relative change in exposure and risk based on aggregated results from the sites I-IV (index for April = 1).*

The number of cyclists increase both from April to June and from June to September, while the amount of motor vehicles does not change much. As a result, the combined exposure measure follows the cyclist number quite close, and the two risks are also very similar. This however is rather a coincidence and one cannot generalise by saying the cyclists count are equally good exposure as the combined measure that takes into account the motor vehicle counts.

The study supports the hypothesis of the Safety-in-Numbers effect in case of the seasonal variation in cyclist number in Norway. However, the mechanisms behind this effects are quite complex. It appears to be a delay in risk reduction following the increased amount of cyclists. The proposed explanations are the learning time for cyclists and motor vehicle drivers to adapt to the new conditions and the change in the cyclists population as the new cyclists coming in the traffic system might be quite different in many aspects compared to all-year-round cyclists.

All in all, we can conclude that the risk of being involved in a conflict for a cyclist is steady in the first part of the cycling season, and then drops significantly in the latter part of the season.

# 6 Results of cross national comparison - survey data

This chapter contains results for the bicyclists, car drivers and pedestrians respectively. The selected variables focus mainly on interplay with other road users. The chapter is structured in accordance with the hypotheses (8 to 13) in the introduction. The field survey and home survey data are analysed in separate subsections. The home survey contains data about traffic culture and the infrastructure cyclists use, these results are discussed in sections 9 and 10. Further details about results in this chapter can be found in publications 13 and 14 in the publication list (appendix 1).

## 6.1 H8: Norwegian bicyclists are more often overlooked by cars

### 6.1.1 Field survey data

The bicyclists were asked to think about their current cycle trip and encounters with cars in different situations (crossings, roundabouts, exit roads, parking areas, etc.). Then they were asked how many times they had experienced that a car driver had failed to see them. Figure 11 show how many times the bicyclists have felt overlooked by a driver.

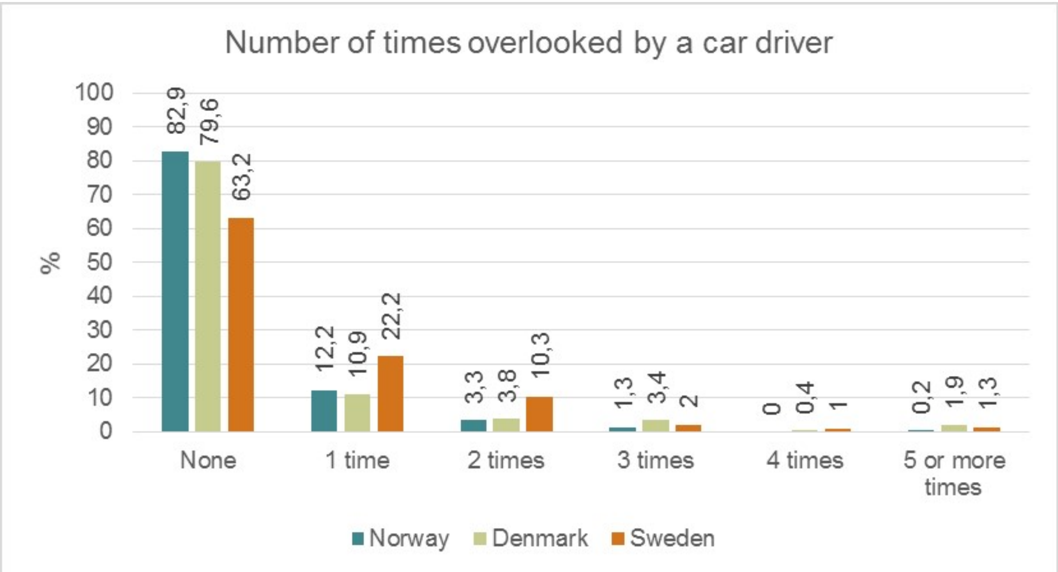


*Figure 11 Bicyclists were asked to think about their current trip and report the number of times they had experienced not being seen by a car driver. The number of interviewed bicyclists are 449 in Norway, 265 in Denmark, and 302 in Sweden. The figure shows percentages within countries.*

The Swedish bicyclists report that drivers fail to see them more frequently than the bicyclists in Norway and Denmark do, 36.8% have been overlooked one or more times (compared to 17.1% in Norway and 20.4% in Denmark)

Due to the distribution of the data, we choose to model being overlooked as a dichotomous variable instead of assessing the number of times overlooked. Table 11 show parameter estimates, lower and upper limits of the confidence intervals, standard error, z-scores and p-values after a logistic regression model was fitted to the response variable "overlooked by car driver" (yes = 1, no = 0). The explanatory variables are trip duration, age, gender, and country. Note that since the aim is to assess whether there is a difference between countries, thorough model selection and investigation of model fit was omitted. However, interaction terms were included and not found significant.

*Table 11 Logistic regression model for response variable* ***overlooked by car driver*** *(yes/no). The explanatory variables are; trip duration (<10 min is reference category), age, gender (female is reference category), country (Norway is reference category). The number of respondents are 449 from Norway, 302 from Sweden, and 265 from Denmark. Regression coefficients estimated to be significantly different from zero at the 0.05 level is indicated with bold text. Model fit: AIC is 1080, null deviance is 1116 (1015 d.f.), and the residual deviance is 1066 (1009 d.f.) ($\chi^2_{0.05,6}$= 12.6<50 and the proposed model is to prefer over the null model.)*

| | *Estimate* | *Std. Error* | *2.5 %* | *97.5 %* | *z value* | *Pr(>\|z\|)* |
|---|---|---|---|---|---|---|
| Intercept | -1.26 | 0.29 | -1.83 | -0.70 | -4.35 | 0.00 |
| Duration: 10-20 min | 0.38 | 0.17 | 0.05 | 0.72 | 2.23 | 0.03 |
| Duration: > 20 min | 0.49 | 0.22 | 0.07 | 0.92 | 2.28 | 0.02 |
| Age | -0.01 | 0.01 | -0.03 | 0.00 | -2.17 | 0.03 |
| Male | -0.07 | 0.16 | -0.38 | 0.24 | -0.45 | 0.66 |
| Denmark | 0.21 | 0.21 | -0.20 | 0.61 | 1.02 | 0.31 |
| Sweden | 0.83 | 0.19 | 0.46 | 1.21 | 4.36 | 0.00 |

Not surprisingly, the coefficient for trip duration is estimated to be significantly different from zero. The interpretation of the estimated parameters of 0.38 for "10-20 min" and 0.49 for ">20 min" are that a longer trip increases the log odds of being overlooked. This is as one would expect; a longer trip is likely to imply more interactions with cars. The effect of age is that it reduces the log odds of being overlooked, so does being a male, but gender is not a significant effect. The largest effect is the variable representing Sweden, with an estimate of 0.83 or odds ratio exp(0.83) = 2.3. Note also that the confidence interval is far away from zero. Thus, the observed tendency in the data in Figure 11, is that Swedish bicyclists are more overlooked, also holds when the variables trip duration, age, and gender are controlled for. Being from Denmark does not significantly alter the log odds compared to the reference country Norway.

### 6.1.2 Home survey data

In the home survey, the respondents were asked about their experiences over the last week, their evaluation of other road users, bicycle type/equipment, infrastructure, and personality.

The home survey respondents were asked to think about the last week that had passed and imagine that they encountered 100 cars. Then they were asked to state how many of the car drivers that would have acted in such a way that they must have failed to see them. The scale was "none", "ca. 10", "ca. 20", …,"ca. 90", "all". Figure 12 show the data.

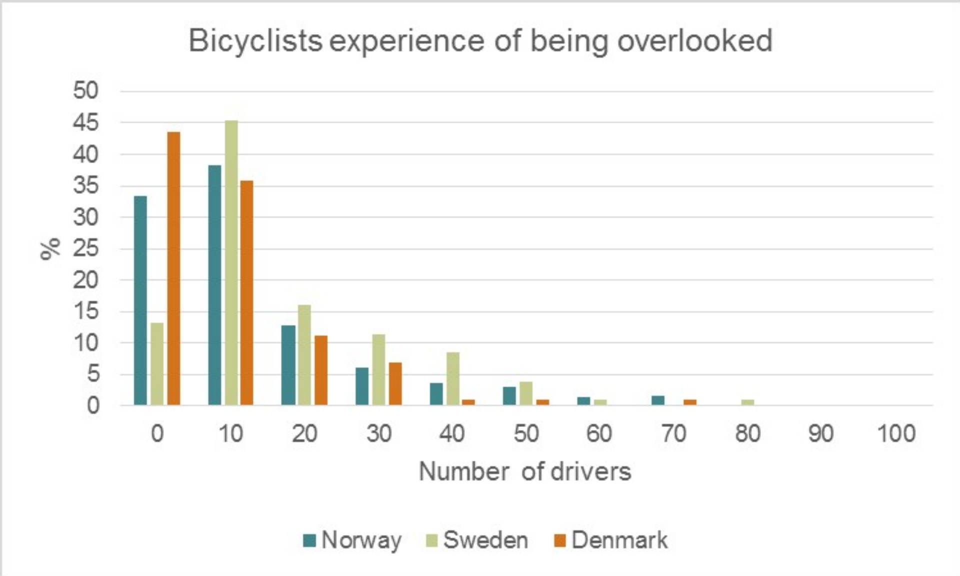


*Figure 12 Bicyclists were asked to think about their encounters with cars over the last week and state how many of in total 100 that would have failed to see them. The figure shows percentage within each country. The number of respondents are 384 from Norway, 106 from Sweden, and 117 from Denmark.*

The Swedish bicyclists report that they are overlooked more frequently than Norwegian and Danish bicyclists do. To control for other variables, linear regression models were fitted to the data and the outcome variable is the number of times overlooked by a car driver. Three models were fitted: in Model 1 country is the only explanatory variable included, in Model 2 demography variables are included in addition to the country effect, and in Model 3 personality variables are added to the set of explanatory variables. Results are given in Table 12.

*Table 12 Linear regression model with* ***number of times overlooked by car driver*** *as response variable. The explanatory variables are country (with Norway as reference category), age, gender (with female as reference category) and personality traits. The number of respondents are 384 from Norway, 106 from Sweden, and 117 from Denmark.Regression coefficients estimated to be significantly different from zero at the 0.05 level is indicated with bold text.*

| | Model 1 | | | Model 2 | | | Model 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Estimate | Std.error | p-value | Estimate | Std.error | p-value | Estimate | Std.error | p-value |
| Intercept | 2.31 | 0.07 | 0.00 | 2.96 | 0.23 | 0.00 | 2.43 | 0.65 | 0.00 |
| Sverige | 0.47 | 0.16 | 0.00 | 0.23 | 0.18 | 0.19 | 0.21 | 0.18 | 0.24 |
| Danmark | -0.38 | 0.15 | 0.01 | -0.50 | 0.16 | 0.00 | -0.49 | 0.16 | 0.00 |
| Age | | | | -0.01 | 0.00 | 0.04 | -0.01 | 0.00 | 0.07 |
| Male | | | | -0.40 | 0.12 | 0.00 | -0.41 | 0.13 | 0.00 |
| Extraversion | | | | | | | -0.04 | 0.06 | 0.54 |
| Neuroticism | | | | | | | 0.04 | 0.06 | 0.53 |
| Openness | | | | | | | 0.06 | 0.05 | 0.28 |
| Conscientiousness | | | | | | | -0.09 | 0.07 | 0.18 |
| Agreeableness | | | | | | | 0.14 | 0.08 | 0.07 |
| $R^2$ | 0.03 | | | 0.06 | | | 0.07 | | |

When country is the only variable included in the model, there is a significant difference between Norway and the two other countries. The effects of Sweden and Denmark have opposite signs; more overlooks in Sweden and fewer overlooks in Denmark. When the demographic variables age and gender are added to the model, there is no longer a significant country effect for Sweden. This indicates that the observed difference in the response variable is because there are more females in the group of Swedish respondents. However, the effect of Denmark remains significant. Both age and gender are significant effects. The younger respondents report more overlooks and female respondents report more overlooks. In Model 3, the personality variables are included. None of them are significant at the 0.05 level, but when controlled for personality, age is no longer significant.

### 6.1.3 H8 conclusion

The *field survey* data failed to produce any difference between Norway and Denmark, even if the tendency was in the assumed direction. Contrary to assumptions, the Swedish bicyclists more often experience to be overlooked by car drivers. When looking at the results of the *home survey*, the data confirms that cyclists in Norway are more often overlooked than in Denmark. Hence, the hypothesis is partly confirmed.

## 6.2 H9: Norwegian bicyclists are more often overlooked by pedestrians

### 6.2.1 Field survey data

The bicyclists were asked to think about their cycle trip and encounters with pedestrians in different situations (crossings, sidewalks, etc.). Then they were asked how many times on their current trip they had experienced that a pedestrian had failed to see them. Figure 13 shows how many times bicyclists from the different countries have experienced not being seen by a pedestrian.

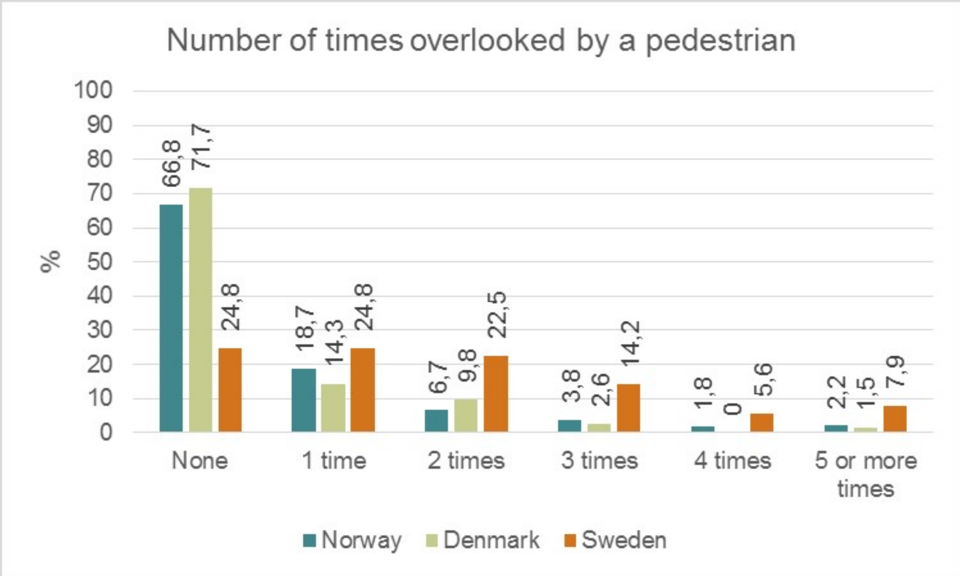


*Figure 13 Bicyclists were asked to think about their current trip and report the number of times they had experienced not being seen by a pedestrian. The number of interviewed bicyclists are 449 from Norway, 265 from Denmark, and 302 from Sweden. The figure shows percentages within countries.*

The Swedish bicyclists report that pedestrians fail to see them more often than Norwegian and Danish bicyclists do, only one quarter of the Swedish bicyclists have not been overlooked A simplified analysis was carried out by representing being overlooked with a binary variable. Table 13 show the results of the model fit.

*Table 13 Logistic regression model for response variable* **overlooked by pedestrian** *(yes/no). The explanatory variables are; trip duration (<10 min is reference category), age, gender (female is reference category), country (Norway is reference category). The number of respondents are 449 from Norway, 302 from Sweden, and 265 from Denmark. Regression coefficients estimated to be significantly different from zero at the 0.05 level is indicated with bold text. Model fit: AIC is 1215, null deviance is 1396 (1015 d.f.), and the residual deviance is 1201 (1009 d.f.). ($\chi^2_{0.05,6}$= 12.6<195 and the proposed model is to prefer over the null model.)*

| | Estimate | 2.5 % | 97.5 % | Std. Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|---|---|
| Intercept | -0.44 | -0.94 | 0.05 | 0.25 | -1.75 | 0.08 |
| Duration: 10-20 min | 0.55 | 0.24 | 0.86 | 0.16 | 3.49 | 0.00 |
| Duration: > 20 min | 0.72 | 0.33 | 1.12 | 0.20 | 3.60 | 0.00 |
| Age | -0.02 | -0.03 | -0.01 | 0.01 | -2.90 | 0.00 |
| Male | 0.01 | -0.27 | 0.29 | 0.14 | 0.05 | 0.96 |
| Denmark | -0.21 | -0.56 | 0.14 | 0.18 | -1.17 | 0.24 |
| Sweden | 1.62 | 1.27 | 1.98 | 0.18 | 8.95 | 0.00 |

Being from Sweden is what increases the log odds of being overlooked the most. Being from Denmark on the other hand, reduces the log odds, although not significantly.

### 6.2.2 Home survey data

A similar analysis was conducted for overlooks by pedestrians reported in the home survey. The Swedish bicyclists report that more pedestrians fail to see them. Figure 14 show the data and Table 14 show a summary of the linear regression analysis.

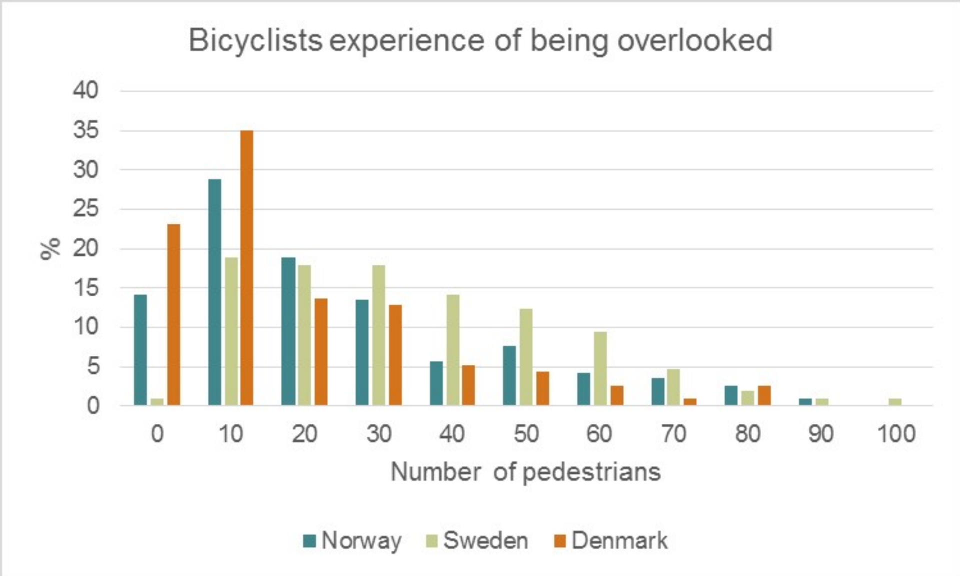


*Figure 14 Bicyclists were asked to think about their encounters with pedestrians over the last week and state how many of in total 100 that would have failed to see them. The figure shows percentage within country. The number of respondents are 384 from Norway, 106 from Sweden, and 117 from Denmark.*

*Table 14 Linear regression model with* ***number of times overlooked by pedestrian*** *as the response variable. The explanatory variables are country (with Norway as reference category), age, gender (with female as reference category) and personality traits. The number of respondents are 384 from Norway, 106 from Sweden, and 117 from Denmark. Regression coefficients estimated to be significantly different from zero at the 0.05 level is indicated* ***with bold text****.*

| | Estimate | Std.error | p-value |
|---|---|---|---|
| Intercept | **3.97** | 0.95 | 0.00 |
| Sweden | **0.83** | 0.26 | 0.00 |
| Denmark | **-0.69** | 0.23 | 0.00 |
| Age | 0.00 | 0.01 | 0.69 |
| Male | -0.27 | 0.18 | 0.14 |
| Extraversion | 0.08 | 0.08 | 0.36 |
| Neuroticism | 0.02 | 0.09 | 0.83 |
| Openness | 0.16 | 0.08 | 0.05 |
| Conscientiousness | -0.03 | 0.10 | 0.77 |
| Agreeableness | -0.22 | 0.11 | 0.05 |
| $R^2$ | 0.07 | | |

There is a statistically significant country effect; more frequent overlooks in Sweden and less frequent overlooks in Denmark (when compared to Norway). The country effect is significant also controlling for demography and personality variables.

### 6.2.3 H9 conclusion

As for H8, there was tendency, but not significant for Norwegian cyclists to be more often overlooked than Danish, when looking at the field survey data. The home survey data showed a significant difference in the hypothesised direction. Again, contrary to assumptions, Sweden was the country where cyclists where mostly overlooked (field and home survey)

## 6.3 H10 and H11: Near-misses with cars and pedestrians

Bicyclists were asked if they had experienced a near miss with car and a pedestrian during their trip, i.e. that either they or the other party had to abruptly brake or make a turn to avoid collision. These results are presented in publication 14 (appendix 1), but can be summarized as follows:

- There is no significant difference between the countries when it comes to near-misses with cars.
- Swedish cyclists are more often involved in near misses with a pedestrian, but there is no difference between Norway and Denmark.

## 6.4 H12: Norwegian car drivers are relatively more often surprised by a bicyclist

### 6.4.1 Field survey data

The total number of motorists recruited to the roadside interview were 591. Of these: 34% (203) come from Norway, 39% (230) come from Sweden, and 27% (158) come from Denmark. Further details about background variables can be found in publication 14 (appendix 1).

The interviewed car drivers were asked the question: "*Approximately how many bicyclists do you think you passed in total?*" The scale is a nine-point scale from none to more than fifty bicyclists. Norwegian car drivers report to have met fewer bicyclists than the Swedish and Danish drivers did. In Denmark, the cars have passed more bicyclists than in Sweden. The number of bicyclists met is included in the analysis that follows as a metric variable with integer values from 0 to 8.

The interviewed drivers were asked to think about the trip they just had taken and their encounters with bicyclists in different situations (crossings, roundabouts, exit roads, parking areas etc.). Then they should state how many times they had experienced being surprised by a bicyclist. What they answered can be seen in Figure 15. Data from 65 Norwegians and 6 Swedes were missing for this particular variable.

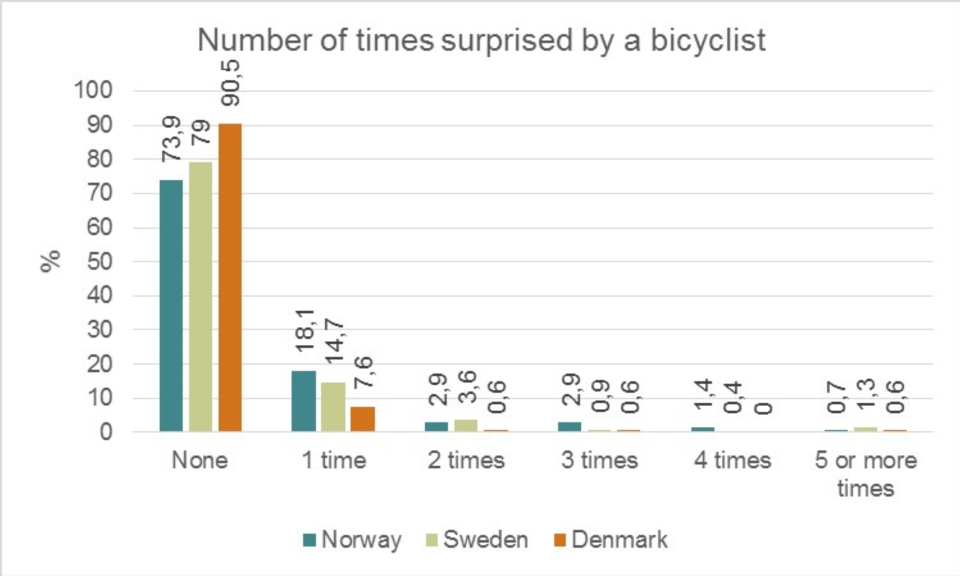


*Figure 15 Car drivers in the field survey were asked how many times they had experienced being surprised by a bicyclist. The figure shows percentages within country. The number of respondents are 138 from Norway, 224 from Sweden, and 158 from Denmark.*

A majority of the car drivers had not been surprised by a bicyclist. To simplify the analysis a binary variable, "surprised"/"not surprised", was created and logistic regression was carried out with surprised (yes = 1, no = 0) as the response variable and the number of bicyclists met, age, gender and country as explanatory variables.

As expected the more bicyclists met the higher is the log odds of being surprised by one. For Danish car drivers the log odds of being surprised is smaller than for Swedish drivers, who again have a smaller odds than the Norwegian drivers. This is in accordance with Figure 15, and adding gender, age and the number of bicyclists met as explanatory variables did not remove the country-effect seen on the figure.

### 6.4.2 Home survey data

The home survey data consist of answers from 87 Norwegians, 51 Swedes, and 69 Danes. Due to an error, no question was asked about number of times car drivers had been surprised by bicyclists in the home survey. The data about near misses can be used as a proxy for situations with overlooks.

Figure 16 show percentages of car drivers that have experienced a near miss with a bicyclist the last week.

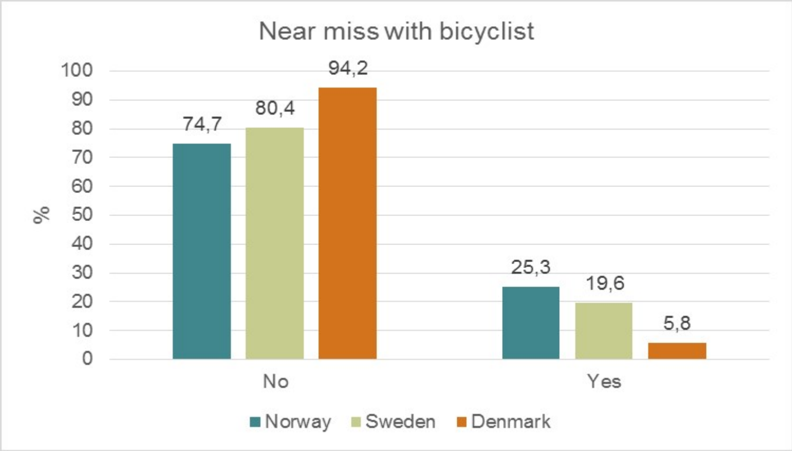


*Figure 16 Home survey motorists were asked if they had experienced a near miss with a bicyclist the last week. Number of respondents; Norway: 87, Sweden: 51, and Denmark: 69.*

Very few Danish drivers have experienced a near miss with a bicyclist, but as many as 25.3% of the Norwegian drivers have experienced this. There is a clear difference between the countries, but can this be explained by other factors? To investigate this, a logistic regression model was fitted to the response variable near miss with bicycle with explanatory variables; country age, gender, personality traits, and infrastructure variables.

There is a significant difference between the countries when controlling for demography, personality and infrastructure. The other coefficients are estimated not to be significantly different from zero. Danish motorists experience fewer near misses with bicyclists. The lower risk of near misses in Sweden is in the right direction, but not significant.

### 6.4.3 H12 conclusion

All in all, these results confirms the hypothesis, since Danish car drivers are less often surprised by cyclists and are less often involved in near misses. The expected difference between Norway and Sweden, was partially confirmed.

## 6.5 H13: Norwegian pedestrians are relatively more often surprised by a bicyclist

### 6.5.1 Field survey data

The field survey data contains answers from 527 pedestrians: 42% (224) are from Norway, 27% (141) are from Sweden, and 31% (162) are from Denmark.

The pedestrians that were stopped and interviewed while they were walking, were asked whether they could recall being surprised by one or more bicyclists on their current trip. Answers are missing from 21 Norwegians, 5 Swedes, and 8 Danes. Figure 17 shows what the rest of the respondents answered.

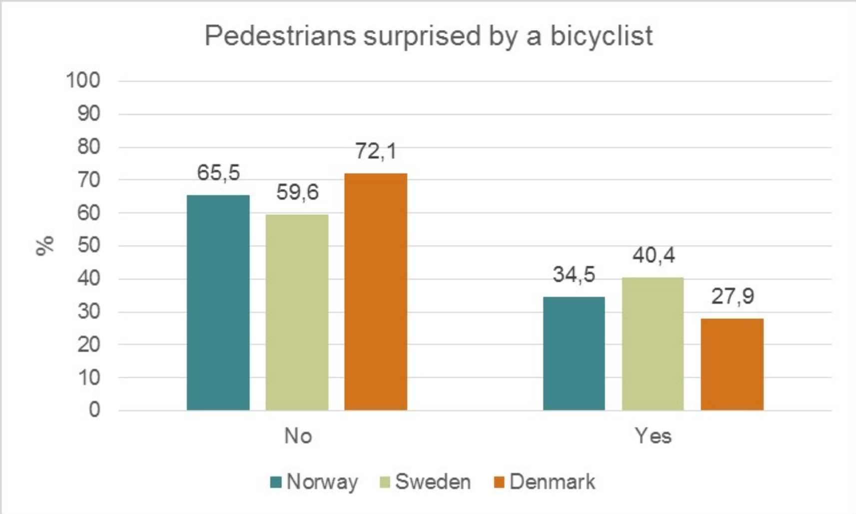


*Figure 17 Field survey pedestrians were asked if they could recall being surprised by one or more bicyclists during their trip. The figure shows percentages within countries. Number of respondents: Norway (N=203), Sweden (N=136), Denmark (N=154).*

A logistic regression model was fitted to the data with "surprised"/"not surprised" as dependent variable and trip duration, number of bicyclists passed, age, gender, and country as independent variables. The only variable that is statistically significant ($p<0.05$) is the number of bicyclists passed. Not surprisingly, having met many bicyclists increases the log odds of being surprised. Being from Denmark decreases the log odds of being surprised ($p=0.07$).

### 6.5.2 Home survey data

The dataset used in the analysis contains answers from in total 221 pedestrians: 139 (63%) from Norway, 30 (14%) from Sweden, and 52 (23%) from Denmark. As for car drivers, no question was asked about surprises in the home survey, so we use near misses as a proxy.

The question the pedestrians were asked is: "*Have you the last week experienced a near miss with a bicyclists, i.e. that one or both of you had to stop or turn suddenly to avoid collision?*" Figure 18 presents the answers.

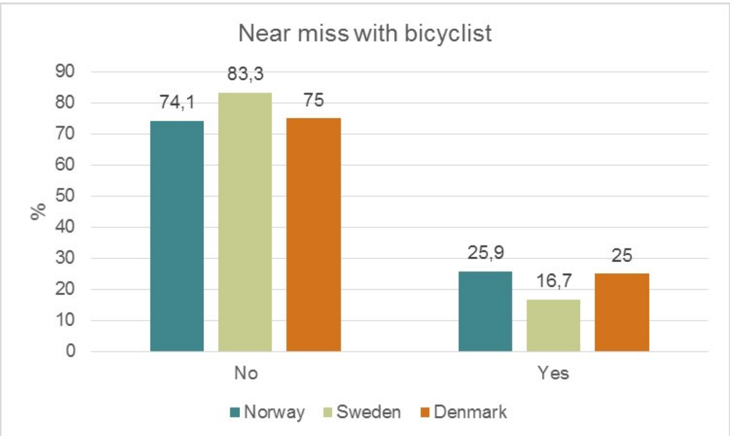


*Figure 18 Pedestrians were asked if they had experienced a near miss with a bicyclist the last week. The figure shows percentage within country. The number of respondents are 139 from Norway, 30 from Sweden, and 52 from Denmark.*

Norwegian and Danish pedestrians have answered quite similarly, approximately a fourth part have experienced a near miss with a bicyclist. A slightly smaller percentage of the Swedish pedestrians report a near miss. However, there are few respondents to base this observation on. Note that the Swedish bicyclists reported more near misses with pedestrians than the Norwegian and Danish bicyclists did.

To see if any of the factors demography, personality or infrastructure are associated with having experienced a near miss, logistic regression was carried out with "near miss"/"not near miss" as the binary outcome variable. This analysis confirmed that the Swedish pedestrians' lower reported number of near misses was statistically significant (p=0.06) when controlling for demography, personality, and infrastructure variables.

### 6.5.3 H13 conclusion

The hypothesis was that Norwegian pedestrians were more often surprised by cyclists than other pedestrians. The data from the field survey showed that Danish pedestrians are least often surprised by cyclists. The home survey data looking at near misses found that the Swedish pedestrians were less often involved in near miss situations. In all, the hypothesis is thus confirmed.

# 7 Results of cross national comparison - video observations

The study sites in Denmark and Sweden were selected according to one of the criteria: *i*) the design should be comparable with a corresponding Norwegian intersection; or *ii*) the design should be "typical" for the country and different from the design of the corresponding Norwegian intersection, but relatively similar in motor vehicle and cyclist flow composition. Sites selected according to the first criterion would allow to compare the effects of difference in the safety culture and quality of the interactions and those selected according to the second one would allow to analyse also the effects of the infrastructure. Further details about these results can be found in publication 15 in the publication list (appendix 1).

Table 15 gives a summary of findings for the comparison between Norway and Denmark.

*Table 15 Exposure, conflicts and risks aggregated for sites N1-N4 (Norway) and D1-D4 (Denmark).*

| | | **Norway** | **Denmark** |
|---|---|---|---|
| **Exposure** | Hours | 275 | 300 |
| | Cyclists (C) | 46513 | 45171 |
| | Motor vehicles (MV) | 390422 | 312740 |
| | $\Sigma(^{C}/_{h} \cdot {}^{MV}/_{h}) / 10^6$ | 77.52 | 49.32 |
| **Conflicts** | all types | 37 | 25 |
| **Risk** | Conflicts $\cdot 10^3$ / cyclists | 0.80* | 0.55* |
| | Conflicts $\cdot 10^6 / \Sigma(^{C}/_{h} \cdot {}^{MV}/_{h})$ | 0.48 | 0.51 |

* difference in risk (conflicts per cyclist) is significant at 90%.

The total number of counted cyclists were quite comparable, but there were fewer motor vehicles in Denmark. The number of conflicts for all hours of recording were 37 in Norway and 25 in Denmark. When we calculate a risk per cyclist for each country this sums up to 0.8 for Norway and 0.55 in Denmark, which is a statistically significant difference ($p<0.1$). When we calculate the risk as function of motor vehicles times cyclists, the difference no longer becomes significant.

Figure 19 presents the relation between the number of cyclists and conflict risk per cyclist for all the sites in Norway, Denmark and Sweden used in this study.

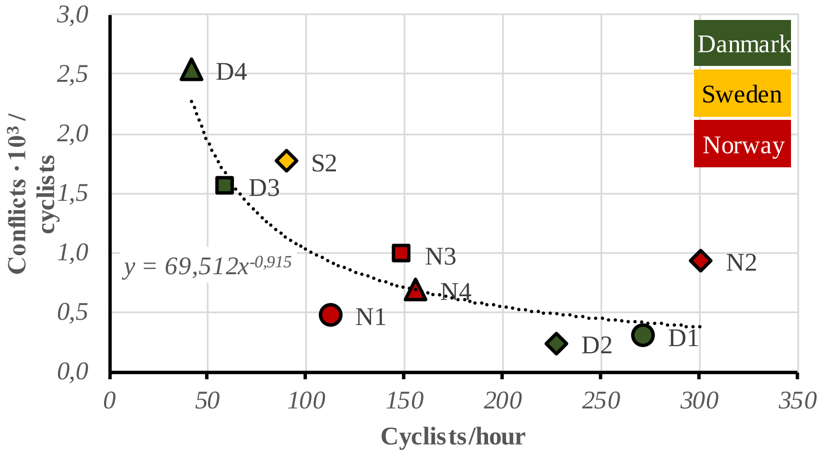


*Figure 19 Relation between cyclist number and conflict risks per cyclists at all sites (N1-N4, D1-D4, S2).*

At first sight, the data supports the Safety-in-Number phenomenon, even to a larger extent than when we look at the aggregated cross-country differences. Upon inspection of individual pairs of sites, we can see that sites N4 and D4 (the roundabouts) differs from all the others. For all other sites the risk of conflicts is lower in Denmark than in Norway, whereas for the roundabout the risk of a conflict is higher in Denmark. As we discuss in chapter 9 the difference in conflict levels can probably be ascribed to particularities about the infrastructure design of the roundabout. We therefore recalculated the risk of conflicts for the sites 1-3. Results are given in Figure 20.

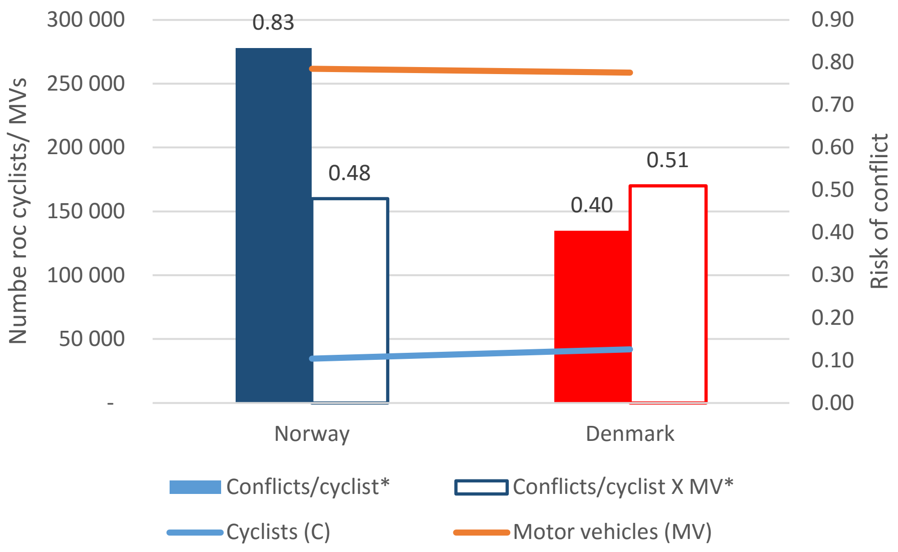


*Figure 20 Exposure, conflicts and risks aggregated for sites N1-N3 (Norway) and D1-D3 (Denmark).*

In total the number of cyclists and motor vehicles for these sites is quite comparable, but the number of conflicts is far lower in Denmark than in Norway. As a function of this the risk of being involved in a conflict, is far lower in Denmark, regardless of how we have calculated exposure.

## 7.1 H14: There are more traffic conflicts between car drivers and bicyclists in Norway than in Denmark when controlling for exposure (video observations)

The cross-country comparison also seems to support Safety-in-Numbers. Individual intersections with few cyclists have more conflicts. At an aggregated level, Denmark where cyclists are more common have fewer bicycle related conflicts per road user than Norway. However, additional factors have to be taken in consideration, such as the individual design of the intersections compared and the general traffic culture in each country. These issues will be addressed in Chapters 9 and 10.

# 8 Survey of tram drivers

This study was done as a separate part of the project. The aim was to investigate:

- if tram drivers experienced a change in number of surprises through the cycling season
- if there is a difference in how tram drivers perceive types of cyclists

Data was collected in three time periods in 2014: week number 18 (April), week number 25 (June) and week number 38 (September). Participants were tram drivers in the "Sporveien Trikken AS" (Oslos municipal tram company). Prior to the first data collection, an information meeting with the drivers was held, in which they were informed about the general purpose of the survey. Two data collections were carried out, a field survey and a home survey. Further details about these results can be found in publications 16 and 19 in the publication list (appendix 1).

## 8.1 H15: Tram drivers are less surprised by bicyclists through late in the cycling season

Table 16 shows the number of times tram drivers are surprised thoughout the season, and relative number of cyclists. The number of surprises are an average of all three interview days and morning an afternoon pass for each period. The relative number of cyclists is the same as used to calculate car drivers' surprises (section 4.4).

*Table 16 Number of times tram drivers are surprised thought the season, and relative number of cyclists.*

| | *April (90)* | *June (72)* | *September (63)* |
|---|---|---|---|
| A cyclist appeared unexpectedly at an intersection | 1.28 | 0.93 | 1.28 |
| A cyclist appeared unexpectedly between two parked cars | 0.50 | 0.23 | 0.60 |
| Relative number of cyclists | 1.0 | 1.5 | 1.4 |

Both types of surprise situations drop from April to June, and then increases from June to September, whereas the number of cyclists is estimated to increase in steadily in the season.

In order to test if these changes are statistically significant we computed a mean surprise risk variable ((unexpected at intersection/ relative number of cyclists + unexpected between parked cars/relative number of cyclists)/2).

An independent samples t-test was conducted to compare overlooks in April and June, and in June and September, respectively. There is a statistically significant drop in the number of times tram drivers are surprised by cyclists from April (Mean= 0.89) to June (Mean=0,37), $t(72)=3.83$, $p<.001$). The increase from June (Mean= 0.37) to September (Mean=0.99) is also statistically significant $t(63)=2.49$, $p=0.013$).

Because a number of the tram drivers responded several times (22 in April/June and 20 in April/September), it is possible to make a repeated measures design from these data. Again we used the mean surprise risk variable.

A paired-samples t-test was conducted to compare overlooks in April and June, and in June and September, respectively. There is a statistically significant drop in the number of times tram drivers are surprised by cyclists from April (Mean= 1.89) to June (Mean=0.99), $t(22)=4.15$, $p<0.001$). The increase from June (Mean=1.07)[3] to September (1.16) is not statistically significant.

## 8.2 What types of cyclists cause poor interplay?

Among the questions asked in the home survey, was one question about what types of cyclists that they perceived as most unpredictable in traffic (on a scale from 1 "to a little degree" to 7 "to a large degree"). The drivers were presented with three types of cyclists "Hipsters", "Lycra-cyclists"/"Birken" [4] and "older women with a basket". Each category was illustrated with a picture, as seen in the figure below.

Figure 21 shows the mean scores for types of cyclists that are most unpredictable.


*Figure 21 What type of cyclists tram drivers perceive as unpredictable. Mean scores.*

The hipster cyclists are perceived as the most unpredictable and the older lady type as least unpredictable, with the lycra cyclist in the middle. Only the difference between older lady and the others is significant (one sample t-test).

[3] Note that the means for June differs in the first and second paired comparison, since the pairs represent slightly different parts of the sample.

[4] The name is from a traditional cycling race in Norway.

# 9 Can infrastructure differences explain SiN effects?

As we showed in chapter 6 there are significant differences between Norway and Denmark when it comes to how expectant car drivers and pedestrians are of cyclists in traffic. The difference between Norway and Sweden is not so clear-cut. Nevertheless, the question then arises, can these differences be ascribed to differences in infrastructure? Further details about these results can be found in publications 7, 13, 14 and 15 in the publication list (appendix 1).

The degree of separation with other road user groups is believed to influence the number of conflicts a bicyclist experience. Thus, we use infrastructure variables to include information about the traffic environment each bicyclist is exposed to in the models. Figure 22 gives an overview of the infrastructure the bicyclists report to use.

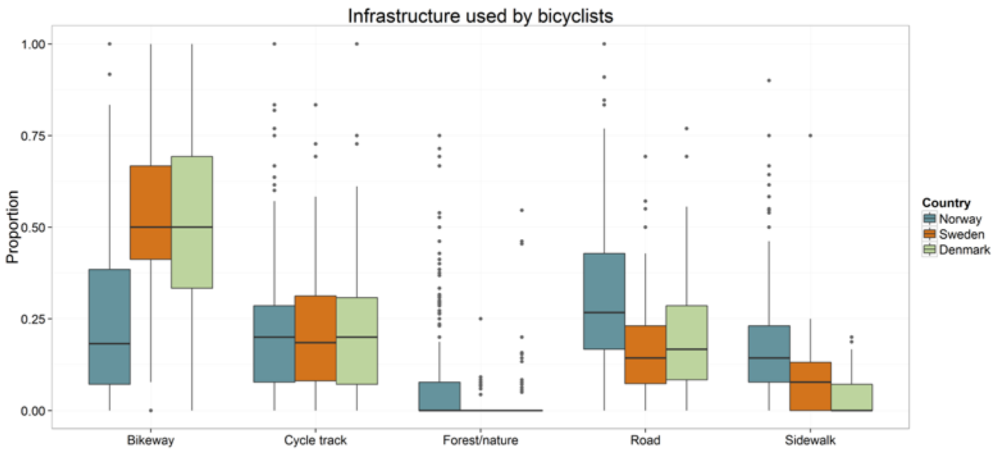


*Figure 22 Comparison of proportions of the infrastructure used by bicyclists from Oslo (N=384), Gothenburg (N=106), and Aalborg (N=117).*

A simple one-way ANOVA analysis shows what the figure already reveal, there is a statistical significant country effect for all infrastructure types except for “cycle track”. These data reflect already known differences between the road types available for bicyclists in the three countries, e.g. less use of bikeways and more use of roads/sidewalks in Norway. If Norway is held out of the analysis, there is a significant difference between Denmark and Sweden for “road” and “sidewalk”, but not for the other infrastructure types.

In order to test if infrastructure influences number of overlooks or surprises, we included these variables in the final step of the above reported regression models for home survey data (see section 6.1.2).

In a model with number of times cyclists being overlooked as a dependent variable, none of coefficients for the infrastructure variables are found to be significantly different from zero, but their signs are in the direction one would expect. If a bicyclist has a high share of trips on roads, cycle tracks, or sidewalks, they are more overlooked by cars. Separate bikeways reduces the number of times overlooked. These effects are not statistically significant, but it is interesting that the data show the tendency "common sense" would say. Also for overlooks by pedestrians, the infrastructure variables did not come out with effects significantly different from zero. But also here the pattern was as expected, with those cyclists being less exposed to pedestrians being less often victims of overlooks.

## 9.1 Results from video data

Closer examination of the conflicts at each site reveals, that the individual differences in design of the infrastructure have an important role in how many and what type of conflicts that take place. Sites N4 and D4 provide a very good example. Being both roundabouts, the sites have a different solution for handling cyclists. In Norway, the cyclists are integrated with the motor vehicles and the most common conflict types are either motor vehicle or cyclist not yielding properly when entering the roundabout. In Denmark, the cyclists have a separate lane in the roundabout ring, and the dominating conflict type is the situation when a motor vehicle wants to exit the roundabout while the cyclists continues in the ring. The latter are in fact the most serious types of conflicts, and as mentioned also more common. For this reason Danish road authorities now advice against this form of roundabout design, and move more towards total separation in roundabouts.

Also sites N3-D3 handle the cyclist in very different way. The Danish intersection has clearly marked cycle lanes and passages through the intersection while the Norwegian one has only a cycle lane at one leg of the intersection. As a result, even though the total number of cyclists is lower at the Danish site, the interactions with motor vehicles (e.g. C straight, MV right) are much more frequent, and the risk of conflicts is in fact somewhat larger in Denmark than in Norway.

## 9.2 Conclusion

All in all, our results support previous research showing that different solutions for infrastructure design can contribute to differences in conflict levels, and that the SiN phenomenon can partly be explained by this. But as we have shown, not all of the SiN effect can be explained by this, and we have also shown that even countries with high cycling numbers, such as Denmark have applied some conflict-inducing solutions that function to dilute a potential positive effect of increased numbers.

# 10 Can SiN be ascribed to differences in traffic culture?

Further details about these results can be found in publications 7, 13, 14, 15 and 19 in the publication list (appendix 1).

## 10.1 Survey data

### 10.1.1 Other road users' behaviour

A number of questions from the cross national comparison can be used to illustrate differences in traffic culture between the different countries.

All participants were asked questions about how the other road users behaved towards them in traffic. As an example, bicyclists were asked the following questions; Think about how it has been to cycle the last week. To what extent have you experienced that car drivers:

i. pay attention to you as a bicyclist in traffic,

ii. show consideration towards you as a bicyclist,

iii. comply with the duty to yield right-of-way,

iv. comply with the traffic rules.

The answers are given on a seven-point Likert scale from not at all (1) to very much (7). To summarise the bicyclists' experience of car drivers' behaviour, an index is computed as the mean of the four variables. Figure 23 show density plots of the behaviour index for each country.

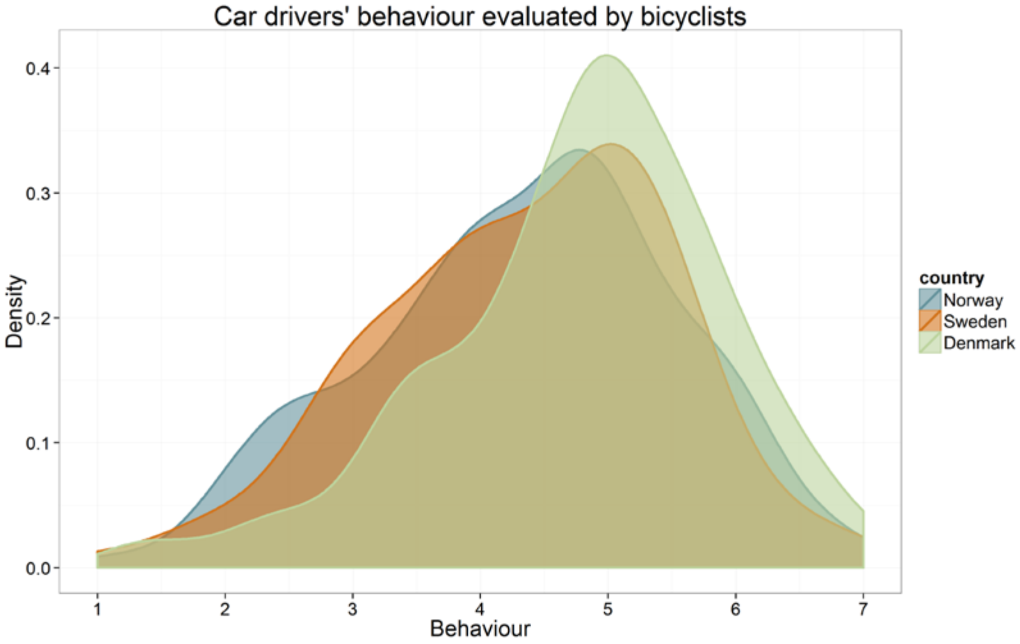


*Figure 23 Density plots of the car drivers' behaviour index. Higher values on the x-axis means that the bicyclists have reported better behaviour. The number of respondents are 384 from Norway, 106 from Sweden, and 117 from Denmark.*

The Danish bicyclists evaluate the car drivers' behaviour as better than the Norwegian and Swedish bicyclists do. The mean values are for Norway: 4.3, Sweden: 4.4, and Denmark: 4.8. A linear regression confirms that Danish bicyclists evaluate Danish car drivers' behaviour as better than Swedish and Norwegian bicyclists evaluate the drivers in their respective countries, when demography, personality, and infrastructure is controlled for.

In order to compare all road users' assessments of the other road users' behavior we have summarized the mean behavioral assessment scores. Figure 24 shows as radar plot of mean scores on the behavioural index for car drivers, pedestrians and bicyclists from Norway, Sweden and Denmark. The assessing road user group is placed in brackets.

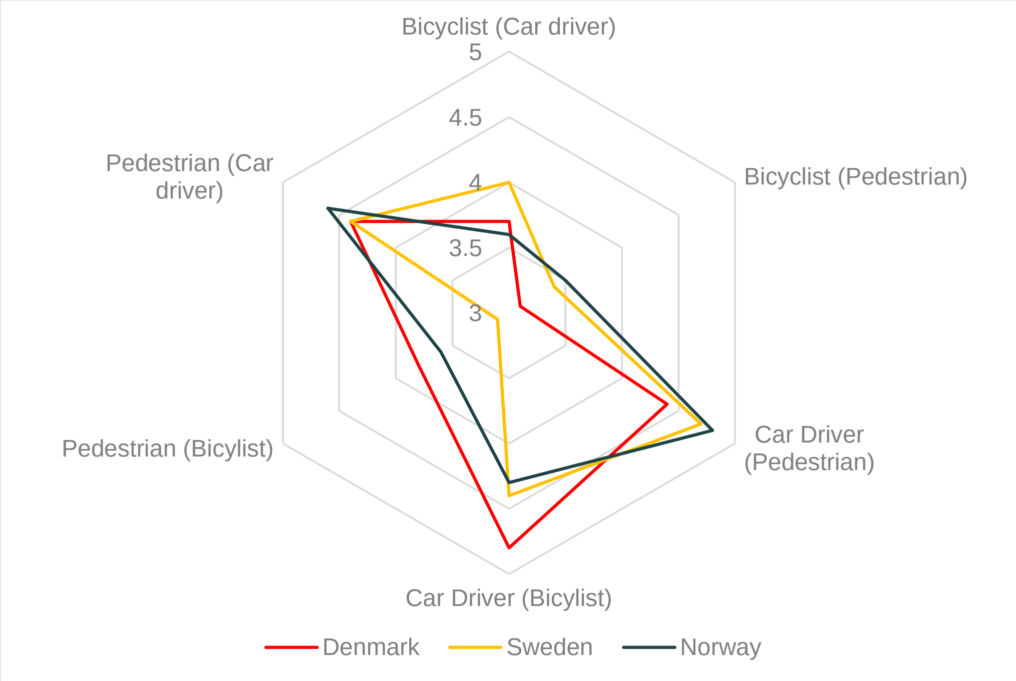


*Figure 24 Radar plot of mean scores on the behavioural index for car drivers, pedestrians and bicyclists from Norway, Sweden and Denmark. The assessing road user group in brackets.*

Generally speaking, road users in each county agree with each other on the assessment of other road users. The worst interaction pattern (shortest distance) is between cyclists and pedestrians, and the best is between pedestrians and car drivers. Car drivers are seen as more considerate by cyclists than vice versa. When we compare the different countries we see that Swedish bicyclists and Danish car drivers stand out as the most well-behaved, and that Swedish pedestrian and Danish bicyclists are seen as most bad-behaving.

In order to make the scores easier to interpret, we have calculated the mean scores of each pair of road user groups' assessment of the others. Figure 25 shows the mean scores of theses pairs of assessments for each country. A high score is indicative of a good interplay, and a low score is indicative of a poor interplay.

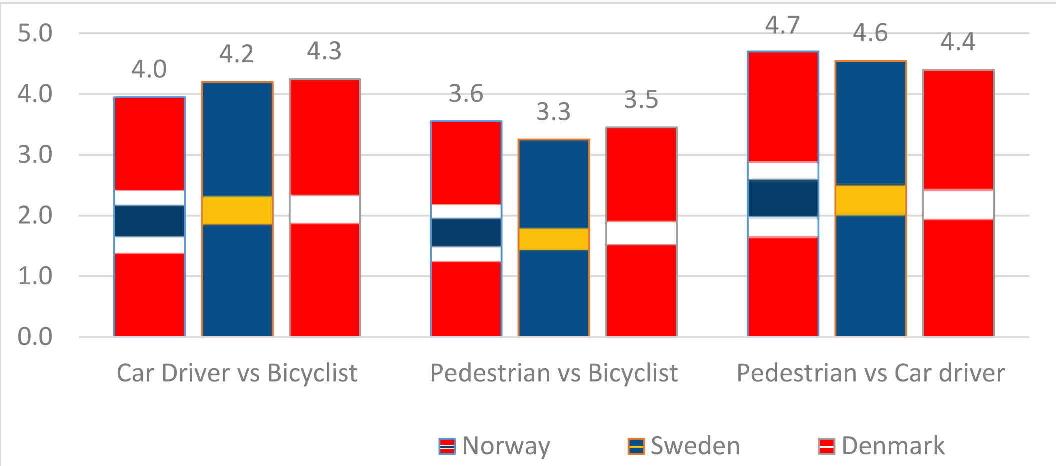


*Figure 25 Mean scores on the behavioural index of pairs of road user groups, car drivers, pedestrians and bicyclists from Norway, Sweden and Denmark.*

Again we see that the worst interaction is between cyclists and pedestrians, and the best is between pedestrians and car drivers. The best interaction is between Norwegian pedestrians and car drivers, and the worst is between Swedish pedestrians and cyclists. Note that this figure conceals the discrepancies shown in the radar plot above, where for instance car drivers were seen as quite well behaving by cyclists, but that cyclists were comparatively more bad-behaving.

### 10.1.2 Norms and rule obedience

To further investigate differences in traffic culture we look at the bicyclists' compliance with two normative statements. The respondents were asked to state how much they agreed with the following:

i. It is my moral obligation to be considerate of other road users regardless of their behaviour.
ii. Bicyclists can break some traffic rules to navigate more quickly in traffic.

Agreement with the consideration norm is fairly equally distributed for the three Scandinavian countries, but the picture looks different for the rule obedience norm.

Linear regression analyses were conducted on the rule obedience norm for all groups of road uses, with country, age, gender and personality as independent variables. Figure 26 shows these results, as the relative difference between Norway, Sweden and Denmark on the rule obedience norms, after controlling for age, gender and personality (based on the parameter estimates plus intercept values from linear regression analyses).

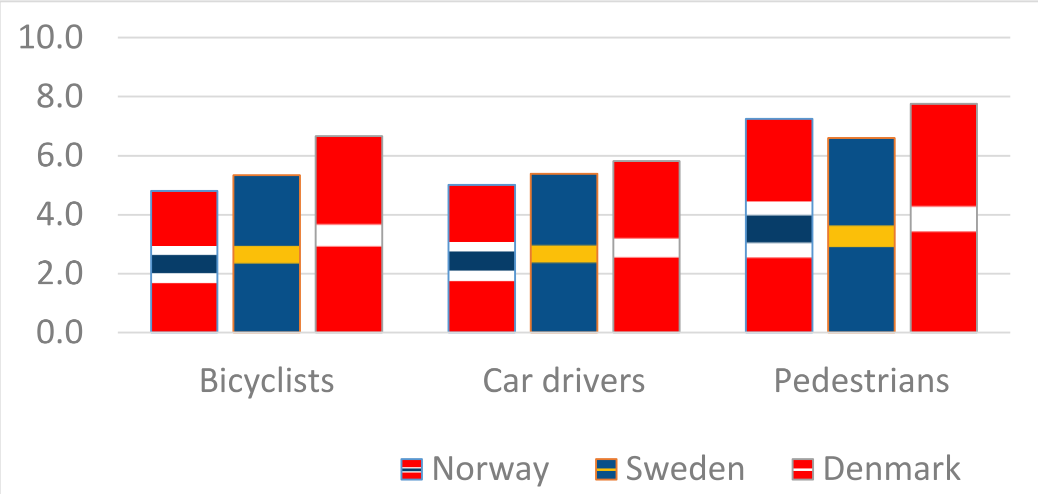


*Figure 26 The relative difference between Norway, Sweden and Denmark on the rule obedience norms, after controlling for age, gender and personality. Parameter estimates plus intercept values from linear regression analyses.*

The regression analysis confirms that Danish road users are more rule obedient, regardless of transport mode. Norwegian bicyclists and car drivers are the less rule obedient. Among pedestrians the Swedes stand out as the least rule obedient, which might explain why interaction between cyclists and pedestrians is worst in Sweden.

An interesting difference between the countries is that there is positive relationship between consideration and rule obedience for cyclists in Denmark (r=0.34) and Sweden (r=0.29), but not in Norway (r=0.07). Hence it could have been argued that some of the poor interplay between motorists and cyclists in Norway stems from the relatively higher share of disobedient Norwegian cyclists. However, when we perform similar analyses for car drivers and pedestrians, we find the same pattern, i.e. there is no correlation between norms and rule obedience in Norway, but there is in Denmark and Sweden.

### 10.1.3 Summary of survey data

The results presented above all indicate that there are systematic differences between the countries and between road user groups in how they behave and how they adhere to traffic rules and regulations. The results also fit well with the patterns we have observed in previous chapters regarding conflicts and interaction between road users. It is hard to assess *how much* of the overlooks and near-misses that can be explained by traffic culture, in the way that we have operationalised it, since these two variables by their very nature are quite close together. Including assessment of other road users into a regression model of number of overlooks would lead to a circular argumentation, since for each individual road user their assessment would to a large extent be affected by their experiences with others.

## 10.2 Video observations

The general impression during the observations was that the Danish cyclists are very rule-obedient and predictable, while the Norwegian cyclist are much of “anarchists”. This can be seen, for example, in the number of red-running cyclists in front of motor vehicles that are very frequent in Norway and nearly absent in Denmark. This behaviour is also reflected in the frequencies of red-light related conflicts that are very few in Denmark but common in Norway.

There is a quite notable difference between the frequency of the red-running cyclists in the three countries. While it is quite common in Norway and Sweden it is nearly absent in Denmark. It is hard to suggest any infrastructural factors that affect this behaviour and it probably should be attributed to the general traffic culture and particularly cycling culture in Denmark. As a results, conflicts related to red-running are literally absent in Denmark. In Norway and Sweden, this type of conflict has very high risk compared to other types of interactions with motor traffic.

## 10.3 Conclusion

We have observed some differences in traffic culture, that might contribute somewhat to explaining the differences in the numbers of conflicts, and subsequently in accident levels, between the three countries. In Denmark, where conflict levels are the lowest, all road users are more rule obedient, both self-reported and observed. We cannot conclude about the magnitude of the influence of traffic culture on conflict levels, only indicate that it is a factor that plays a role. Neither can we say much about causal direction, in other words we cannot say if poor traffic culture is caused by poor infrastructure or if it provides a separate influence on conflict levels.

# 11 Accident record data and bicycle counts

## 11.1 Method

### 11.1.1 Accident data

Accident data were collected from a prospective population-based study. During 2014, all patients who contacted the Oslo Emergency Clinic after a bicycle accident were asked to fill out a bicycle injury form. The receiving nurse gave a form to the patient upon entry to the emergency clinic, and the patient filled out the form in the waiting period before medical consultation. The form contained 14 items about the accident, which were then quality checked and signed by the attending doctor in connection with the consultation. For patients who could not fill out the form themselves, relatives or attending health professionals filled in the form on the basis of present information. In those cases a bicycle injury was registered in the National Health Database electronic patient record, but where there were no completed form, the patient was contacted afterwards and a form filled out according to verbal information.

Injury severity was registered in accordance with the Norwegian health directorate's Common minimum dataset (revised 02/2011) based on AIS (Abbreviated Injury Scale). Accident type was registered with 21 different categories, as well as free text. Based on this, accidents are classified as either *single accidents* (1364 cases) or *collisions* (307 cases).

Overall, 2,184 people were treated for a bicycle injury. 65.2% of patients were men. The median age for males was 34 years of age, ranging from 2 to 88 years. The median age for women was 32 years of age ranging from 2 to 88 years.

### 11.1.2 Bicycle counts

Bicycle flow data were collected from four stationary inductive loop counters located along the main cycling routes at different places in Oslo (Tåsen, Veitvet, Helsfyr and Mosseveien). All counters are placed on separate pedestrian/cycle routes. The counters belong to the public roads authorities and are all regularly maintained and quality assured according to a specific program. The total number of bicycles counted was 722465 for the whole of the year 2014.

## 11.2 Results

Table 17 shows the monthly number of bicyclists, single accidents and collisions as well as the monthly percentage of accidents from all accidents.

*Table 17 Monthly number of bicyclists, single accidents and collisions. Monthly percentage of accidents from all accidents.*

| | Bicycle traffic flow | Single accident | Collision | Accidents % |
|---|---|---|---|---|
| Jan | 16443 | 15 | 5 | 1 % |
| Feb | 14964 | 13 | 2 | 1 % |
| Mar | 43613 | 67 | 17 | 4 % |
| Apr | 69353 | 146 | 34 | 9 % |
| May | 95000 | 235 | 47 | 15 % |
| Jun | 106188 | 234 | 44 | 15 % |
| Jul | 80223 | 226 | 26 | 13 % |
| Aug | 96550 | 227 | 55 | 15 % |
| Sep | 94088 | 200 | 57 | 13 % |
| Oct | 53392 | 110 | 26 | 7 % |
| Nov | 34481 | 80 | 20 | 5 % |
| Dec | 18170 | 18 | 7 | 1 % |
| Total | 722465 | 1571 | 340 | 100 % |

There is an increase in cycling from January to a peak in June, a dip in July (during summer vacation) another increase in August and September, and a subsequent drop towards December. The accident figures follow the same pattern, more or less, when we see all accidents in total. However, there seems to be a difference between the seasonal pattern of single accidents and collisions. In order to investigate this further, we calculated the ratio of collisions to single accidents for each month (collision/single accidents). The bivariate correlation (Pearson's *r*) between cycle traffic flow and single accidents is 0.94. The correlation between cycle traffic flow and collisions is similar (0.94).

Collisions comprise 18 % of all cyclist accidents on average. This share is highest in winter, with 28 % in December, and drops to 10 % in July.

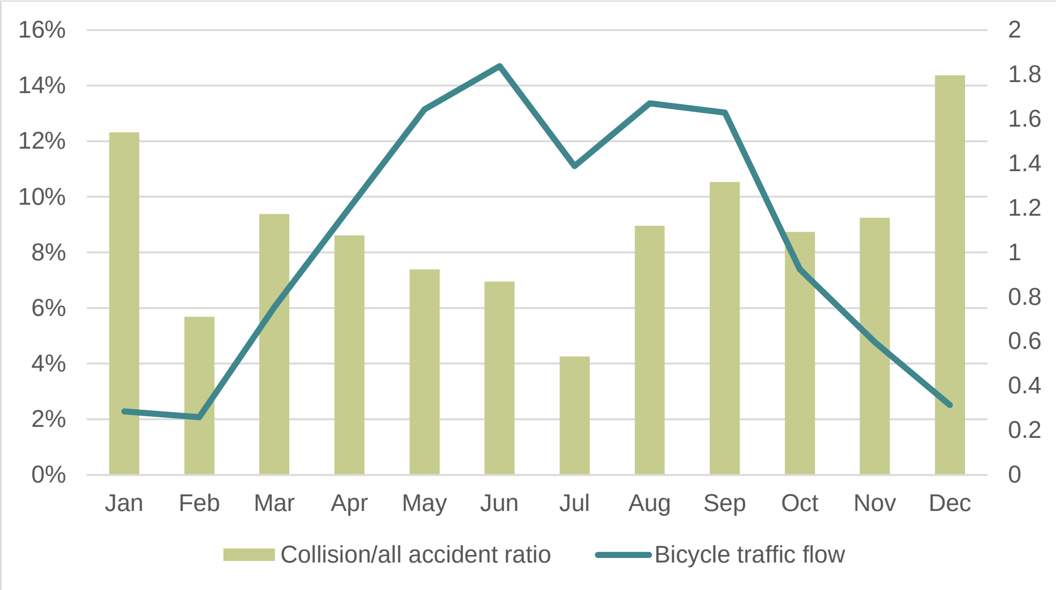


*Figure 27 Monthly share of bicyclist counts from yearly total (left axis) and ratio of collisions to all accidents (right axis).*

Figure 27 shows the monthly share of bicyclist counts from the yearly total (left axis) and the ratio of collision on all accidents (right axis). The collision ratio is at its highest in December and January, when cycling numbers are lowest. The ratio drops alongside with an increase in numbers of cyclists through the spring, and increases steadily with decreasing cycling counts though the fall. The bivariate correlation between these two variables is 0,41 (Pearson's *r*).

## 11.3 Discussion

The analysis of cycle flow and accident data shows that both collisions and single accidents are closely related to the number of cyclists on the road. However, when we look at the relative difference between single accidents and collisions (the ratio), we see that collisions decrease relative to single accidents when cyclist numbers increase. In other words, if a cyclist is involved in an accident during winter, this accident is more likely to involve another road user (normally a motorist) than if it were summer.

This pattern of seasonal changes can be seen as indicative of a SiN effect: However, there are several possible alternative explanations, which at least might explain some of this effect. First of all, the number of cyclists is fairly closely related to daytime length. Hence, cyclists are more victim to poor lightning and poor visibility during winter than summer. Collisions are probably more related to poor visibility than single accidents. Secondly, some of the increase in single accidents during summer might be related to off-road (i.e. not counted) cycling activity.

Another point worth mentioning is the rather close relation between changes in collision ratio towards changes in cycling activity. We would have expected there to be some lag effect, due to a certain learning time among car drivers. But, there is no lag: once the cycling rate drops, the collision ratio increases. This indicates that safety in numbers only can be part of the explanation, and that factors such as visibility also may play a role here.

# 12 Discussion and conclusion

The current report contains a lot of results from diverse sources. In order to make a comprehensive discussion, and to see these in conjunction, we have summarised the results in one table for the seasonal data and one for the cross national comparisons below.

*Table 18 Summary of hypotheses 1-7 and 12 (seasonal effects). The arrows indicate increase, decrease or no change between different periods. Green colour indicates confirmation of hypothesis, yellow indicates that it is not confirmed and red indicates that change is opposite of what is hypothesised.*

| | | April to June | June to September |
|---|---|---|---|
| H1 | Cyclists overlooks by cars | ↘ | ↘ |
| H2 | Cyclists overlooks by pedestrians | → | ↘ |
| H3 | Car drivers surprise by cyclists | → | → |
| H4 | Pedestrians' surprise by cyclists | → | → |
| H5 | Cyclists near-misses with cars | ↘ | → |
| H6 | Cyclists near misses with pedestrians | ↘ | ↗ |
| H7 | Conflicts with cars (video) | → | ↘ |
| H15 | Tram drivers' surprise by cyclists | ↘ | → |

Regarding seasonal variation, only the first hypothesis is fully confirmed, in the sense that overlooks drops both from April to June and from June to September. H2, H5, H6 and H7 are all partly confirmed since overlooks and near misses drops at one point in the season. H3 and H4, regarding other road users' surprises are not confirmed. However, H15 regarding tram drivers' surprises is confirmed.

The results suggest that bicyclists experience a short term Safety in Numbers effect through the season. Each individual cyclist experiences fewer occasions of being overlooked by cars and fewer safety critical situations (near-misses). Video observation data confirm this pattern. However, the SiN effect seems to be countered by another mechanism taking place at the same time: The influx of inexperienced and risk-taking cyclists through the season. Thus car drivers and pedestrians also report to find themselves being surprised by cyclists in traffic late in the season.

The table below summarizes the cross national comparisons in the report, as gold, silver and bronze medals.

*Table 19 Summary of hypotheses 8-14. Ranks from 1st (gold) via 2nd (silver) to 3rd (bronze) place.*

| | | **Denmark** | **Sweden** | **Norway** |
|---|---|---|---|---|
| H8 | Overlooks by cars | 1 | 3 | 2 |
| H9 | Overlooks by pedestrians | 1 | 3 | 2 |
| H10 | Near miss with car | 1 | 1 | 1 |
| H11 | Near miss with pedestrian | 1 | 3 | 1 |
| H12 | Car drivers' surprise by cyclists | 1 | 2 | 3 |
| H13 | Pedestrians' surprise by cyclists | 1 | 2 | 3 |
| H14 | Conflicts between cars and cyclists | 1 | | 2 |

Our hypotheses regarding cross national differences are partly confirmed. For all of the hypotheses, except number 10 (near misses with cars), Denmark (Aalborg) comes out as the sole winner. This was as expected. When comparing Sweden (Gothenburg) and Norway (Oslo), the results are mixed. Depending on the data, we find that interplay between cyclists and other roads users sometimes is worse, sometimes the same, and some times better in Norway. Hence there seems to be certain differences in how cyclists interact with other road users, that has evolved over time, a long term SiN effect.

One explanation for the not-expected poor level of interplay in Sweden compared to Norway, might be related to the specific site chosen for interviews. Even if we attempted to match the interview sites, the site chosen for recruitment of cyclists and pedestrians in Gothenburg was a more busy, downtown type of location (due to some practical limitations) than in Oslo and Aalborg. Hence, the type of traffic environment these cyclists were exposed to might have been comparatively more conflict prone than it should have been. However, the fact that we find the same pattern in the home survey, where the context is less dependent upon recruitment site, and the fact that Swedish pedestrians report *fewer* surprises than Norwegian, works counter to such an explanation. Another more likely explanation is the particular infrastructure design used in many central parts of Gothenburg, where there are designated marked cycle paths either on pavements, or in the central part of bidirectional boulevards, where also pedestrians are supposed to walk.

Our discussions regarding the role infrastructure and traffic plays in explaining this long term effect is inconclusive. We see that infrastructure does play a role, the badly designed Danish solutions (such as marked cycle paths in roundabouts) give *more* conflicts than the typical Norwegian solution where traffic is mixed. Also, the Swedish solution mentioned above, seems to be conflict inducing. But, including infrastructure as a variable in multivariate models does not explain away national differences, which can be seen as indicative of a SiN effect regardless of different infrastructure quality. Further we find that road users are far more rule obedient and considerate in Denmark than in Sweden and Norway. But again, including a measure of traffic culture into the multivariate models does not explain any differences in near misses or surprises.

Finally, the accident record data for Oslo show a pattern that can be interpreted as a Safety in Numbers effect, with a higher share of collisions relative to single accidents in winter, where there are few cyclists. When spring arrives, and cyclists turn to the streets, the number of accidents increase, but the number of collisions increases less than single accidents.

Thus, we can conclude that there is quite strong evidence of a Safety in Numbers effect where other road users (mainly motorists) are more expectant (un- or subconsciously) when there are more cyclists on the roads. Further we find strong evidence for an attenuating effect of infrastructure on this mechanism. Finally, we see clearly that traffic culture plays a role. Whether traffic culture is formed by the design of infrastructure or whether it is a function of road user being more accustomed to interacting through exposure, or if this is an effect of a completely separate mechanisms is hard to tell with our data.

# 13 References


Bhatia, R., & Wier, M. (2011). "Safety in Numbers" re-examined: Can we make valid or practical inferences from available evidence? *Accident Analysis and Prevention, 43*(1), 235-240. doi: DOI 10.1016/j.aap.2010.08.015

Bisgaard, S., & Fuller, H. T. (1994). QUALITY QUANDARIES. *Quality Engineering, 7*(2), 429-443. doi: 10.1080/08982119408918794

Bjørnskau, T. (1994). Spillteori, trafikk og ulykker - en teori om interaksjon i trafikken (pp. 1-451). Oslo: Transportøkonomisk institutt.

Bjørnskau, T. (1996). Why are the 'safest' norms, attitudes and types of behaviour not typical for the safest drivers? *Transport Reviews, 2*(169-181).

Bjørnskau, T. (in press). The Zebra Crossing Game – Using game theory to explain a discrepancy between road user behaviour and traffic rules. *Safety Science*. doi: http://dx.doi.org/10.1016/j.ssci.2015.10.007

Bjørnskau, T., & Fyhri, A. (2012). Sykling mot enveiskjøring. Oslo: Institute of Transport Economics.

Brindle, R. E. (1994). Lies, damned lies and "automobile dependence" : some hyperbolic reflections. *Papers of the Australasian Transport Research Forum., 19*, 117-131.

Elvik, R. (2009). The non-linearity of risk and the promotion of environmentally sustainable transport. *Accident Analysis and Prevention, 41*(4), 849-855. doi: DOI 10.1016/j.aap.2009.04.009

Elvik, R. (2013). Can a safety-in-numbers effect and a hazard-in-numbers effect co-exist in the same data? *Accident Analysis & Prevention, 60*(0), 57-63. doi: http://dx.doi.org/10.1016/j.aap.2013.08.010

Elvik, R., & Bjørnskau, T. (in press). Safety-in-numbers: A systematic review and meta-analysis of evidence. *Safety Science*. doi: http://dx.doi.org/10.1016/j.ssci.2015.07.017

Engvik, H., & Clausen, S.-E. (2011). *Norsk kortversjon av Big Five Inventory (BFI-20).*

Engvik, H., & Føllesdal, H. (2005). The Big Five Inventory på norsk. *Tidsskrift for norsk psykologforening, 42*, 128-129.

Fyhri, A., Bjørnskau, T., & Backer-Grøndahl, A. (2012). Bicycle helmets A case of risk compensation? *Transportation Research Part F: Traffic Psychology and Behaviour, 15*(5), 612-624.

Geyer, J., Raford, N., Ragland, D., & Pham, T. (2006). *The continuing debate about safety in numbers: Data from Oakland, CA.* Paper presented at the Proceedings of the 85th Annual Transportation Research Board Meeting, January 2006.

Hjorthol, R., Uteng, T. P., & Engebretsen, Ø. (2014). Den nasjonale reisevaneundersøkelsen 2013/14 : nøkkelrapport *TØI rapport (Oslo : 1992- : trykt utg.)* (Vol. 1383/2014). Oslo: Transportøkonomisk institutt.

Hydén, C. (1996). Traffic Conflict Technique: State-of-the-art. In H. H. Topp (Ed.), *Traffic Safety Work with Video-Procesing*. Kaiserslautern: University Kaiserslautern.

Jacobsen, P. L. (2003). Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Injury Prevention, 9*(3), 205-209.

John, O. P., Srivastava, S., & Pervin, L. (1999). The Big-Five trait taxonomy: History, measurement, and theoretical perspectives *Handbook of personality: Theory and research* (Vol. 2, pp. 102-138). New York: Guilford.

Juhra, C., Wieskötter, B., Chu, K., Trost, L., Weiss, U., Messerschmidt, M., . . . Raschke, M. (2012). Bicycle accidents – Do we only see the tip of the iceberg?: A prospective multi-centre study in a large German city combining medical and police data. *Injury, 43*(12), 2026-2034. doi: http://dx.doi.org/10.1016/j.injury.2011.10.016

Knowles, J., Adams, S., Cuerden, R., Savill, T., Reid, S., & Tight, M. (2009). Technical Annex to PPR445 Collisions involving pedal cyclists on Britain's roads: establishing the causes. Wokingham: Transport Research Laboratory.

Laureshyn, A. (2010). Application of automated video analysis to road user behaviour.: Department of Technology and Society, Faculty of Engineering, LTH.

Phillips, R. O., Bjornskau, T., Hagman, R., & Sagberg, F. (2011). Reduction in car-bicycle conflict at a road-cycle path intersection: Evidence of road user adaptation? *Transportation Research Part F-Traffic Psychology and Behaviour, 14*(2), 87-95. doi: DOI 10.1016/j.trf.2010.11.003

Rothengatter, T. (1991). Normative Behaviour is Unattractive if it is Abnormal: Relationships between Norms, Attitudes and Traffic Law. In M. J. Koornstra & J. Christensen (Eds.), *Enforcement and Rewarding: Strategies and Effects, Proceedings of the International Road Safety Symposium in Copenhagen, Denmark, September 19-21, 1990* (pp. 91-93).

Svensson, Å. (1992). Vidareutveckling och validering av den svenska konflikttekniken. Lund, Sweden: Dept of Technology and Society, LTH, Lund University

# 14 Appendix 1, publication list

| | Conference Papers/Journal articles | Authors | Place /nr/type |
|---|---|---|---|
| 1 | Safety in Numbers - Uncovering the mechanisms of interplay in urban transport with survey data | AF, TBJ | ICSC, 2013, Helmond |
| 2 | Exploring the mechanisms behind the Safety in Numbers Effect: A behavioural analysis of interactions between cyclists and car drivers in Norway and Denmark | MdG, AF, ALA, TBJ | ICSC, 2014, Gothenburg |
| 3 | Safety in Numbers - combining a panel design and cross-cultural survey to examine the suggested mechanisms | AF, TBJ, HBS | ICSC, 2014, Gothenburg |
| 4 | Analysing traffic conflicts – comparing the Swedish Traffic Conflict Technique (TCT) and the Dutch Objective Conflict Technique for Operation and Research* | MdG, ALA | ICTCT, 2014, Karlsruhe |
| 5 | Safety in Numbers for cyclists – conclusions from a multidisciplinary study of seasonal change in interplay and conflicts | AF, TBJ, HBS, ALA | ICSC, 2015, Hannover |
| 6 | Cross-comparison of three surrogate safety methods to diagnose cyclist safety problems at intersections in Norway | ALA, MdG, N. Saunier, AF | ICSC, 2015, Hannover |
| 7 | Safety in Numbers for cyclists – conclusions from a multidisciplinary study of seasonal change in interplay and conflicts | AF, TBJ, HBS, ALA | AAP special issue |
| 8 | Cross-comparison of three surrogate safety methods to diagnose cyclist safety problems at intersections in Norway | ALA, MdG, N. Saunier, AF | AAP special issue |
| | **Reports** | | |
| 9 | Datainnsamling og datapreparering - Safety in Numbers | AF, HBS | Working paper 50543 |
| 10 | Oversikt over datamaterialet og innledende analyser – Safety in Numbers | HBS | Working paper 50562 |
| 11 | Safety in Numbers - What does the survey data tell us about seasonal changes? | AF, TBJ | Working paper 50822 |
| 12 | Safety in Numbers - What does the survey data tell us cross national differences? | AF, TBJ | Working paper 50823 |
| 13 | Data fra Norge, Sverige, Danmark – en oppsummering av spørreundersøkelsen i felt og hjemme | RII | Working paper 50816 |
| 14 | Safety in Numbers – a cross national comparison using survey data | RII | Working paper 50924 |
| 15 | Video-observations to understand the Safety-in-Numbers effect for cyclists | ALA | Working paper 50881 |
| 16 | SiNTrikk – feltundersøkelse blant trikkeførere i Oslo (2014) | HBS | Working paper 50833 |
| 17 | Sikkerhetskultur og arbeidsmiljø i Sporveien Trikken AS – kartlegging høsten 2014 | Lise Andersen, TBJ | Working paper 50953 |
| | Others | | |
| 18 | Oslo – A bicycle city for the concerned, the speedy and the rebels - Exploring preference for infrastructure using a multidimensional bicyclist typology | Ragnhild B.Ø. Skaugen | Master thesis, Aalborg university |
| 19 | Kampen om gata - En analyse av trafikantgruppers mikrosamspill i Oslo | Mari A. Hjorteset | Master thesis, University of Oslo |

## Institute of Transport Economics (TØI)

### Norwegian Centre for Transport Research

Established in 1964, the Institute of Transport Economics is an interdisciplinary, applied research centre with approximately 70 professionals. Its mission is to develop and disseminate transportation knowledge that has scientific quality and practical application.

A private, non-profit foundation, TØI receives basic funding from the Research Council of Norway. However, the greater part of its revenue is generated through contract research. An important part of its activity is international research cooperation, mostly in the form of projects under the Framework Programmes of the European Commission.

TØI participates in the Oslo Centre for Interdisciplinary Environmental and Social Research (CIENS) located near the University of Oslo. See www.ciens.no

TØI covers all modes of transport and virtually all topics in transportation, including road safety, public transport, climate change and the environment, travel behaviour, tourism, land use and urban planning, decision-making processes, freight and travel demand, as well as general transport economics.

Claiming copyright to its products, TØI acts independently of its clients in matters of scientific approach, professional judgment and evaluation. TØI reports are generally downloadable for free at www.toi.no.

**Visiting and postal address:**
Institute of Transport Economics
Gaustadalléen 21
NO-0349 Oslo

+ 47 22 57 38 00
toi@toi.no
**www.toi.no**