PANK RY
Päällystealan neuvottelukunta Ry

13.2.2019

MUISTIO
PANK ry, tiemerkintävaliokunnan kokous 1/2019

Aika: **13.2.2019 klo 15.00**
Paikka: **Ravintola Pöllöwaari, Jyväskylä**

Osallistujat:
pj. Antti Hietakangas, Skanska Oy
Harri Spoof Ramboll CM
Tero Ahokas Varsinais-Suomen ELY-keskus
Jarmo Nousiainen Tiemerkintä A&E
Tapani Ritamäki, Hotmix Oy
Rami Muotka, Elfing Signum Oy
Hannele Mikkola, Carement Oy

Siht. Anne Valkonen, Via Blanca Oy

Mika Launonen Cleanosol Oy
Mika Honkasalo STARA, Helsingin kaupunki
Tuomas Österman Liikennevirasto
Keijo Pulkkinen Autori Oy
Ossi Saarinen, Väylävirasto
Tuomas Vasama Kaakkois-Suomen ELY-keskus
Jaakko Dietrich, Ramboll CM
Mikael Sulonen, Ramboll Finland Oy
Risto Lappalainen, Väylä (puhelinyhteys)

1. Tiemerkintävaliokunnan jäsenmuutokset

Erkki Greggilä jää pois tiemerkintävaliokunnasta.

2. Edellisen kokouksen muistio — A. Valkonen

Käytiin läpi edellisen kokouksen muistio

3. Toimintasuunnitelman 2019 alustus ja toimenpiteet — A. Hietakangas

Käytiin läpi toimintasuunnitelma 2019.

4. Turvallisuusasiat — R.Lappalainen

Turvallisuusvideoiden jatkokäyttö
Risto Lappalainen on lähettänyt hakemukset YLE:lle turvallisuusvideoiden levittämisestä. YLE päättää levittämisestä helmikuun 2019 aikana.

Turvallisuuskierrokset
Turvallisuuskierrokset VAR ELY ja POP ELY. ELY:jen edustajat sopivat ajankohdat. Teemana turvallisuuskierroksilla ovat vilkasliikenteiset tiet.

Turvallisuuspäivä
Turvallisuuspäivän 24.4.2019 ohjelma: Risto Lappalainen ja Ossi Saarinen kokoavat ohjelman rungon ja lähestyvät tämän jälkeen urakoitsijoita. Urakoitsijoilta toivotaan osallistumista päivien ohjelman laadintaan. Risto Lappalainen varaa turvallisuuspäivän paikan.

5. Uuden tieliikennelain vaikutusten arviointi, sekä niihin vaikuttaminen.

13.2.2019

Siirtymäajan työryhmän ehdotus käytiin läpi edellisessä kokouksessa.

Ehdotuksen sisältö: Uusille mustille pinnoille tehdään ensin sulkuviivat valkoisella massalla. Tämän jälkeen sulkuviivojen päälle tehdään keltaiset viivat maalilla tai ohutspray -tekniikalla.

Ossi Saarinen kokoaa ryhmän uuden tieliikennelain vaikutusten arviointiin ja laittaa ryhmälle kokouskutsun.

6. Digitalisaation hyödyntäminen tiemerkinnöissä K.Pulkkinen

Keijo Pulkkisella on tästä aiheesta huomenna esitys tiemerkintäpäivillä. Liitteenä Keijo Pulkkisen pohjoismaisilla tiemerkintäpäivillä pitämä esitys.

7. Automaattisten ajoneuvojen vaatimukset tiemerkintöihin A.Hietakangas

Ossi Saarinen perustaa tähän teemaan työryhmän, kun asia on ajankohtainen

8. Mobiilimittaukset PANK-menetelmiksi T.Vasama

Kitkan mittauksen PFT (Portable Friction Tester) ja jatkuvatoimisen paluuheijastavuuden mittausten hyväksyminen PANK-menetelmiksi etenee. Menetelmäkortit tulevat näillä näkymin käyttöön tälle kesälle. PANK-hyväksyntä menetelmille saadaan aikaisintaan 9.4.2019.

9. Tiemerkintämateriaalien CE- vaatimusten ja standardien seuranta.

Tuomas Österman kävi läpi Samuel Hintukaisen valmisteleman aineiston. Aineisto on tämän pöytäkirjan liitteenä.

10. Tiemerkinnän ammattitutkintokoulutus A. Hietakangas

Toivotaan, että mikäli koulutukseen ei ole riittävästi osallistujia, luennoitsijoita informoidaan peruutuksesta ajoissa, jotta ei tehdä turhaa valmistelutyötä.

11. Erityissääolosuhteiden huomioon ottaminen T. Ahokas

Ryhmä on kokoontunut kerran ja aiheesta on tehty urakoitsijakysely. Vastausten perusteella tehdään esitys tiemerkintäurakoiden asiakirjojen päivittämisestä.

12. Investointihankkeiden tiemerkintöjen kehittäminen O. Saarinen

Investointihankkeiden työryhmä on kokoontunut kerran. Ylläpitourakoissa suunniteltu siirtymäajan ”kaksivärikäytäntö” pyritään ottamaan käyttöön myös investointihankkeissa.

13.2.2019

Antti Hietakangas ottaa yhteyttä investointiverkon vetäjään ja pyytää päästä investointiverkkoon kertomaan tiemerkintätöistä, tiemerkintöjen ylläpidon vaatimuksista ja ylipäätään tiemerkintöjen suunnittelun tärkeydestä.

Tiemerkintöjen suunnittelun osaamisen tärkeyttä halutaan korostaa. Tästä syystä Antti Hietakangas on yhteydessä myös alan oppilaitoksiin ja tarjoaa opetusta alan opiskelijoille sekä ammattikorkeakouluihin että yliopistoihin.

(Tampereen yliopiston tierakennusmateriaalien opintojakso sisältää jo tiemerkintöjen luentokerran (4 h). Tässä jaksossa käydään läpi erilaiset tiemerkintämateriaalit, tiemerkintöjen hankinta, tiemerkintöjen toteutus sekä työturvallisuus.)

13. Tiemerkintäpäivät 2020 H. Spoof

Tiemerkintäpäivät järjestetään 2020 Jyväskylässä Versossa 13-14.2.2020. Valiokunnan kokous pidetään 12.2.2020.

14. Toimintasuunnitelma 2020 A.Hietakangas

Toimintasuunnitelma vuodelle 2020 suunnitellaan yhdessä 21.5.2019 Rambollin Espoon toimipisteessä klo 13 alkaen.

Huom! Rambollin toimitila on muuttanut uuteen osoitteeseen.

15. Muut asiat

16. Seuraavat kokoukset

21.5. 2019 klo 13.00 Ramboll, Espoo.
22.10.2019 klo 13.00 STARA, Talttakuja 1, Malmi.

PANK RY
Päällystealan neuvottelukunta Ry

13.2.2019

tietomekka

MANAGING COMMUNICATION

Nordisk vejafmærknings konferense

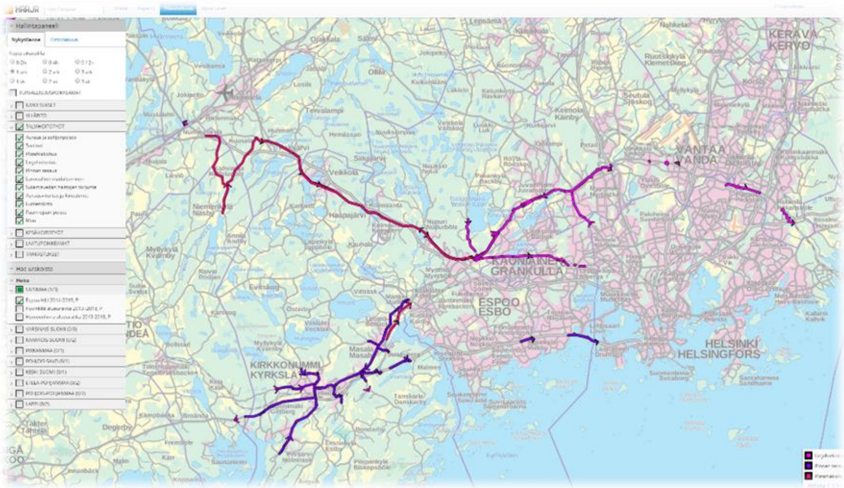
7 – 8 februari 2018

Digitaliserad vägmarkeringsprocess & HARJA databasen

Innehåll

HARJA

- Introduktion av Tietomekka
- Digitaliserad vägmarkeringsprocess
- HARJA-databasen
- Finska vägdatabasen och underhållet



Introduktion till Tietomekka

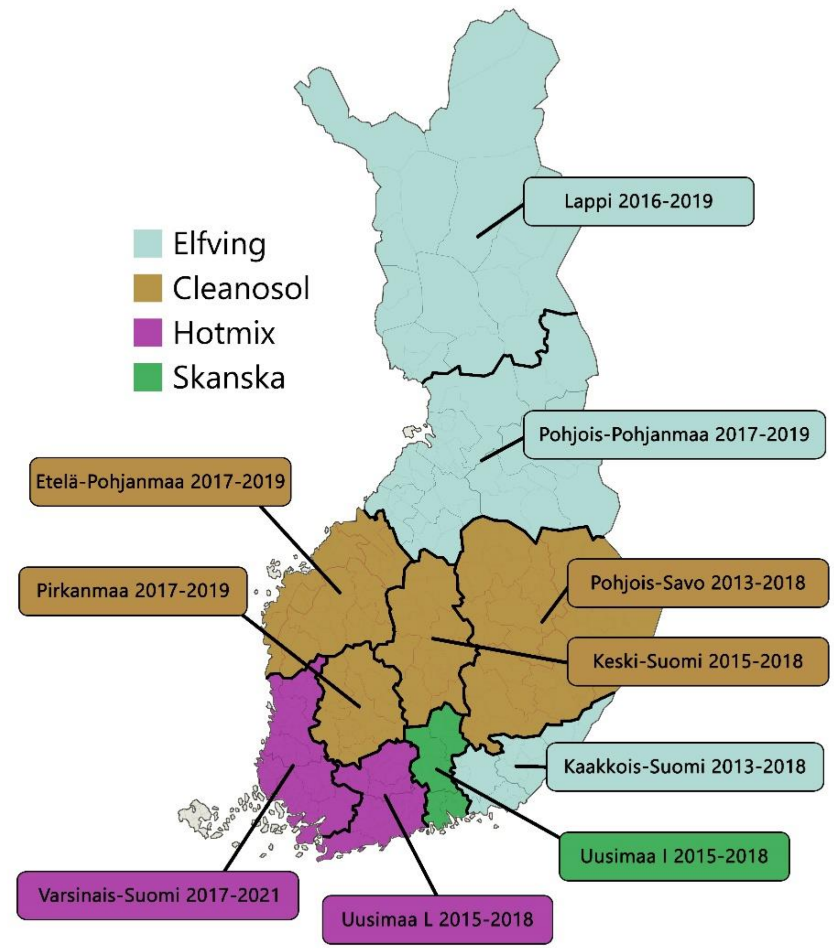
- Finskt mjukvarubolag grundat 1988
- Huvudsaklig produkt: administrations- och rapporteringssystemet AUTORI
- Kunderna finns inom infrakstrukturunderhåll
- Finlands fyra största vägmarkeringsbolag använder AUTORI

YIT
Lemminkäinen
NCC
CLEANOSOL
SKANSKA
ELTEL
SITOWISE
ELFVING SIGNUM
Infratek

Autori®

AUTORI för funktionskontrakt

- Motsvarande service för driftskontrakt utvecklades för att passa vägmarkeringarnas funktionskontrakt
- För bruk ute på vägarna i både PC och mobil
- Service har f.n. ca 120 användare

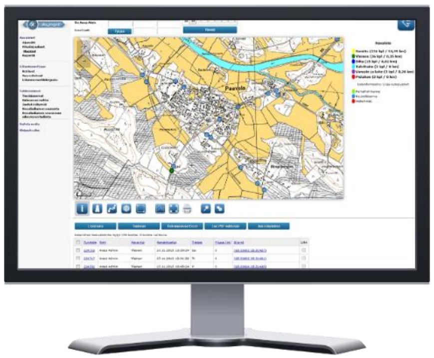


Autori®

AUTORI service

Autori®

Cloud-lösning som presenterar, processar, och flyttar data



Webapplikation

Extern datainsamling

Mobilapplikation

HARJA

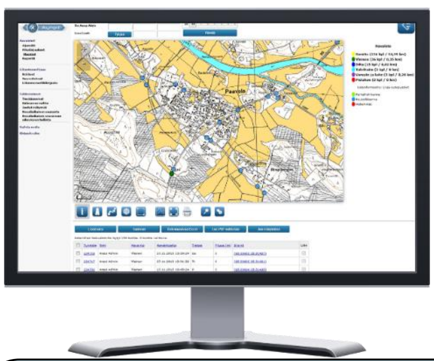
Gränssnitt till andra system

tietomekka
MANAGING COMMUNICATION

Digitaliserad vägmarkeringsprocess

Autori®

Cloud-lösning som presenterar, processar, och flyttar data



- Mätning av märkningskvalitet
- Förbered märkningsplan
- Leverera planen för vägen till anställda
- Jämförelserapport över kvalitet, kvalitetsbrister och gjorda märkningar

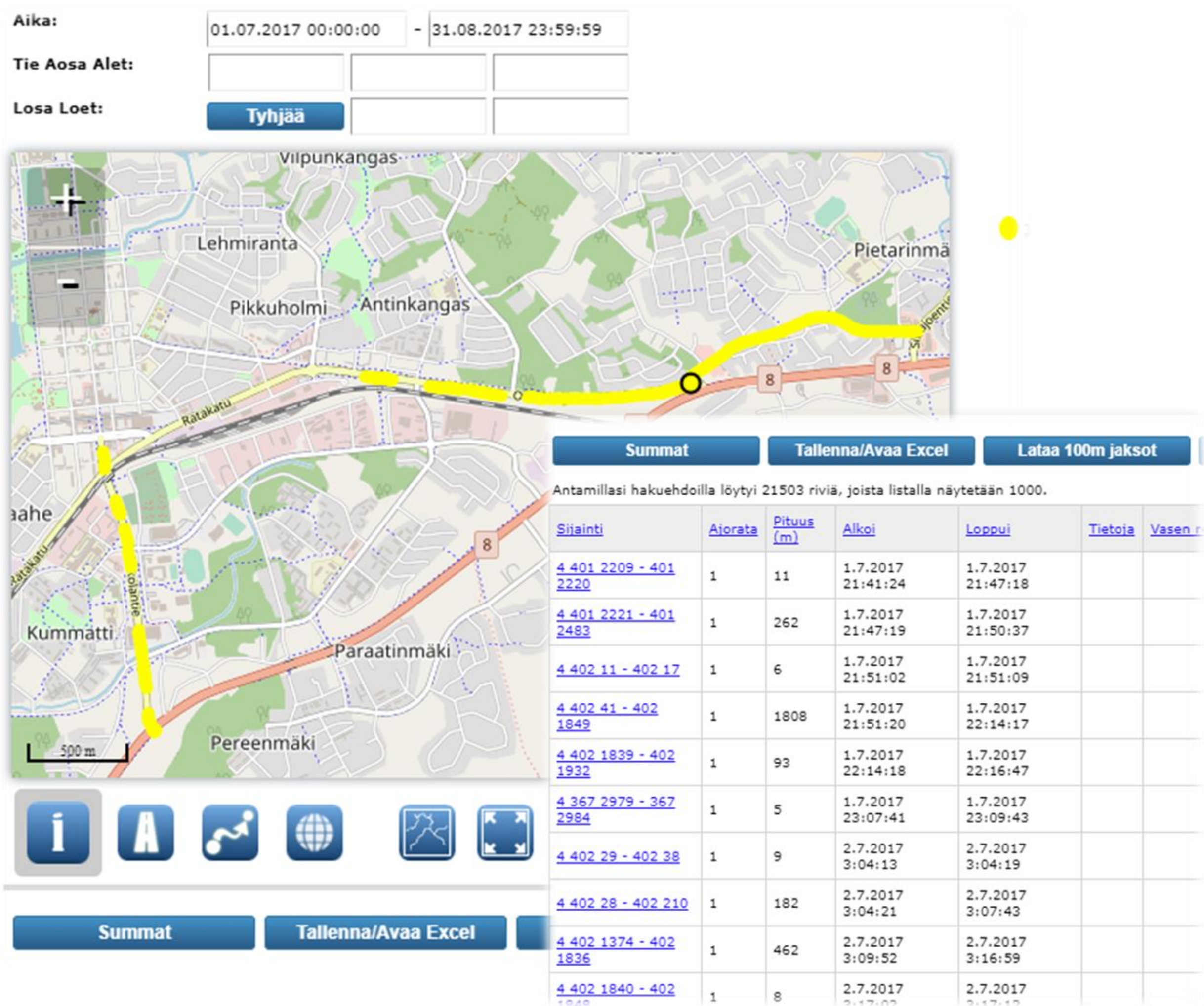
- Automatics samlar in märknings- och positionsinformation

- Märkningsplan på kartan och i listform
- Automatiserad kontroll över var märkning skall ske

HARJA

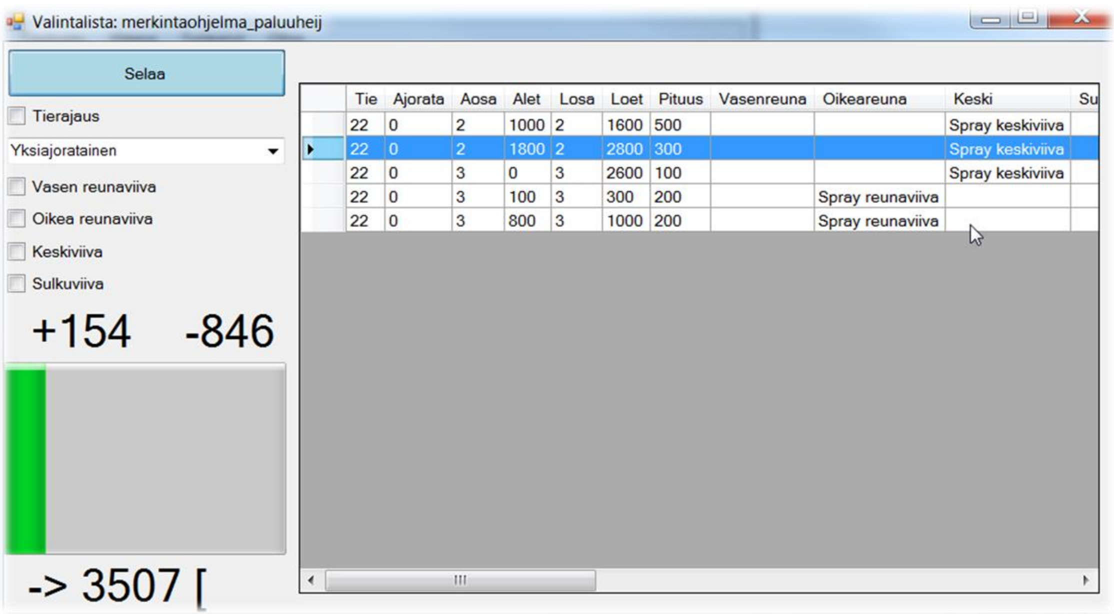
- Realtidsövervakning av märkningsmaskinerna
- Samarbete med asfalteringsentreprenörer
- Arbetssäkerhetsrapportering

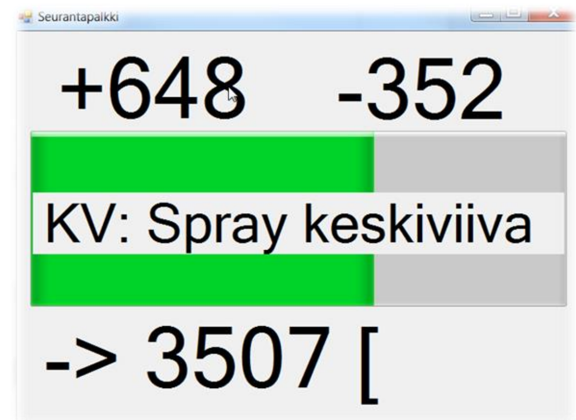
Exempel – rapportera utförda märkningar

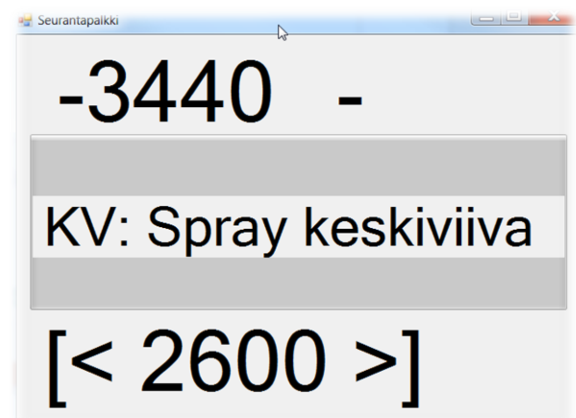


Sijainti	Ajorata	Pituus (m)	Alkoi	Loppui	Tietoja	Vasen r
4 401 2209 - 401 2220	1	11	1.7.2017 21:41:24	1.7.2017 21:47:18		
4 401 2221 - 401 2483	1	262	1.7.2017 21:47:19	1.7.2017 21:50:37		
4 402 11 - 402 17	1	6	1.7.2017 21:51:02	1.7.2017 21:51:09		
4 402 41 - 402 1849	1	1808	1.7.2017 21:51:20	1.7.2017 22:14:17		
4 402 1839 - 402 1932	1	93	1.7.2017 22:14:18	1.7.2017 22:16:47		
4 367 2979 - 367 2984	1	5	1.7.2017 23:07:41	1.7.2017 23:09:43		
4 402 29 - 402 38	1	9	2.7.2017 3:04:13	2.7.2017 3:04:19		
4 402 28 - 402 210	1	182	2.7.2017 3:04:21	2.7.2017 3:07:43		
4 402 1374 - 402 1836	1	462	2.7.2017 3:09:52	2.7.2017 3:16:59		
4 402 1840 - 402 [illegible]	1	8	2.7.2017 [illegible]	2.7.2017 [illegible]		

Exempel – automatiserad kontroll över var märkning skall utföras



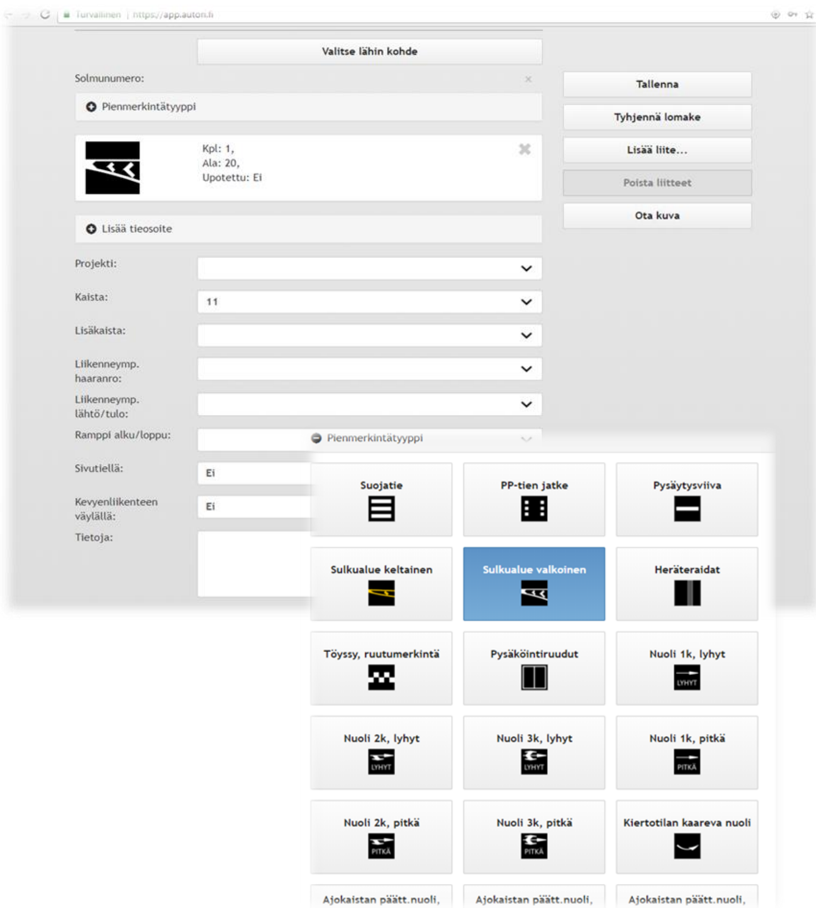


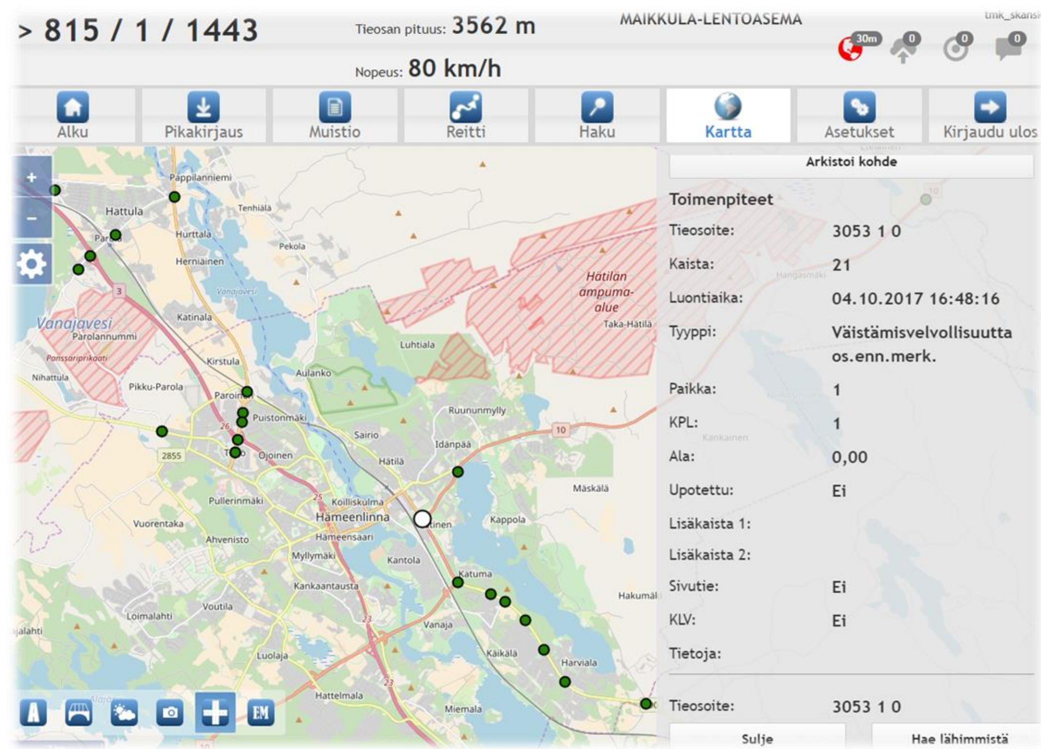


- Listan visar planerade märkningsjobb
- Fält som följer märkningsarbetet och även flyttar till nästa objekt
- Rutan med nästa objekt visar avståndet till nästa märkningsplats samt vilken längd som skall märkas

tietomekka
MANAGING COMMUNICATION

Exempel – verktyg för att administrera mindre märkningsarbeten

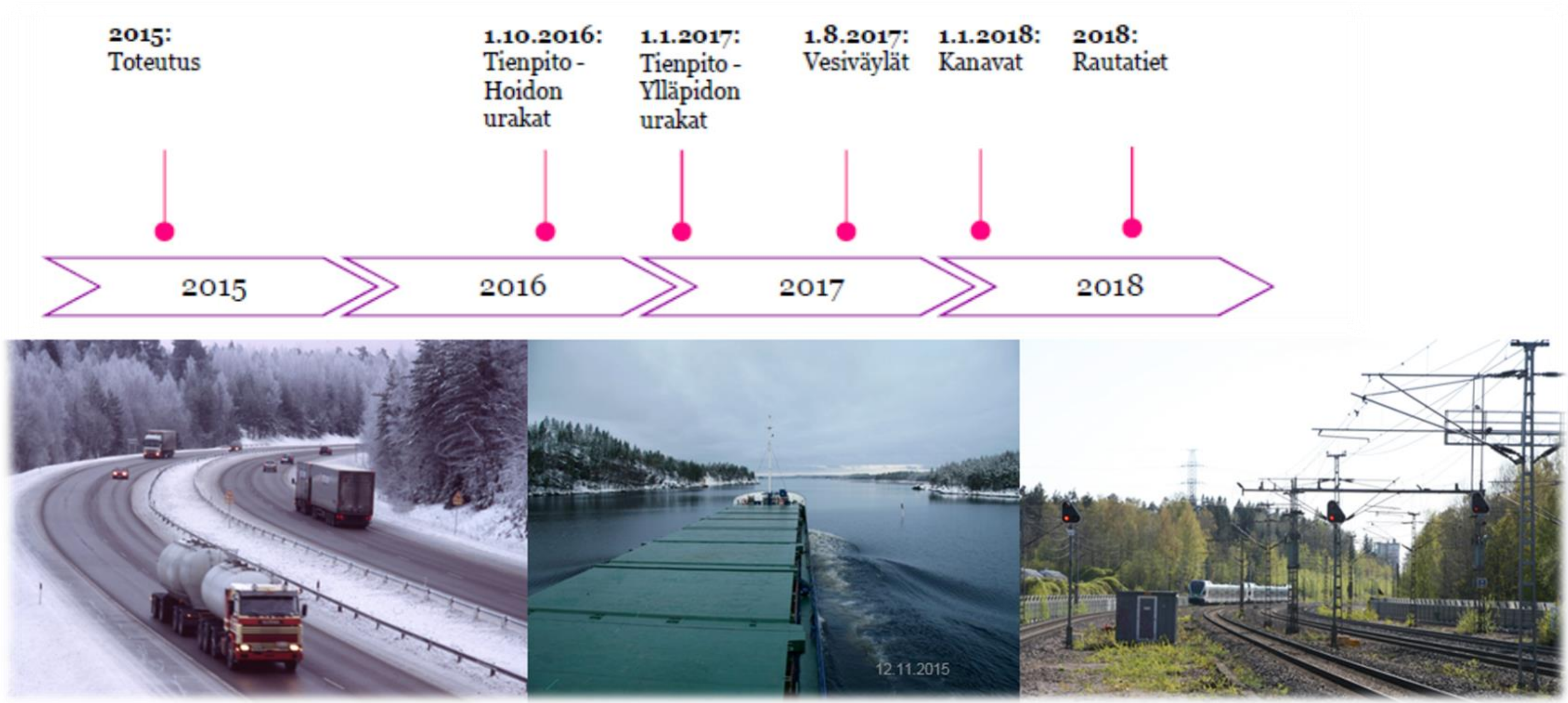




Vad är Harja-databasen?

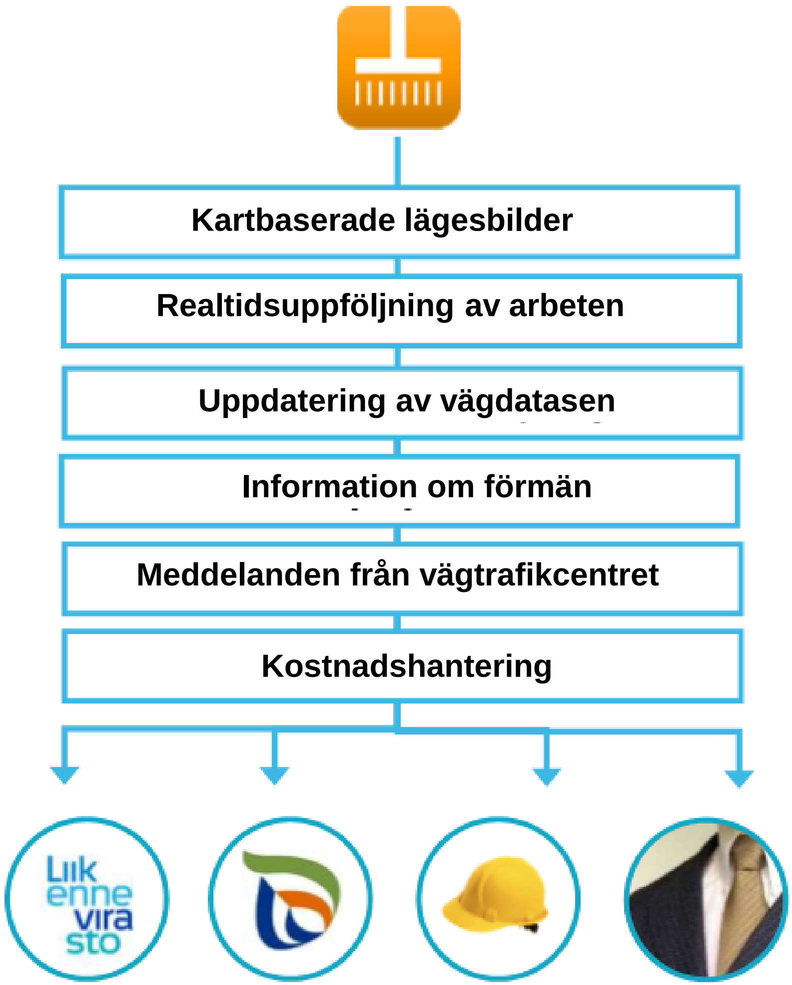
HARJA

HARJA är finska trafikverkets system för uppföljning av underhåll inom alla infrastrukturområden (väg, vatten, spår) och kontrakt samt för att hantera feedback.



Vad är målet med Harja?

HARJA möjliggör för olika parter inom vägunderhållet (Trafikverket, NTM-centraler, entreprenörer, konsulter) att arbeta tillsammans och belysa frågor på ett sätt som inte varit möjligt tidigare



Vad betyder Harja för vägmarkeringskontrakt?

Entrprenörens egna system

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HARJA

- Datainsamling
- Visualisering
- Kartbaserad datahantering
- Realtidsuppföljning

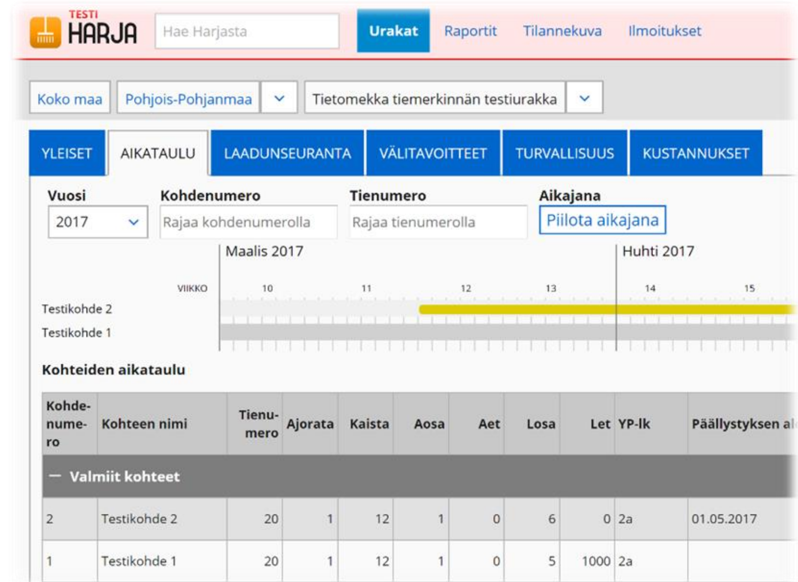
Feedback från trafikanter

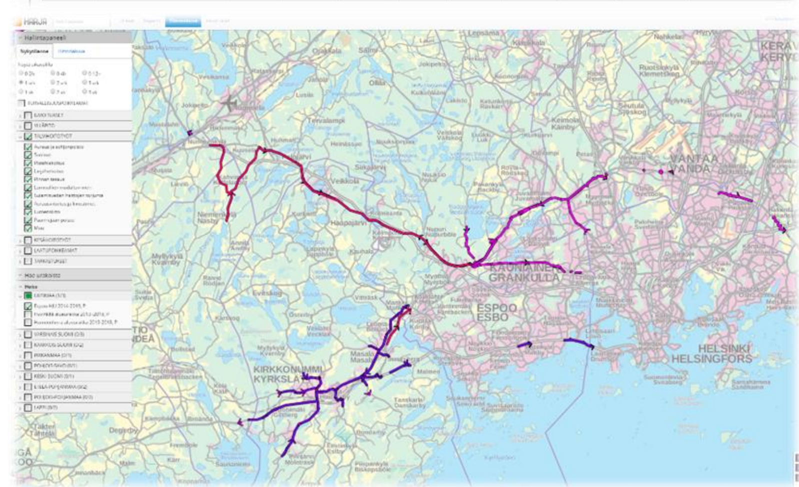
Konsulter som övervakar underhållet

Övervakning från myndigheterna

Vad betyder Harja för vägmarkeringskontrakt?

- Möjlighet att söka på kontrakt och position
- Skicka schemaförändringar
- Övervaka asfalteringskontrakt och eventuella schemaförändringar
- Skicka realtidsinformation till maskinoperatörerna
- Skapa och skickar arbetssäkerhetsrapporter
- Skapa och skickar kvalitetsdata
- Updatera nationella vägdatabasen





Nytt vägdatasystem och service

- Uppdatering av nuvarande vägdatabas
- Realtidsinformation
- Ny data
- Positions- och kartuppgifter
- Automatiserade processer
- Användarvänligt
- Öppen data och öppna gränssnitt
- Modulbaserat och skalbart
- Användbart under kommande 20år

Varför?

- Öka marknadsbaserade transporttjänster
- Öka digitaliseringen inom transportsektorn
- Styra, leda och kontrollera trafiknätet
- Sociala mål

Vägmarkeringsinnehåll

- Typ av markering
- Material
- Mått
- Kvalitet
- Vibrationsmärkning

Tack för att ni lyssnade!

För mer information

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Ilkka Juusola, +35840 5305517,
ilkka.juusola(at)tietomekka.fi

TEKNOS

Tiemerkintämateriaalien standardien ja CE- vaatimusten seuranta

Sisältö

- Standardien & CE-merkinnän tilanne
- Suomen tekniset kommentit käsittelykierroksella oleviin standardeihin
  (käsitellään ainoastaan sisältöä koskevat tekniset kommentit, ei editoriaalisia, kuten terminologia, kirjoitusvirheet ym.)
  - EN 1824 (Road marking materials – Road Trials)
  - EN 1871 (Road marking materials - Paint, thermoplastic and cold plastic materials - Physical properties)
- Pohjoismainen koekenttä

Standardien & CE-merkinnän tilanne

- Tällä hetkellä kommentointikierroksella ovat standardit:
  - **EN 1824 (Road marking materials – Road Trials)**
    - Standardi määrittelee tiemerkintämateriaalien koekenttäjärjestelyt (Mitä vaatimuksia koekentälle asetetaan, miten materiaalit applikoidaan, mitä parametrejä mitataan ja miten jne…
  - **EN 1871 (Road marking materials - Paint, thermoplastic and cold plastic materials - Physical properties)**
    - Standardi määrittelee laboratoriomittauksiin pohjautuvat tiemerkintämateriaalien fysikaaliset ominaisuudet (värikoordinaatit, peittokyky, UV-kestävys, varastointikestävyys jne…)
  - **EN 12802 (Road marking materials - Laboratory methods for identification)**
    - Standardi määrittelee tiemerkintämateriaalien tunnistamiseen käytetyt laboratoriomenetelmät
- EN 1871:sta on pyritty aiemmissa ehdotuksissa luomaan harmonisoitua standardia, joka koskisi valmiin merkinnän ominaisuuksia tien päällä. Näitä versioita ei kuitenkaan ole hyväksytty äänestyksissä.
- Nyt äänestyksessä olevassa EN 1871 ehdotuksessa standardi on ”palautettu” vapaaehtoiseksi materiaalistandardiksi, joka koskee ainoastaan tehtaalta ulos tulevan materiaalin fysikaalisia ominaisuuksia, ei itse valmista merkintää.
- **CE-merkintä ei ole mahdollinen harmonisoimattoman EN 1871 standardin pohjalta.**

EN 1824 (Road marking materials – Road Trials)

- Ehdotetut muutokset:
  1. **Lisätään huomautus: mikäli koekenttäalueella käytetään nastarenkaita, viralliset mittaukset on suoritettava vasta kesällä (ei heti keväällä talven jälkeen).**
     - Perustelu: Nastarenkaat kuluttavat tiemerkintöjä talvella erittäin voimakkaasti. Kuumamassamerkintöjen paluuheijastuvuuden on kuitenkin havaittu nousevan kesän aikana uusien helmien paljastuessa esiin. Näin ollen keväällä mitattu arvo ei välttämättä edusta merkinnän lopullista paluuheijastuvuuskykyä kesäkauden aikana ja vertailukelpoisten tulosten saamiseksi mittaukset tulisi suorittaa myöhemmin.
  2. **Poistetaan koekentällä tapahtuvaa kuivumisaikamittausta koskeva kappale ja liitteet. Tarvittaessa lisätään EN 1871:n uusi tarkempi metodi materiaalien kuivumis- / kovettumisnopeuden määrittämiseen.**
     - Perustelu: Nykyinen mittausmenetelmä on erittäin työläs ja epätarkka, antaa eri olosuhteissa voimakkaasti vaihtelevia ja huonosti keskenään korreloivia tuloksia samalle materiaalille → Ei tuota hyödyllistä informaatiota.

EN 1871 (Road marking materials - Paint, thermoplastic and cold plastic materials Physical properties)

- Ehdotetut muutokset:
  - **Lisätään EN ISO 16474 viitattujen standardien listaan**
    - Perustelu: EN ISO 16474-3 on vastaava UV-koestusstandardi maaleille, kuten jo ennestään viitattu EN ISO 4892-3 on massoille.
  - **Korvataan EN 1824:n liitteessä kuvattu koekentällä suoritettava kuivumisaikamittausmetodi ASTM D711-10 (*Standard test method for no-pick-up time of traffic paints*) mukaisella laboratoriotestausmenetelmällä**
    - Perustelu: Uuden menetelmän mukaiset mittaukset ovat helpommin toteutettavia ja toistettavia. Tulokset kuvaavat materiaaliominaisuuksia luotettavammin ja vertailukelpoisemmin kuin nykyinen menetelmä.
      - ASTM D711-10 mukaisessa menetelmässä materiaalin kuivumisaika määritetään hallituissa laboratorio-olosuhteissa vierittämällä kumirenkailla varustettu ~5kg metallisylinteri mitattavan standardipaksuuteen applikoidun materiaalikalvon yli esim. minuutin välein ja kirjaamalla ylös aika jolloin materiaali ei enää tartu kumirenkaisiin.

Pohjoismainen koekenttä

- Päivitys kaudella 2019 vaadittaviin materiaalisertifikaatteihin Norjassa, Ruotsissa & Tanskassa:
  - Norja:
    - P4 → Valkoinen kuumamassa
    - P3 → Keltainen kuumamassa & valkoinen 2K ruiskutettu massa
    - P2 → Keltainen 2K ruiskumassa
  - Ruotsi:
    - P4 → Kaikki urakat
  - Tanska:
    - P4 → Valkoinen pitkäkestoinen merkintä (4v takuu)
    - P1 → Valkoinen, lyhytkestoinen merkintä (1v takuu)


TEKNOS
We make the
world last longer

Report number: 2018-6
EAN number: 9788793689749

ROMA

State assessment of road markings in Denmark, Norway and Sweden - Results from 2017

Project
ROMA, State assessment of road markings in Denmark, Norway and Sweden 2017–2021

Report number
2018-6

Date
2018-11-27

Project manager
Jan-Erik Lundmark, Senior Advisor
Road Maintenance, The Swedish Transport Administration.

Financial partners
The Swedish Transport Administration, Sweden
The Norwegian Public Roads Administration, Norway
The Danish Road Directorate, Denmark

Members of the project group
Anna Vadeby, Erik Kjellman, Carina Fors and Sven-Olof Lundkvist, VTI.
Berne Nielsen, Trond Cato Johansen and Christian Nilsson, Ramböll.

Scientific partners
The Swedish National Road and Transport institute (VTI), Sweden
Ramböll, Sweden

Report title
ROMA . State assessment of road markings in Denmark, Norway and Sweden - Results from 2017

Summary:
Assessment of the performance of road markings are carried out regularly to various degrees in the Nordic countries. During the coming years, the Nordic certification system for road marking materials will come into force, which means that a documented product approval (i.e. certification) will be required for use of the material on roads managed by the national road authorities. The requirements are introduced successively as the existing contracts expire. The aim of this project is to monitor and follow up how road marking quality is influenced by the introduction of the certification system in Denmark, Norway and Sweden. If the performance does not develop as expected, continuous assessments give the opportunity to react and adjust the requirements in the future. Furthermore, the aim is to show possible differences in road marking performance between the three countries, similar regions in the three countries and TEN-T-roads.
The study is based on mobile road assessment measurements carried out in Denmark, Norway and Sweden by Ramböll AB. In total 71 road objects were measured in Denmark, 101 in Norway and 436 in Sweden. The following variables were studied: retroreflectivity of dry and wet road markings, relative visibility of dry and wet road markings, relative pre-view-time (pvt) of dry and wet road markings and cover index.
The results show that the retroreflectivity requirement of dry road markings is roughly fulfilled in 50 % of the measured objects. The retroreflectivity is a little bit higher for lane and centre lines. Some retroreflectivity values are low, e.g. on motorway edge lines in Denmark. However, this is compensated for by a large area, which nevertheless means good visibility. The opposite: edge lines on Swedish two-lane roads have high retroreflectivity, which would imply good visibility. However, the road marking area is small, thus reducing the visibility in comparison with both Danish and Norwegian edge lines. Regarding wet road markings, road markings in Norway has have higher retroreflectivity than in Denmark and Sweden for every road class. The cover index is significantly lower in Denmark than in Norway and Sweden. This fact may be explained the use of studded tyres in the two last mentioned countries, which might lead reconditioning of the road markings more often.
A comparison between the performance on the Trans-European Transport Network (TEN-T) and other roads showed that there are only minor differences between the TEN-T and other roads in Denmark and Norway, while in Sweden the retroreflectivity has somewhat higher levels for the TEN-T network (175 mcd/m2/lx compared to 162 mcd/m2/lx). The results for visibility show larger differences between TEN-T or non-TEN-T and for all countries the visibility is higher for the TEN-T net-

work. The pre-view-time in Denmark and Norway is lower on the measured TEN-T roads while in Sweden there is no significant difference between the road types. For all countries, the mean speed limit is higher on the TEN-T roads than on other roads, which leads to shorter pre-view-time.
In the first year of the project, it is not possible to study any effect of the Nordic certification system for road markings. However, in the coming years, some effects, hopefully positive, would be possible to register.
In conclusion, there is no large difference in road marking performance in the three countries. The only significant difference is the poor visibility of edge lines on two-lane roads in Sweden and the good performance of wet road markings in Norway.

Keywords
Road markings, state assessment, retroreflectivity, relative visibility, relative pre-view-time, cover index, ANOVA, cluster analysis.

Language	**Number of pages**
English	85

Rapport title

ROMA, en studie av vägmarkeringars tillstånd i Danmark, Norge och Sverige - resultat från 2017

Sammanfattning

Bedömning av vägmarkeringarnas tillstånd genomförs regelbundet i olika omfattning i de nordiska länderna. Under de närmaste åren kommer ett certifieringssystem för vägmarkeringsmaterial att träda i kraft i Norden, vilket innebär att ett dokumenterat produktgodkännande (certifiering) kommer att krävas för att materialet ska få användas på vägar som förvaltas av de nationella vägmyndigheterna. De nya kraven införs succesivt efter att de befintliga entreprenaderna löper ut.

Det huvudsakliga syftet med föreliggande studie är att med tillståndmätningar, dels under 2017 skaffa en bra bild av vägmarkeringarnas funktion innan det nya certifieringssystemet börjar tillämpas, dels med fortsatta mätningar under 2018 – 2021 studera utvecklingen och effekterna av certifieringens införande. Syftet är också att visa eventuella skillnader i vägmarkeringsprestanda mellan de tre länderna som ingår i projektet: Danmark, Norge och Sverige.

Studien baseras på mobila tillståndsmätningar utförda i Danmark, Norge och Sverige av Ramböll AB. Totalt mättes 71 vägobjekt i Danmark, 101 i Norge och 436 i Sverige. Följande variabler studerades: retroreflexion för torra och våta vägmarkeringar, relativ synbarhet för torra och våta vägmarkeringar, relativ pre-view-time (pvt) för torra och våta vägmarkeringar samt vägmarkeringens täckningsgrad.

Resultaten visar att retroreflexionskravet för nya, torra vägmarkeringar (150 mcd/m2/lx) är uppfyllt för ca 50 % av de studerade vägobjekten. Retroreflexionen är något högre för körfältsmarkeringar och mittmarkeringar än för kantmarkeringar. För t.ex. kantmarkeringar på motorvägar i Danmark är retroreflexionen låg. Detta kompenseras dock av att dessa vägmarkeringar har en stor area, vilket innebär att den synbarheten ändå blir god. För tvåfältsvägar i Sverige är situationen den omvända, där har kantmarkeringarna hög retroreflexion, men arean är liten och den synbarheten blir därmed lägre än för såväl Danmark som Norge. När våta kantmarkeringar studeras har vägmarkeringar i Norge högre retroreflexion än både de i Danmark och Sverige. Vägmarkeringens täckningsgrad är lägre i Danmark än i Norge och Sverige. Detta skulle kunna bero på att dubbdäck är vanligare i Sverige och Norge vilket innebär att vägmarkeringen behöver kompletteras oftare och en ny vägmarkering förväntas ha högre täckningsgrad än en gammal.

En jämförelse mellan det TransEuropeiska Transportvägnätet (TEN-T) och andra vägar visade att det endast finns mindre funktionsskillnader mellan TEN-T vägnätets och övrigt vägnätets vägmarkeringar i Danmark och Norge, medan den i Sverige är något högre för TEN- T-vägnätet (175 mcd/m2/lx jämfört med 162 mcd/m2/lx). Resultaten för synbarhet visar större skillnader mellan TEN-T eller icke-TEN-T och för alla ingående länder är den synbarheten längre för TEN-T-vägnätet. Pre-view-time i Danmark och Norge är kortare på de studerade TEN-T-vägarna, medan det i Sverige inte finns någon signifikant skillnad i pre-view-time mellan vägtyperna. För alla tre länderna är hastighetsgränserna i medeltal högre på TEN-T-vägnätet än på det övriga vägnätet, vilket ger kortare pre-view-time.

Sammanfattningsvis är det ganska små skillnader i vägmarkeringarnas funktion när man jämför Danmark, Norge och Sverige. Undantagen är den relativt låga synbarheten hos kantlinjerna på svenska tvåfältsvägar, trots en hög retroreflexion, och en hög synbarhet hos våta vägmarkeringar i Norge.

Nyckelord

Vägmarkeringar, tillståndsmätningar, retroreflektion, relative synbarhet, relativ pre-view-time, täckningsgrad, ANOVA, klusteranalys.

Table of contents

0 Glossary

	Explanation
Road object	A 10 km road section which is homogeneous with respect to road number, type of road (two-lane or multi-lane road) and road class (AADT).
Measurement object	The road marking measured within a road object. On each road object, three road markings (edge lines, centre or lane line) are measured.
Retroreflectivity	R_L, represents the brightness of a road marking in darkness as seen by drivers of vehicles under the illumination by the driver's own headlamps and expressed in mcd/m^2/lx (milli-candela per square meter per lux).
Visibility	Visibility is the longest distance at which a road marking in darkness is visible to a driver when illuminated by the headlamps of the vehicle(m).
Relative visibility	Relative visibility refers to the visibility at some condition, but when the exact condition is not known. The measure can be used for comparisons between countries and road classes and is used in this study.
Pre-view-time (pvt)	Pre-view-time is the time it takes to drive the distance that corresponds to the visibility distance of the road marking. Pre-view-time is thus dependent on visibility distance and driving speed.
Relative pre-view-time (pvt)	Relative pre-view-time depends on relative visibility and speed limit.
Cover index	Cover index is defined as the part of the original road marking area that remains at the time of measurement.
TEN-T road network	The trans-European transport network (TEN-T) is a network which comprises roads, railway lines, inland waterways, inland and maritime ports, airports and rail-road terminals throughout the 28 Member States.
AADT	Annual Average Daily Traffic

1 Background

Assessment of the performance of road markings are carried out regularly to various degrees in the Nordic countries. A Swedish study from VTI (Nygårdhs and Lundkvist, 2004) presents "Road marking assessment in the Nordic countries 2003". The primary aim of this study was to show how measurements in the five Nordic countries could be summarized and what comparisons regarding road marking retroreflectivity that could be done. However, data in the different countries was collected using different methods, and therefore no clear conclusions from the analysis could be drawn. The outcome of the study was that the measured road objects must be chosen in the same way in each country and that measurements must be accomplished by professional staff.

Another assessment study was presented in "Road marking assessment in the Nordic countries: a comparison between road marking performance in Norway, Sweden and Finland", (Fors, Yahya and Lundkvist, 2015). The results in this study are based on a large number of mobile measurements carried out in the three countries during the spring/summer/autumn 2014. The lesson learned was that one must consider the partial road marking maintenance that is performed during the summer and autumn, so this maintenance does not affect comparisons. Furthermore, in order not to make analysis too costly, it is desirable that data from different countries is delivered in a similar way.

The management of road equipment and assessment of this equipment should always be pursued with long-term care and continuity. The two pre-studies have shown interesting snapshots of some performance differences. However, to benefit from the assessments, continuity and annual reconciliation is required. Only then, you can study changes and trends between countries and regions. In addition, this would give a possibility to:

- develop and evaluate RMMS[1]
- act using financial instruments to affect negative trends and differences between countries or regions
- analyse and evaluate the effects of economic measures
- evaluate the effects of changes in the requirements
- analyse differences in road marking performance using different types of contracts
- evaluate any relationship between entrepreneur and road marking performance
- perform life cycle analyses

During the coming years, the Nordic certification system for road marking materials will come into force starting in Denmark 2017, Norway 2018 and Sweden probably 2019. This means that a documented product approval (i.e. certification) will be required to use the material on roads managed by the national road authorities. The requirements are introduced successively as the existing contracts expire. The introduction of the certification system is expected

[1] Road Marking Measurement System

to result in better road marking quality, both with respect to durability and performance parameters. Certification is given in relation to the number of wheel passages the road marking material will stand, which will make it possible to select the most feasible materials for a certain road type and/or traffic flow. Materials of low quality will not receive any certification and they will thus not be used any longer. Continuous assessment of the road markings in Denmark, Norway and Sweden is therefore of great importance to investigate whether the certification system will have the desired effects of road marking quality. Further information about the certification system can be found in “Nordic certification system for road marking materials” (Fors, Johansen, Lundkvist and Nygårdhs, 2018).

1.1 Aim of the study

The main aim of the Nordic road marking assessment 2017 is to study the road marking quality before introduction of the certification requirements. Further on, measurements will make it possible to follow the development of the road marking quality and find out any effect of the introduced requirements. Continuous assessments give the opportunity to react and adjust the requirements in the future, if the performance does not develop as expected.

Furthermore, the aim of the study is to show possible differences in road marking performance between the three countries, similar regions in the three countries and TEN-T-roads. The road marking visibility is of special interest as Sweden uses intermittent edge lines to a larger extent than Denmark and Norway. Finally, possible differences between road marking performance, dependent on region, country, type of road and AADT (Annual Average Daily Traffic), will be registered.

2 Method

The study is based on mobile road assessment measurements carried out 2017 in Denmark, Norway and Sweden by Ramböll.

2.1 Objects

A road object is defined as a 10 km road section which is homogeneous with respect to road number, type of road (two-lane or multi-lane road) and traffic flow (AADT). In every two-lane road object, three road markings, the two edge lines and the centre line (if any), are measured. On multi-lane roads, the right edge line is measured in one direction, the left edge line in the opposite direction and one lane line in any direction. In total, one road object includes three measured road markings and data from 30 km of road, see Figure 1**.**

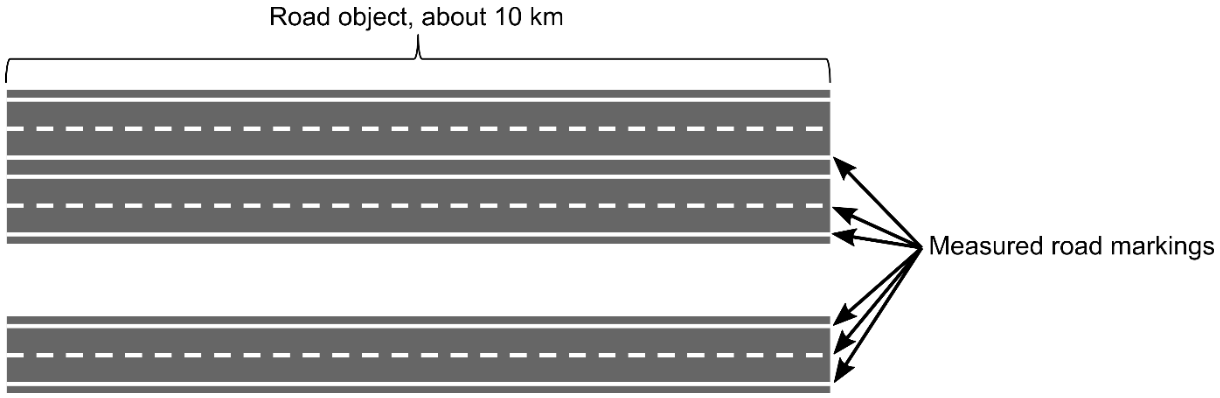

Figure 1. Illustration of road object and measured road markings.

The roads studied are classified into six different road classes defined according to Table 1. For each country and every region, measurements are done from at least five of the classes below.

Table 1. Classification of roads

Road class	**Description**
A	Motorway, AADT > 50 000
B	Motorway or multi-lane roads, 20 000 < AADT ≤ 50 000
C	Motorway or multi-lane roads, AADT ≤ 20 000
D	Two-lane roads, AADT > 5 000
E	Two-lane roads, 2 000 < AADT ≤ 5 000
F	Two-lane roads, 250 < AADT ≤ 2 000

The road objects to be measured are selected randomly from all available roads in each road class. The sampling size was five objects in each road class and region. A more detailed description of the objects and the random selection of objects for each country is given below in section 2.1.1 – 2.1.3. The study handles permanent road markings, only.

The actual measured objects are supposed to be as close as possible to the randomly selected road objects. However, if it was impossible to measure the selected road object, the site had to be moved to the nearest possible site on the same road within the same road class.

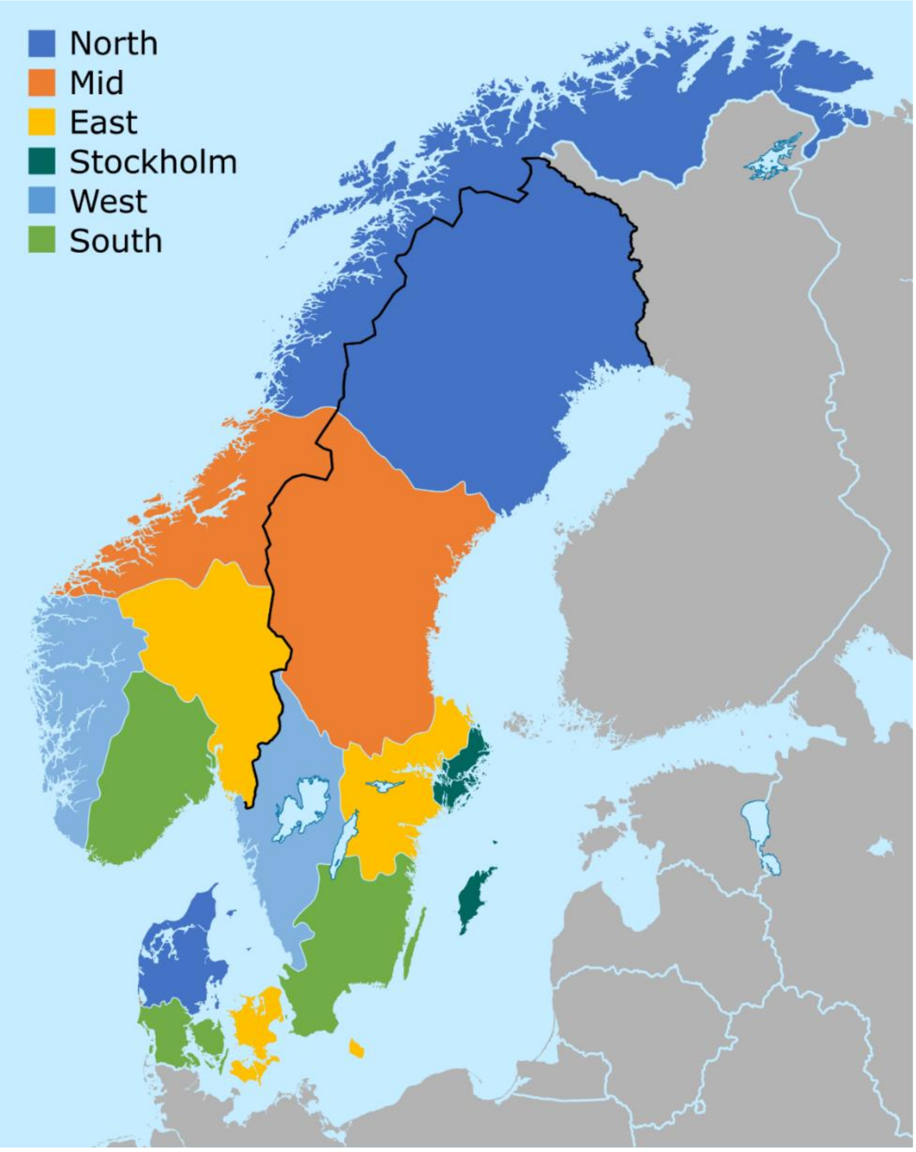

Figure 2. Regions studied in Denmark, Norway and Sweden

2.1.1 Denmark

Denmark is divided into three regions (South, East and North), see Figure 2. In Denmark road classes A – E are studied and for each class and region, five road objects were randomly selected. In one case (region North, class A), the sampling frame did not contain five objects, resulting in only one selected object for that class (the only class A motorway available). In total 71 objects were selected, see Table 2. The selected roads for Denmark are also illustrated in Figure 3. The random selection of objects was done by VTI. In Denmark all permanent road markings are white.

Table 2. Number of road objects for each class and region in Denmark 2017.

	A	B	C	D	E	Total
South	5	5	5	5	5	**25**
East	5	5	5	5	5	**25**
North	1	5	5	5	5	**21**
Total	**11**	**15**	**15**	**15**	**15**	**71**

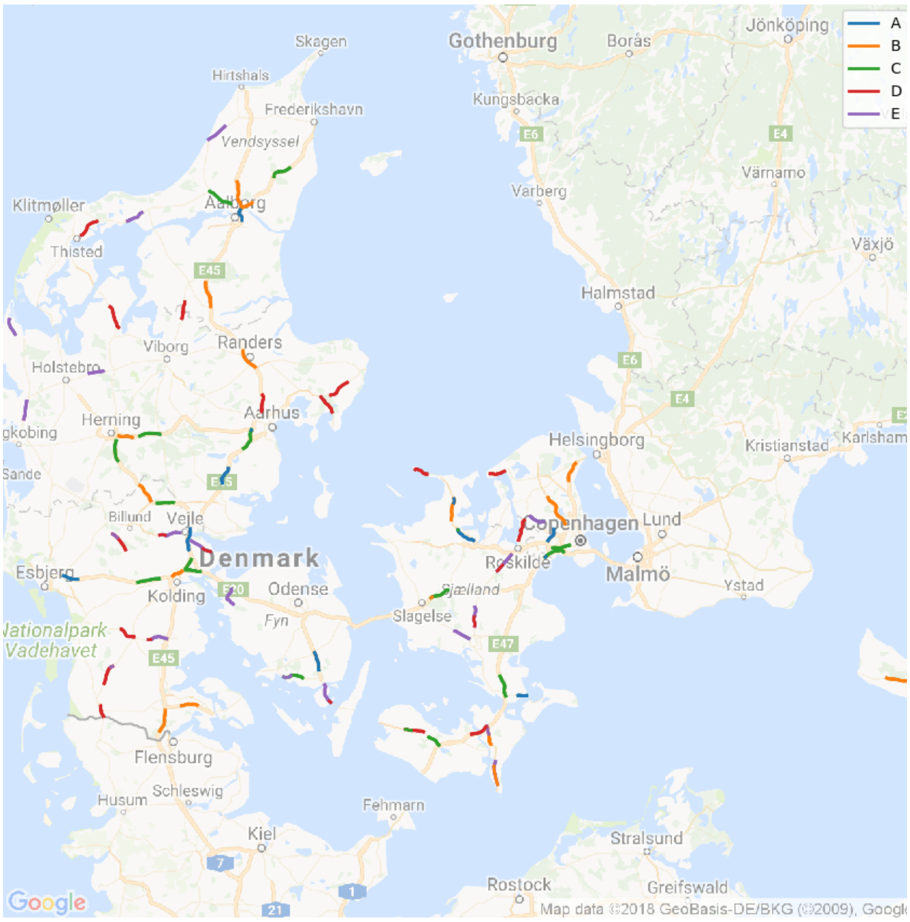

Figure 3. Selected road objects for each class (A-E) in Denmark.

2.1.2 Norway

Norway is divided into five regions (South, West, East, Mid and North), see Figure 2. In Norway road classes B – F are studied and for each class and region, five road objects were randomly selected. In some cases, the sampling frame did not contain five objects (lack of available roads in that region and road class), resulting in fewer objects for those classes. In total, 101 objects were selected for Norway, see Table 3. The selected roads for Norway are also illustrated in Figure 4. The random selection of objects was done by VTI. In Norway the permanent edge lines on two-lane roads are white, while the permanent centre lines and the permanent left edge lines on multi-lane roads are yellow.

Table 3. Number of road objects for each class and region in Norway 2017

Region	B	C	D	E	F	Total
South	5	4	5	5	5	**24**
West	5	5	5	5	5	**25**
East	3	1	5	5	5	**19**
Mid	2	1	5	5	5	**18**
North	-	-	5	5	5	**15**
Total	**15**	**11**	**25**	**25**	**25**	**101**

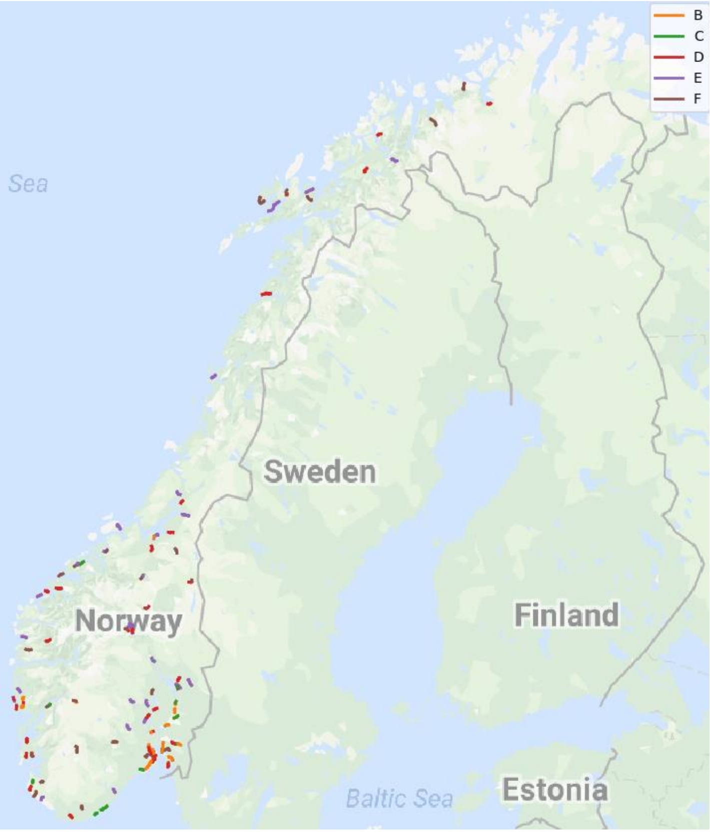

Figure 4. Selected road objects for each class (B-F) in Norway.

2.1.3 Sweden

Sweden is divided into six regions (South, East, West, Stockholm, Mid and North), see Figure 2. The random selection of road objects was done by the Swedish Road Administration in conjunction with the national road assessment programme. For some of the road classes, additional objects were randomly selected to fulfil the needs for the ROMA-project. The total number of objects are specified in Table 4 and in total 436 road objects in road classes A – F were selected for Sweden. The selected roads for Sweden are also illustrated in Figure 7. All permanent road markings in Sweden are white.

Table 4 Number of objects for each class and region in Sweden 2017

Region	A	B	C	D	E	F	Total
South	0	6	21	8	27	40	**102**
West	2	8	8	5	16	26	**65**
East	0	9	23	4	23	38	**97**
Stockholm	5	11	6	5	4	11	**42**
Mid	0	1	10	5	19	48	**83**
North	0	0	7	0	5	35	**47**
Total	**7**	**35**	**75**	**27**	**94**	**198**	**436**

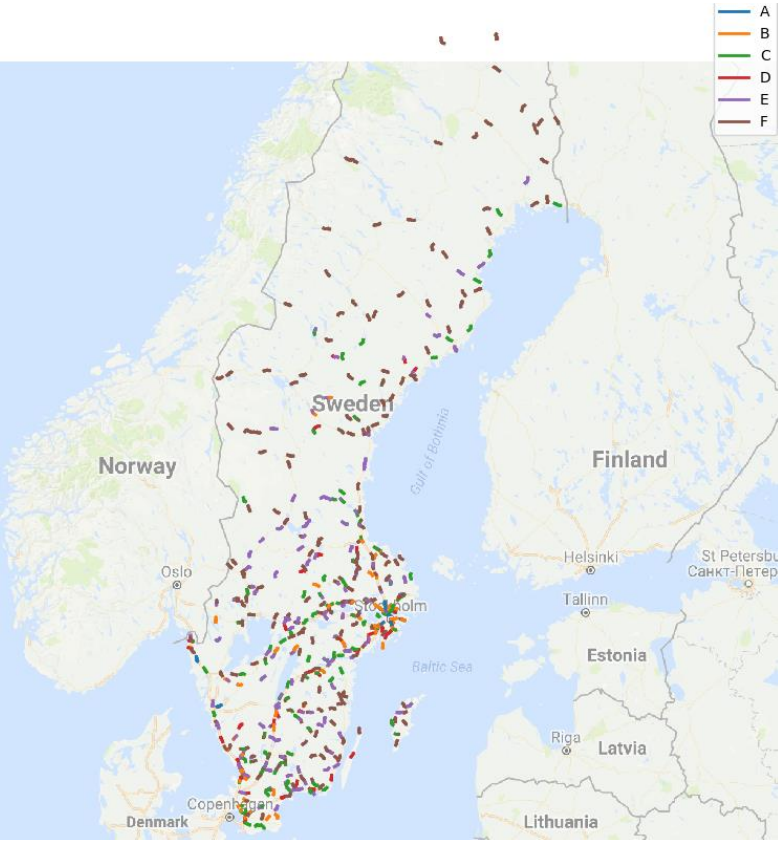

Figure 5. Selected road objects for each class (A-F) in Sweden.

2.2 Measurements and data

The measurements have been performed at speed with Ramböll's mobile measurement system for physical inspection of road markings, RMT (see Figure 6), and according to the Swedish method TDOK 2013:0461_v2 (Trafikverket, 2017).

To ensure the quality of data, calibration of the measuring system shall be performed according to established routines in the quality system of Ramböll. Check against handheld instruments should be performed at least once a week. During 2017, self-control was used for the quality assessments, however all instruments used were also validated by VTI in May 2017.

For registration of the retroreflectivity of *dry* road markings ($R_{L,dry}$) the mobile reflectometer LTL-M (Delta, Denmark) was used. The reflectometer sends out visible light, which will resemble vehicle lighting, and measures how much light is reflected back to the instrument. Along with this instrument, the RMT system consists of an optocator, a laser which registers the mean profile depth (MPD) of the road marking. From these two parameters, the *wet* road marking retroreflectivity ($R_{L,wet}$) can be calculated as described in VTI Report 611 (Lundkvist, Johansen, Nielsen, 2008).

Figure 6. Ramböll's system for control of road markings, RMT

The measurements are carried out on dry road markings during the following time periods:

- Denmark: 15 April – 1 October
- Sweden: 15 May (starting in the south) – 1 October
- Norway: 15 June (starting in the south) – 1 October.

It has not been considered if the measured road has stationary lighting or not, except if there was street lighting for more than 2 km of the measured road object, then retroreflectivity of wet road markings was not analysed[2].

Before the analysis started, the following treatment was done to the data:

- If new pavement – that part of the object was removed from the analysis
- If dirty road markings – that part of the object was removed from the analysis

[2] On a road with stationary lighting, there is no performance requirement for the retroreflectivity of wet road markings and it is therefore not relevant to analyse.

- In case of worn road marking and no value for retroreflectivity is collected - standard values of 40 and 10 mcd/m^2/lx) for dry and wet road markings, respectively, were inserted.
- If a part of the measurement object, less than 2 km, has road lighting, the wet road marking retroreflectivity of this part was excluded.

2.3 Variables

The dependent variables analysed in ROMA are:

- Retroreflectivity of dry and wet road markings
- Relative visibility of dry and wet road markings
- Relative pre-view-time (pvt) of dry and wet road markings
- Cover index

A brief description of the variables follows below:

2.3.1 Retroreflectivity

The coefficient of retroreflected luminance, R_L, represents the brightness of a road marking in darkness as seen by drivers of vehicles under the illumination by the driver's own headlamps, see Figure 7. It is measured in the direction of traffic and is expressed in mcd/m^2/lx, see European Standard EN-1436 (2018).

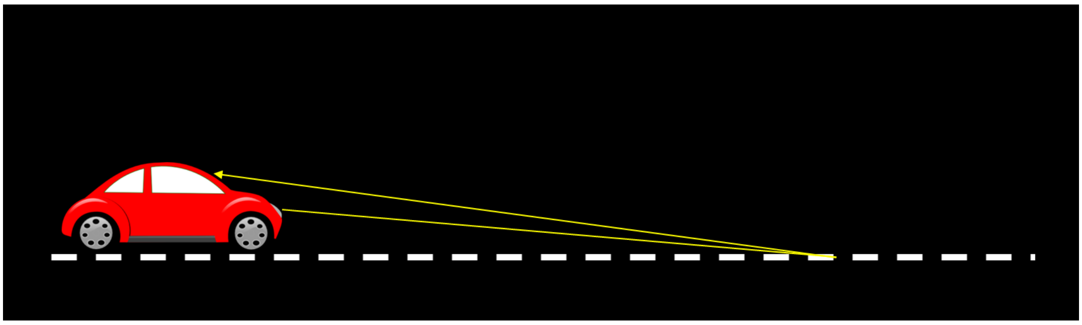

Figure 7. Illustration of retroreflectivity.

The performance requirements for dry and wet retroreflectivity for white and yellow road markings are specified in Table 5. Out of the three countries studied, only Norway has yellow permanent markings and only in the centre line and left edge line on multi-lane roads.

Table 5. Performance requirements

Parameter	White markings	Yellow markings
Coefficient of retroreflected luminance, R_L dry [mcd/m^2/lx]	150	100
Coefficient of retroreflected luminance, R_L wet [mcd/m^2/lx]	35	35

2.3.2 Relative visibility

The longest distance (m) at which a road marking is visible to a driver when illuminated by high beam illumination, Figure 8, depends on the retroreflectivity and the area of the road marking, but also on the driver's eyesight, the vehicle lighting, the traffic situation, the road geometry, etc.

The model for calculating visibility is under revision and we have therefore chosen to study *relative visibility*. Relative visibility refers to the visibility of some condition, but we cannot say exactly which condition, except that the road marking is illuminated by high beam. This means that it is not relevant to draw conclusions of the specific values of relative visibility reported, but the measure is intended for comparison between, for example, visibility of road markings in the three countries or in different road classes.

Relative visibility, S_{rel} is defined as:

$$S_{rel} = k \cdot \log(R_L \cdot A), \qquad \text{Eq. (1)}$$

where
R_L = retroreflectivity [$mcd/m^2/lx$]
A = area of the road marking of a 60 m long section of the road [m^2]
k = constant reflecting visibility level, which depends on the age of the driver, the status of the headlights etc.

In the analyses, k = 25 which gives the realistic visibility distance of 75 m in high beam illumination for a continuous road marking of width 10 cm and R_L = 150 $mcd/m^2/lx$.

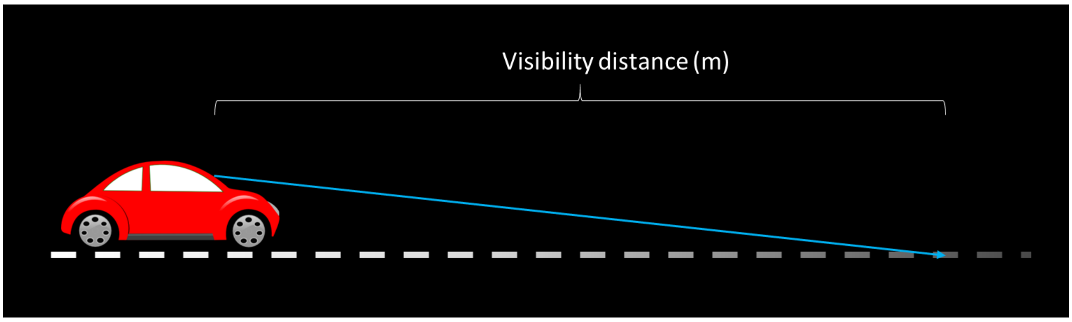

Figure 8. Visibility distance [m]

2.3.3 Relative pre-view-time

Pre-view-time is defined as the time it takes to drive from point A to point B, see Figure 9 and is depending on visibility distance and driving speed. *Relative pre-view-time d*epends on relative visibility distance and the speed limit.

Relative pre-view-time has been calculated as $pvt_{rel} = \frac{S_{rel}}{speed\ limit}\ [\frac{m}{\frac{m}{s}}]$. Eq. (2)

The speed limit is defined as the dominating speed limit over the distance of the object. For instance, if 7 kilometres of the road object has the speed limit 90 km/h, and 3 kilometres has 70 km/h, the speed limit for calculation of relative pvt is set to 90 km/h. In this report, only relative pvt is studied.

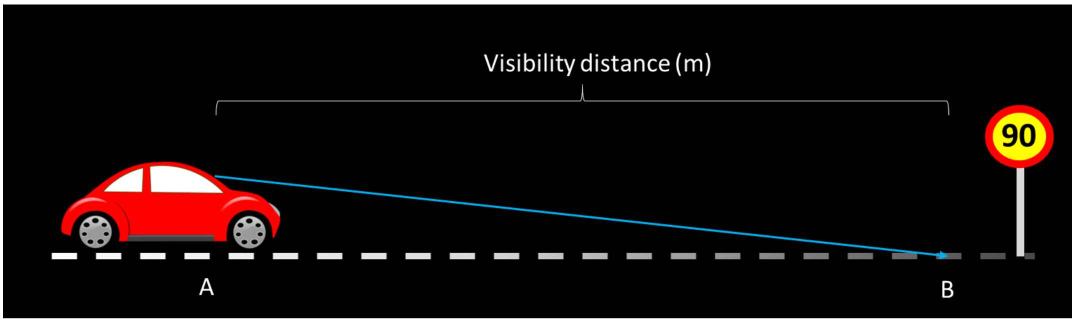

Figure 9. Pre-view-time [s]

2.3.4 Cover index

The cover index (%) has been defined as the part of the road marking area that remains at the time of measurement. The definition is: "*Area of white road marking relative to the area within the theoretical outer dimensions of a longitudinal marking*". This parameter is measured using photo imaging at an angle of 90 degrees to the road marking surface.

The cover index is measured in % and can have values above 100 % if for example a new road marking overlap with an old road marking. Profiled markings might have values below 100 % even when they are new if the pattern contains unfilled parts, such as a chessboard pattern. The measure is new and under development. The ambition for the coming years is to relate the cover index to road marking type (i.e. whether the road marking is profiled or not). However, this information is not available yet. In the future, cover index might be used instead of the theoretical area when estimating the relative visibility.

2.3.5 Other variables

Except the variables analysed in ROMA, also the distance, coordinates and photos every tenth meter are registered. Furthermore, the luminance coefficient (Qd) and the skid resistance, though not analysed here, are available for analysis. This would make it possible to provide other information of interest for future studies.

2.4 Statistical analyses

The results are analysed and compared both between countries and road classes (A-F) for all variables, but also between regions and road classes in each country. The between-countries-results are reported in Chapter 3 and the within-country-results in Annex 1 for Denmark, Annex 2 for Norway and Annex 3 for Sweden.

The between-country-analyses are mainly done using analysis of variance, ANOVA (see Montgomery, 1991). The dependent variables (Y) are retroreflectivity of dry and wet road markings, relative visibility of dry and wet road markings, relative pre-view-time (pvt) of dry and wet road markings and cover index. The factors considered in the model are country and road class and the model is specified below:

$$Y_{ij} = \mu + \alpha_i + \theta_j + \alpha\theta_{ij} + \varepsilon_{ij},$$

where μ is the mean effect and ε is an error term and

α_i = country (Denmark, Norway, Sweden)
θ_j = road class (A, B, C, D, E, F)

The interaction $\alpha\theta_{ij}$ in the model reflects that there might be a different development of the dependent variable between countries and road classes. The mean levels estimated are estimated marginal means and therefore adjusted for unbalance in the design.

If a factor of interest is shown to be significant in the ANOVA analysis, pairwise comparisons between different levels of the factor are made. The comparisons are based on the estimated marginal means which compensate for an unbalanced design if that is the case. The Bonferroni adjustment for multiple comparisons is used. All significant tests are carried out at the risk level 5 %.

The ANOVA-analysis is supplemented by a cluster analysis. Data of mean retroreflectivity on dry roads has been analysed at regional and country level with a cluster analysis (k-means clustering). In short, this analysis means that the different regions are divided into three clusters: one cluster that has higher retroreflection than the rest, one having lower retroreflection and a cluster between them. All cluster analysis applies to mean retroreflectivity.

3 Results

Below, the results from the between-country-comparisons are shown. Some more results from the ANOVA-analysis are shown in Annex D. Results for within country comparisons are shown in Annex A for Denmark, Annex B for Norway and Annex C for Sweden.

3.1 Dry road markings

In Table 6, the number of measured road markings (as described in section 2.1) used in the analyses for dry road markings is shown. For Denmark 210 objects are analysed, while for Norway and Sweden, the numbers are 278 respectively 1270.

Table 6. Number of measured road markings used in the analyses for dry road markings.

Road class	Denmark	Norway	Sweden
A	31		21
B	45	43	103
C	44	32	224
D	45	75	81
E	45	73	280
F		55	561
Total	210	278	1270

3.1.1 Retroreflectivity

In Figure 10, the percentage of road marking length within various levels of retroreflectivity is shown. The figures are based on all road markings and on total measured road length. For Norway, the figure includes both yellow[3] and white road markings, while in Denmark and Sweden only white road markings are used. Since Norway is the only country of the three countries studied that uses yellow road markings, Figure 11 shows the percentage of road marking length for white respectively yellow road markings for Norway.

Looking at all white road markings, the performance requirements for retroreflectivity is 150 mcd/m^2/lx. In Denmark, 42 % of the road markings reach the level of 150, while in Norway, 56 % of the white road markings have a retroreflectivity above 150 mcd/m^2/lx and the level in Sweden is 55 %. Looking at road markings with a level of retroreflectivity below 80 mcd/m^2/lx, Denmark has only 1 %, while Norway has 8 % and Sweden 7 %.

For yellow road markings, the performance requirements for retroreflectivity is 100 mcd/m^2/lx. In Norway, about 84 % of the yellow road markings (centre line) fulfil these requirements.

[3] In Norway, the centre line and the left edge line on multi-lane roads are yellow.

In Figure 12, it is illustrated how the retroreflectivity on dry road markings (RL_t) is distributed for all countries. Denmark and Sweden with only white road markings have a peak around 150 mcd/m^2/lx, while the distribution for Norway with both white and yellow road markings is broader. Annex E shows the distribution of retroreflectivity and relative visibility for right edge road markings only.

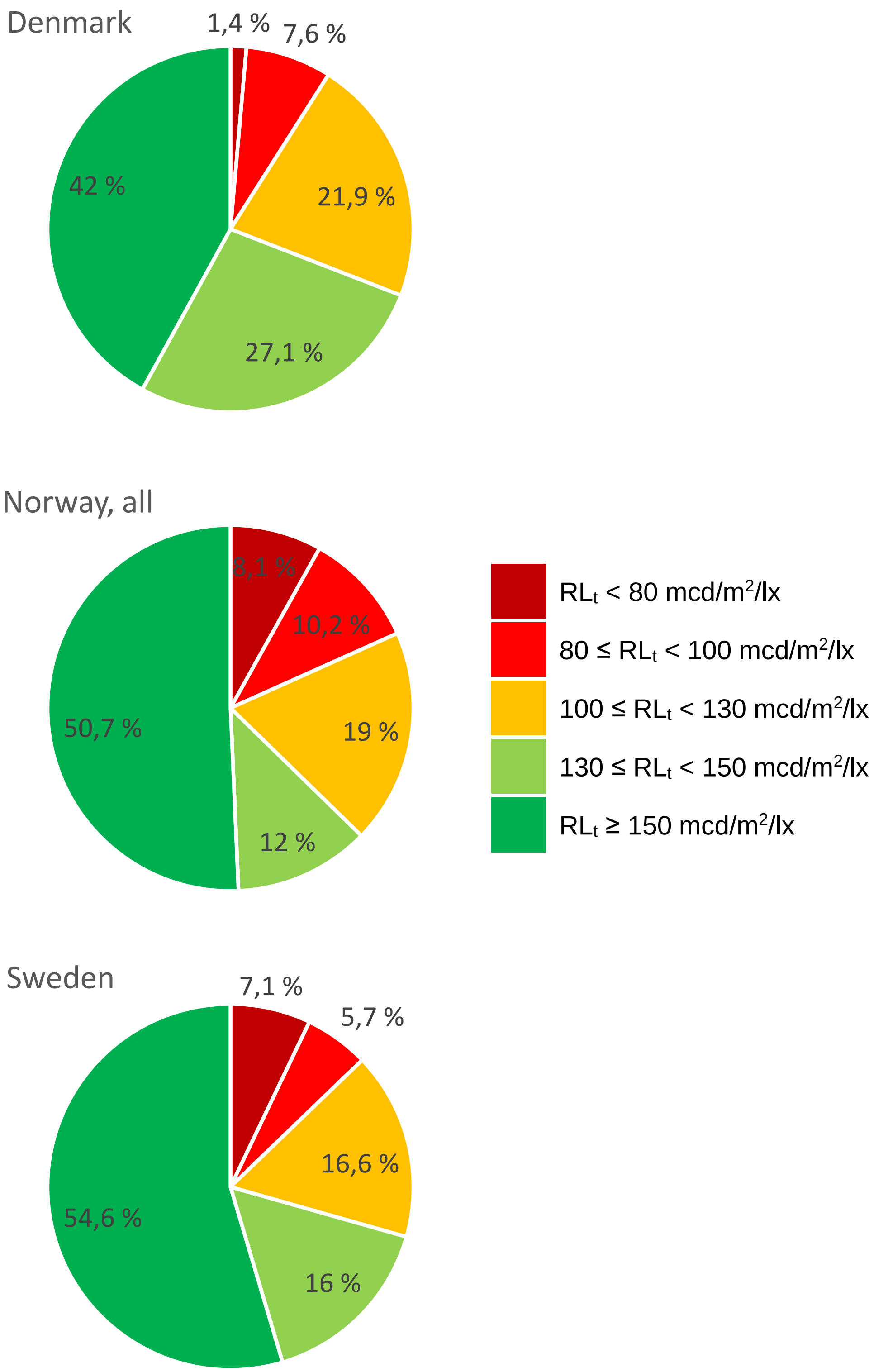

Figure 10. Percentage of road marking length within different levels of retroreflectivity for Denmark, Norway and Sweden. All road markings, white and yellow, based on total measured road length.

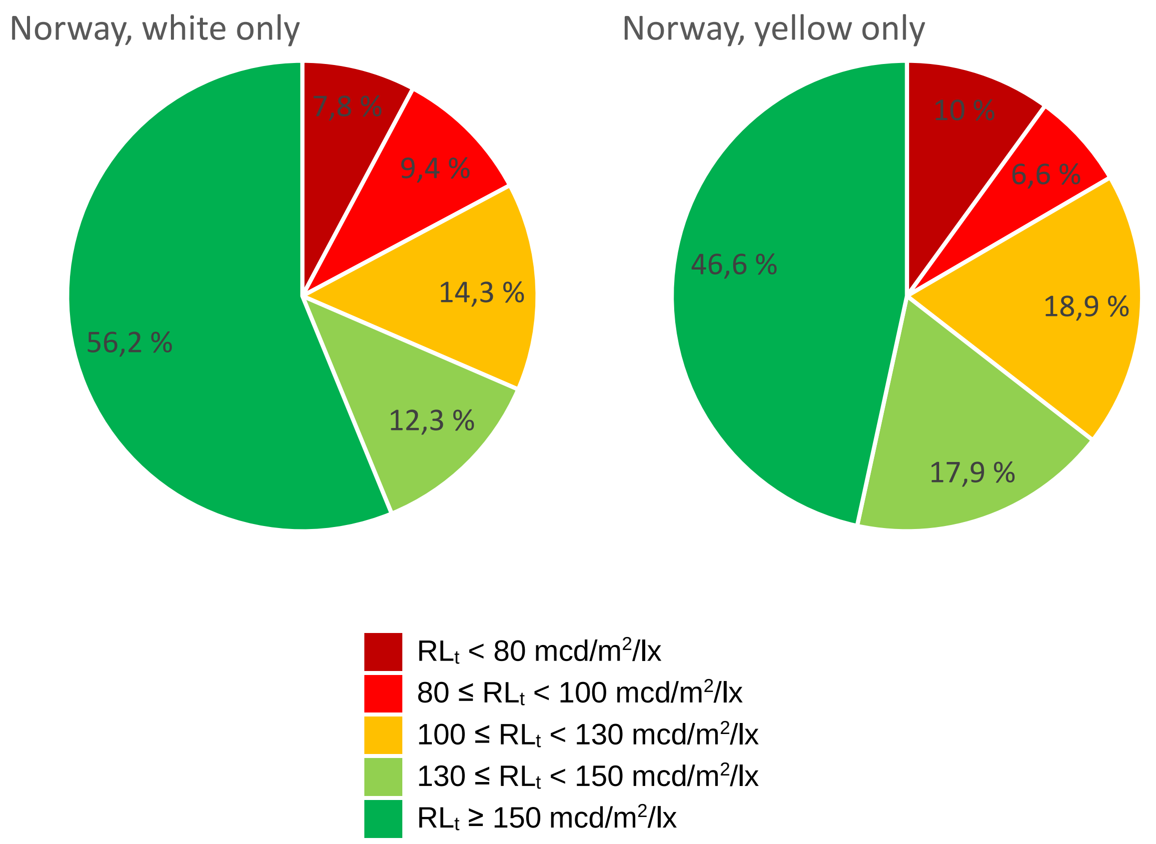

Figure 11. Percentage of road marking length within different levels of retroreflectivity for Norway. Only white respective only yellow road markings.

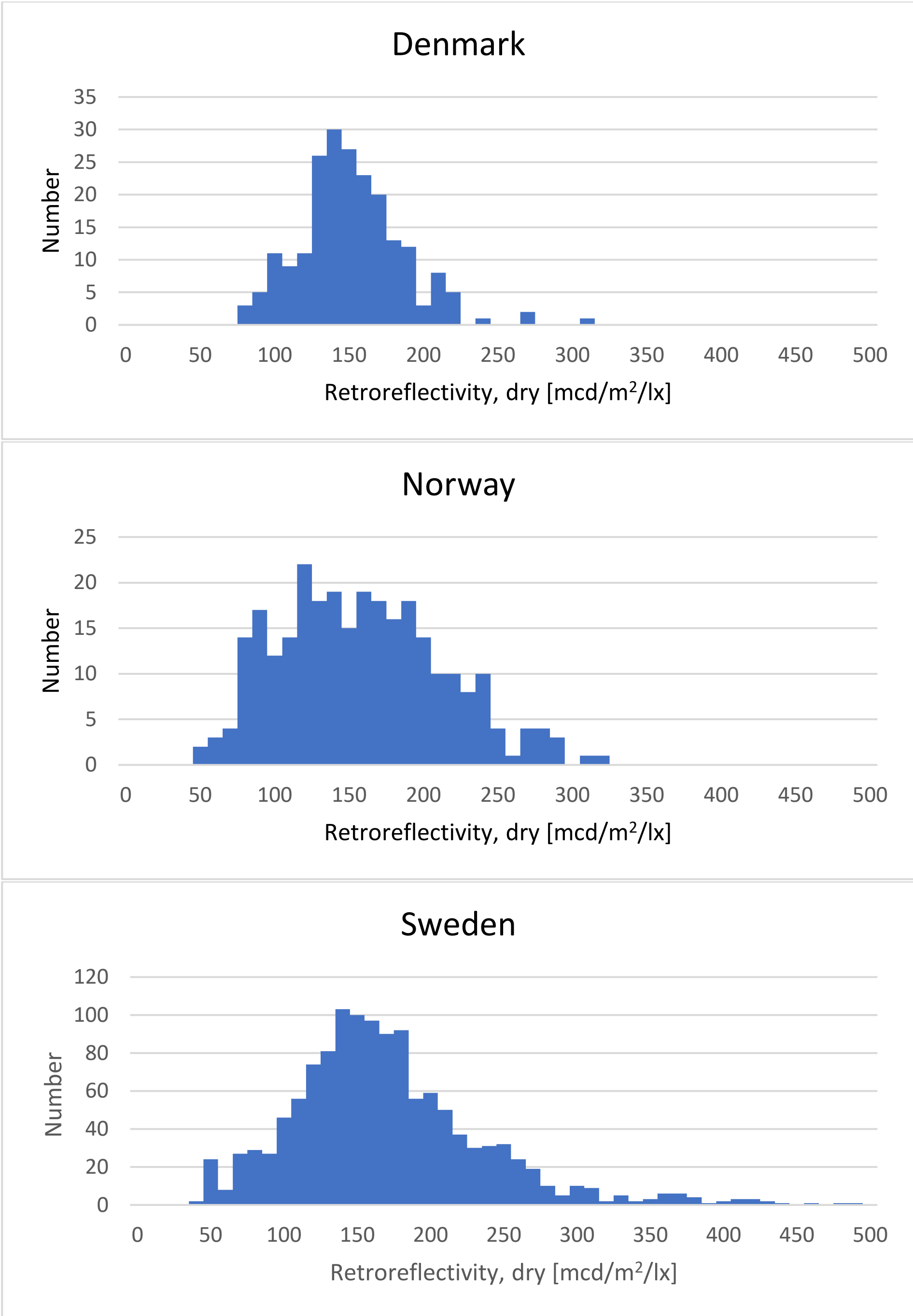

Figure 12. Distribution of retroreflectivity for Denmark, Norway and Sweden. All road markings (refers to edge, centre and lane-lines) dry road markings.

The mean performance of retroreflectivity is studied by an analysis of variance (ANOVA). In Table 7, the result from the ANOVA is shown for dry retroreflectivity of all road markings. There is a significant difference between the retroreflectivity in different countries and between road classes, but the interaction effect (country*road class) is not significant. Table 8 shows mean levels and standard error of dry road marking retroreflectivity for Denmark, Norway and Sweden. The mean levels are estimated marginal means and adjusted for unbalance in the design. In Table 9, the mean levels are compared between countries. Bonferroni adjustment for multiple comparisons are made. Sweden has the highest mean value and Denmark the lowest, the difference between Sweden and Denmark is statistically significant, while the differences between Norway and Denmark respectively Sweden and Norway are not significant. Note that Sweden and Denmark have only white permanent road markings, while Norway has both white and yellow.

Table 7. Results from ANOVA, dry retroreflectivity of all road markings.

Dependent variable	Independent variable	Degrees of freedom	F-ratio	p-value
Retroreflectivity (dry road markings)	Country	2	7.103	0.001
	Road class	5	4.240	0.001
	Country*road class	8	0.428	0.905

Table 8. Mean levels and standard error of retroreflectivity for Denmark, Norway and Sweden.

Country	Mean [mcd/m²/lx]	Standard error [mcd/m²/lx]
Denmark	146	4,3
Norway	154	3,9
Sweden	162	2,9

Table 9. Comparison of mean levels of retroreflectivity between countries. All road markings, white and yellow.

Comparison	Difference (95% CI) [mcd/m²/lx]
Sweden - Denmark	16.5 ± 12.4
Sweden - Norway	8.7 ± 11.6
Norway - Denmark	7.9 ± 13.8

In Figure 13, the retroreflectivity for all dry road markings are compared for different road classes. Note that in Denmark there are no measurements in road class F (rural roads with AADT<2000) and in Norway there are no measurements in road class A (motorways with AADT>50 000). For all road classes, Sweden has the highest mean retroreflectivity, but the differences are rather small.

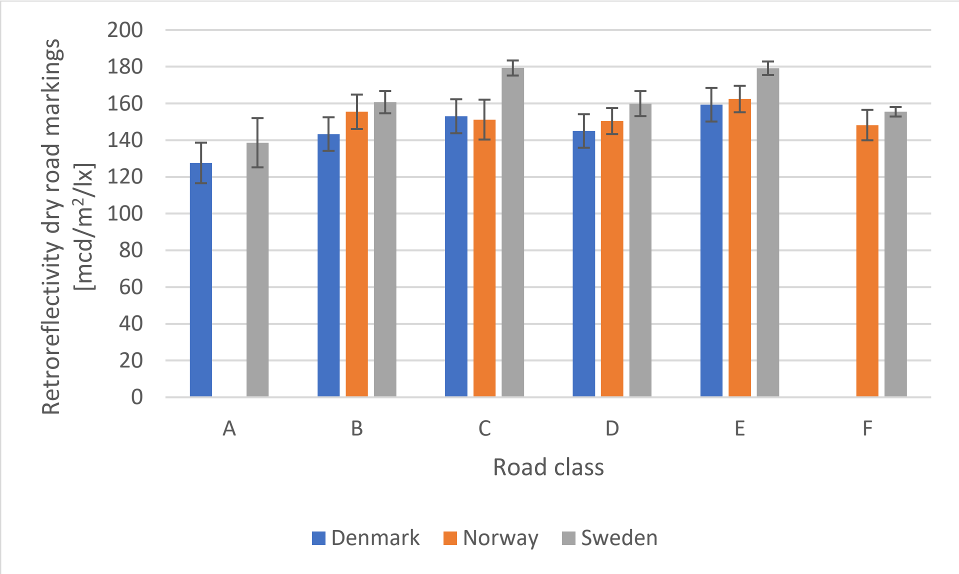

Figure 13. Retroreflectivity for dry road markings. All road markings (white and yellow).

In Figure 14, the retroreflectivity for dry right edge lines are shown. The pattern is similar as in Figure 13 with somewhat higher levels for Sweden.

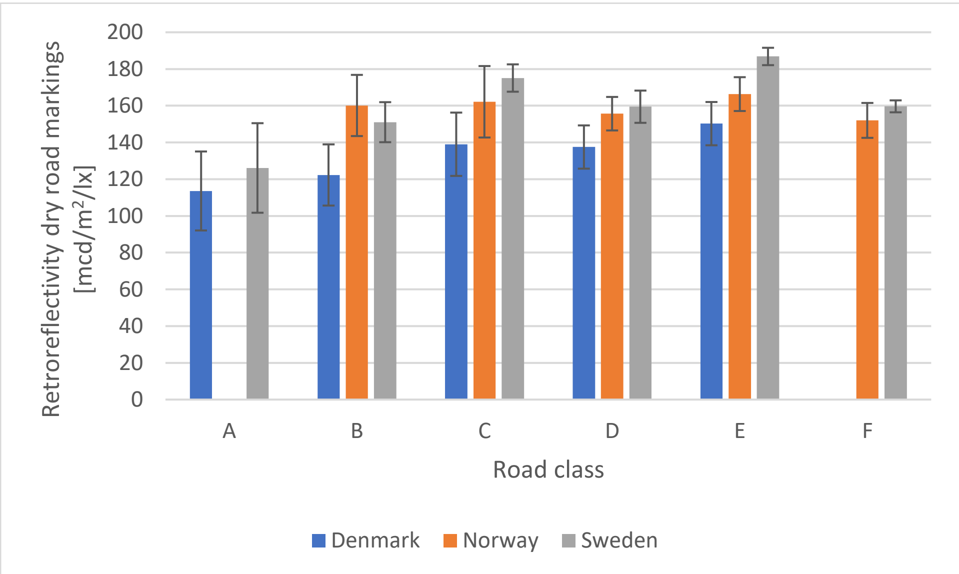

Figure 14. Retroreflectivity for dry road markings. Right edge line (only white).

In Figure 15, retroreflectivity for dry centre/lane lines are shown. For Denmark and Norway, white road markings, and for Norway, yellow road markings.

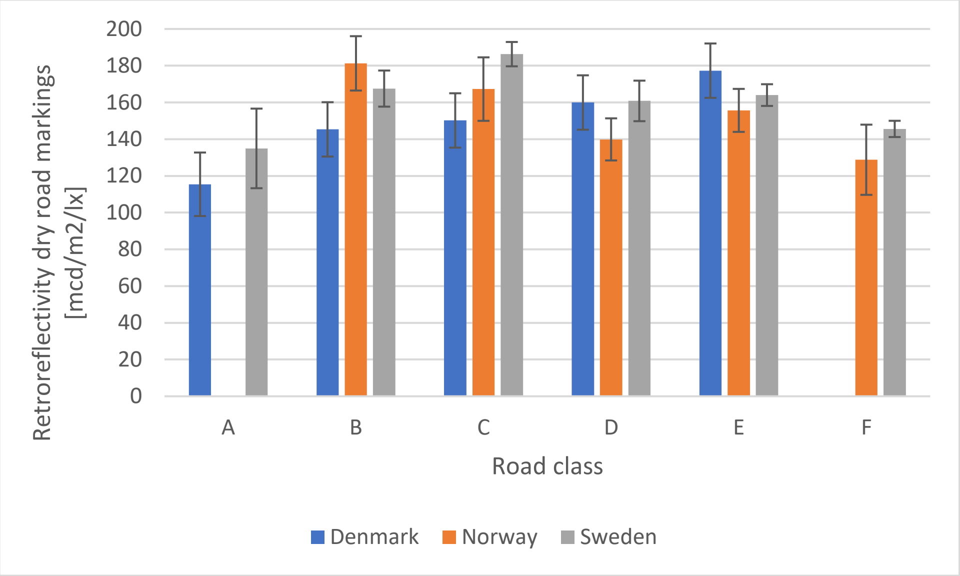

Figure 15. Retroreflectivity for dry road markings. White lane line (class A, B and C), centre line (class D, E, and F), white in Denmark and Sweden and yellow in Norway.

Cluster analysis

The figures below show the results from a **cluster analysis** with three different levels. The three levels indicate how the results in the different regions relate to each other, within the respective category (all, right edge, lane/centre). The results should not be interpreted in absolute terms (i.e. the *high* category means that the retroreflectivity is higher than in the *medium* category, but the categories say nothing about whether the retroreflection is "good" or "approved").

Figure 16 shows mean retroreflectivity for dry road markings divided by country and region. Both white and yellow road markings are included. Figure 17 shows mean retroreflectivity on dry road markings for the right edge line (only white road markings) for all regions and countries and Figure 18 shows mean retroreflectivity on dry road markings for lane lines (class A, B and C), and centre lines (class D, E and F). In Denmark and Sweden white markings and in Norway yellow.

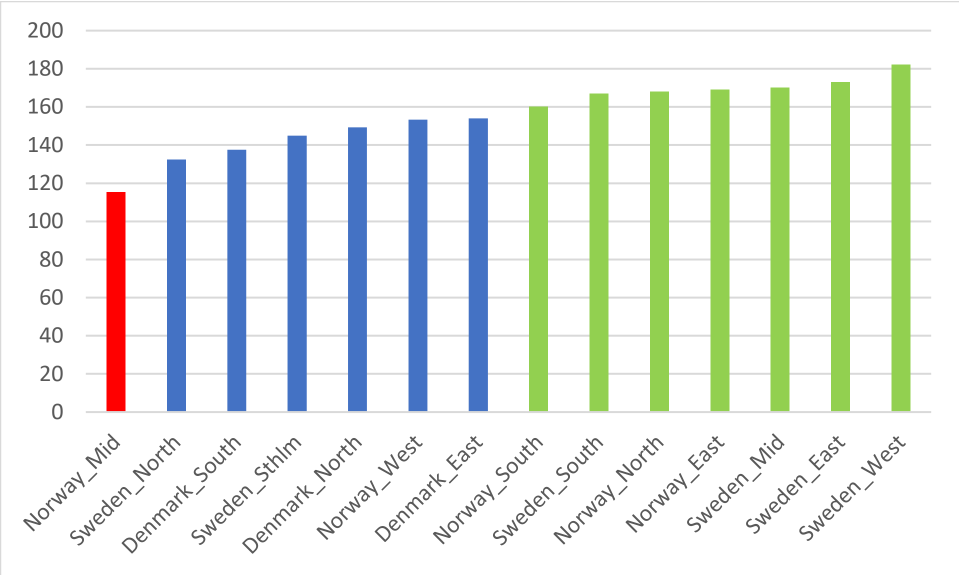

Figure 16. Results from cluster analysis. Mean retroreflectivity [mcd/m^2/lx] on dry road markings. All regions and countries. All road markings (white and yellow).

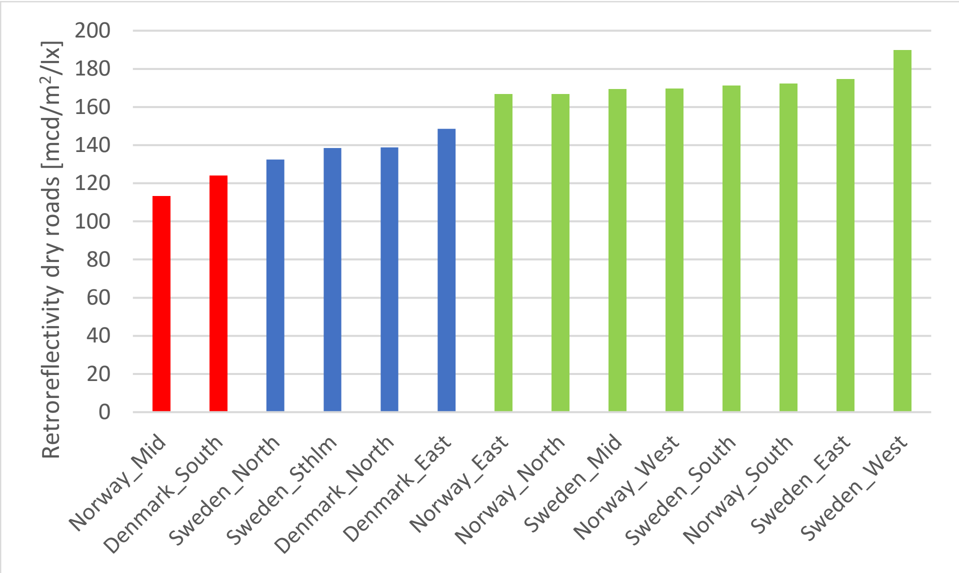

Figure 17. Results from cluster analysis. Mean retroreflectivity [mcd/m^2/lx] on dry road markings. All regions and countries. Right edge line (only white).

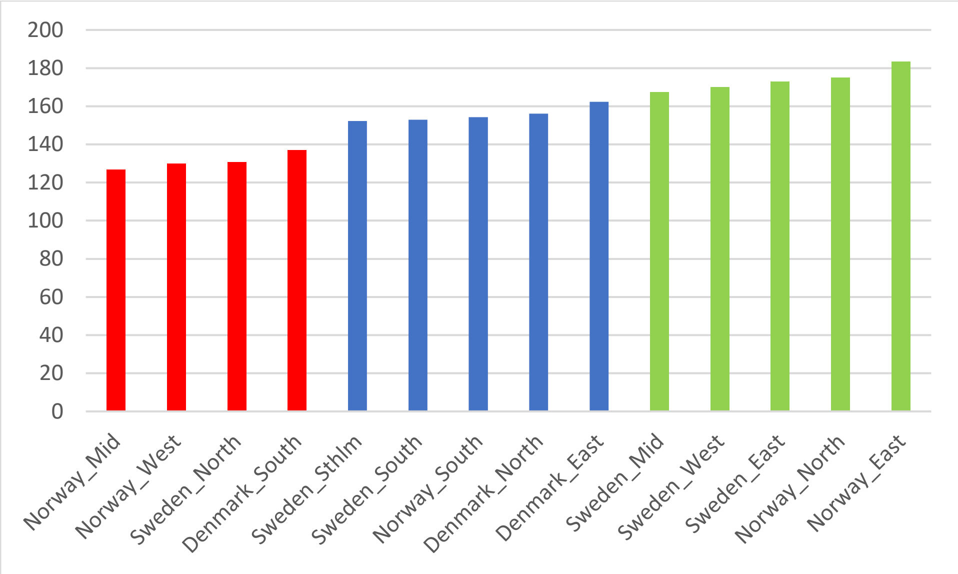

Figure 18. Results from cluster analysis. Mean retroreflectivity [mcd/m^2/lx] on dry road markings. All regions and countries. Lane line (class A, B and C), centre line (class D, E and F). White markings in Denmark and Sweden and yellow in Norway.

Table 10 shows the results from the cluster analysis for all regions in Denmark, Norway and Sweden regarding retroreflectivity for dry road markings, overall as well as for right edge line and lane/centre line respectively.

The results from the cluster analysis show that, at the regional level, the retroreflectivity is generally worst in the Norwegian mid-region and the Denmark south-region. None of the regions in Denmark have been clustered in the "High" category. For Sweden, the northern region is classified as the worst region in comparison to the other Swedish regions.

Table 10. Results cluster analysis regarding mean retroreflectivity [mcd/m^2/lx]. Dry road markings.

Level	All road markings	Right edge line	Lane line (class A, B and C), centre lane (class D, E and F)
High	Sweden_West	Sweden_West	Norway_East
	Sweden_East	Sweden_East	Norway_North
	Sweden_Mid	Norway_South	Sweden_East
	Norway_East	Sweden_South	Sweden_West
	Norway_North	Norway_West	Sweden_Mid
	Sweden_South	Sweden_Mid	
	Norway_South	Norway_North	
		Norway_East	
Medium	Denmark_East	Denmark_East	Denmark_East
	Norway_West	Denmark_North	Denmark_North
	Denmark_North	Sweden_Sthlm	Norway_South
	Sweden_Sthlm	Sweden_North	Sweden_South
	Denmark_South		Sweden_Sthlm
	Sweden_North		
Low	Norway_Mid	Denmark_South	Denmark_South
		Norway_Mid	Sweden_North
			Norway_West
			Norway_Mid

3.1.2 Relative visibility

In Table 11, results from the ANOVA is shown for relative visibility of right edge line on dry road markings. There is a significant difference between the visibility of the road markings in the different countries and between road classes, as well as a significant interaction effect (country*road class). Table 12 shows mean levels and standard errors of dry road marking relative visibility for Denmark, Norway and Sweden. The mean levels are estimated marginal means and adjusted for unbalance in the design. In Table 13, the mean levels between countries are compared. Bonferroni adjustment for multiple comparisons are made. Sweden has the lowest mean value and Denmark the highest. The relative visibility of right edge road markings in Denmark is significantly longer than in both Norway and Sweden. The visibility difference between road markings in Norway and Sweden is small and not significant. Note that all permanent right edge road markings are white.

Table 11. Results from ANOVA, relative visibility of right edge line on dry road markings.

Dependent variable	Independent variable	Degrees of freedom	F-ratio	p-value
Retroreflectivity (dry road markings)	Country	2	5.5	0.004
	Road class	5	81.057	< 0.001
	Country*road class	8	4.668	< 0.001

Table 12. Mean levels and standard error of relative visibility for right edge line on dry road markings for Denmark, Norway and Sweden.

Country	Mean [m]	Standard error [m]
Denmark	80	0.7
Norway	76	0.6
Sweden	75	0.5

Table 13. Comparison of mean levels of relative visibility for right edge lines on dry road markings between countries.

Comparison	Difference (95% CI)
Sweden - Denmark	-4.5 ± 2.2
Sweden - Norway	-1.1 ± 1.9
Norway - Denmark	-3.4 ± 2.3

In Figure 19, the relative visibility for right edge lines are compared for different road classes. Note that in Denmark there are no measurements in road class F (rural roads with AADT<2000) and in Norway there are no measurements in road class A (Motorways with AADT>50 000). For all road classes except class B, Sweden has the lowest mean relative visibility, but the differences are rather small. The largest difference between countries is found in class E, two-lane roads with AADT between 2000 and 5000 vehicles per day.

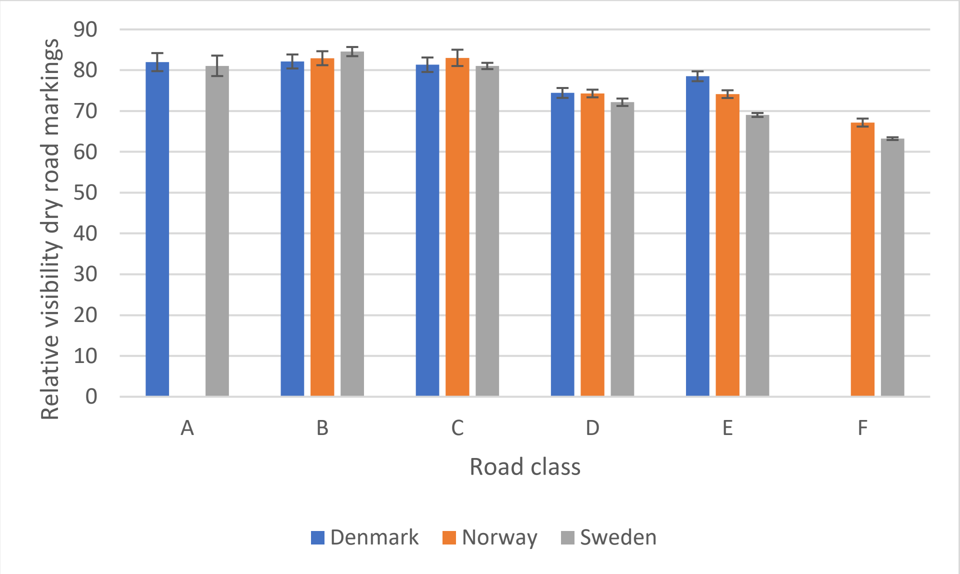

Figure 19. Relative visibility of dry road markings. Right edge line.

In Figure 20, the relative visibility of dry lane and centre lines are shown. For Denmark and Sweden, white road markings, and for Norway, yellow road markings. The pattern is somewhat different from Figure 19 with relatively lower levels for Norway compared to the other countries, especially in road class D, E and F (two-lane roads). The visibility level is significantly lower in Norway compared to Denmark and Sweden.

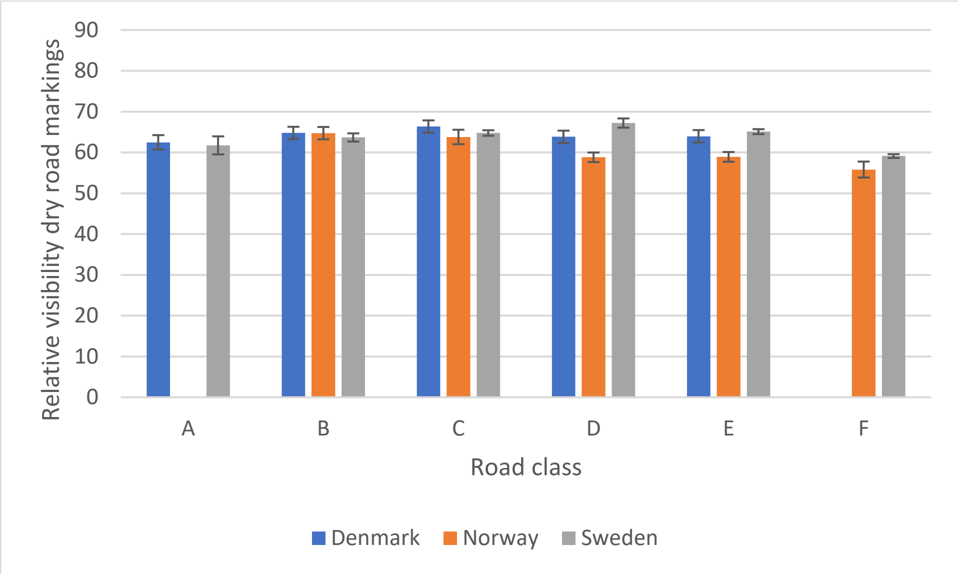

Figure 20. Relative visibility of dry road markings. Lane line (class A, B and C) and centre line (class D, E and F). White markings in Denmark and Sweden and in Norway yellow centre lines.

3.1.3 Relative pre-view-time

In Table 14, results from the ANOVA is shown for relative pre-view-time (pvt) of the right edge line on dry road markings. There is a significant difference between the different countries and between road classes, as well as a significant interaction effect (country*road class) Table 15 shows mean levels and standard errors of relative pvt for dry road markings for Denmark, Norway and Sweden. In Table 16, the mean levels are compared between countries. Norway has the highest mean value and Denmark and Sweden the lowest, the difference between Norway and the other two countries is statistically significant.

Table 14. Results from ANOVA, relative pvt for right edge line on dry road markings.

Dependent variable	**Independent variable**	**Degrees of freedom**	**F-ratio**	**p-value**
Relative pvt (dry road markings)	Country	2	36.633	<0.001
	Road class	5	32.042	<0.001
	Country*road class	8	11.663	<0.001

Table 15. **Mean levels and standard error of relative pvt for right edge line on dry road markings for Denmark, Norway and Sweden.**

Country	Mean [s]	Standard error [s]
Denmark	2.9	0.05
Norway	3.4	0.04
Sweden	3.0	0.03

Table 16. Comparison of mean levels of relative pvt for right edge line on dry road markings between countries.

Comparison	Difference (95% CI)
Sweden - Denmark	0.1 ± 0.14
Sweden - Norway	-0.4 ± 0.13
Norway - Denmark	0.4 ± 0.15

In Figure 21, the relative pvt for all dry road markings are compared for different road classes. Note that in Denmark there are no measurements in road class F (rural roads with AADT<2000) and in Norway there are no measurements in road class A (motorways with AADT>50 000). Norway has the highest relative pvt for road class B, C, D and F.

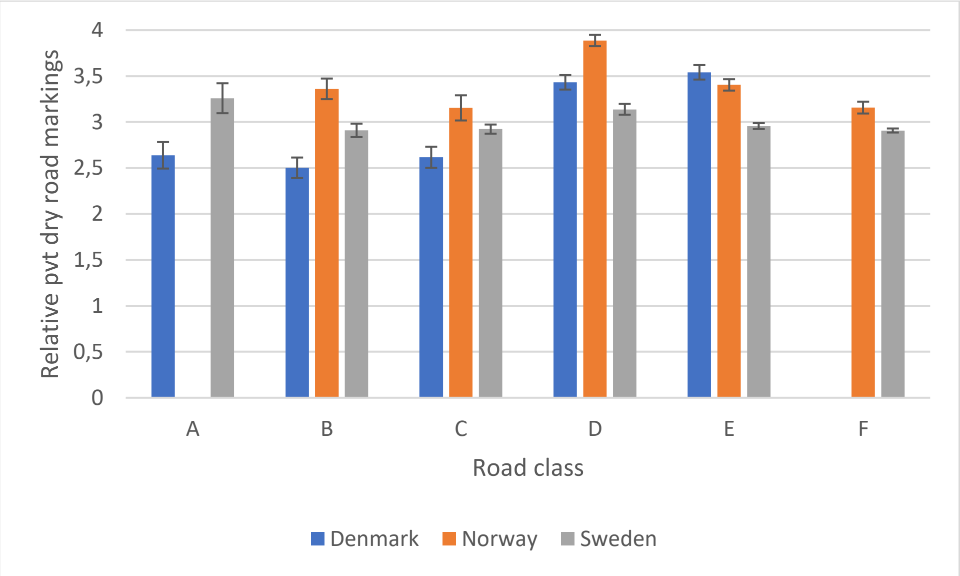

Figure 21. Relative pvt for dry road markings. Right edge line.

In Figure 22 relative pvt for dry lane lines (class A, B and C) and centre lines (class D, E and F) are shown. Denmark and Sweden have white road markings and Norway yellow. For class B, C and D, Norway has the highest relative pvt, while for centre lines in class E and F, the differences are small.

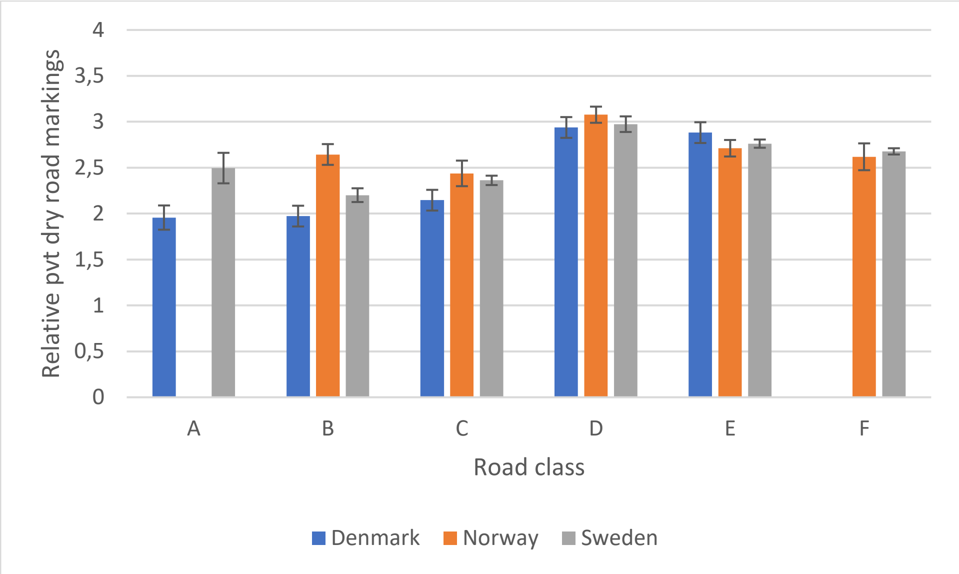

Figure 22. Relative pvt for dry road markings. Lane lines (class A, B and C and, centre lines (class D, E and F). White markings in Denmark and Sweden and yellow in Norway.

3.2 Wet road markings

In Table 17, the number of measured road markings (as defined in section 2.1) used in the analyses for wet road markings is shown. For Denmark 94 objects are analysed, while for Norway and Sweden, the numbers are 48 and 267 respectively.

Table 17. Number of measured road markings used in the analyses for wet road markings.

Road class	Denmark	Norway	Sweden
A	9		
B	15	12	28
C	14	10	67
D	28	8	46
E	28	14	126
F		4	
Total	**94**	**48**	**267**

3.2.1 Retroreflectivity

In Figure 23, the distribution of retroreflectivity for wet road markings in all countries is shown. The values in Norway are distributed towards higher retroreflectivity than in Denmark and Sweden.

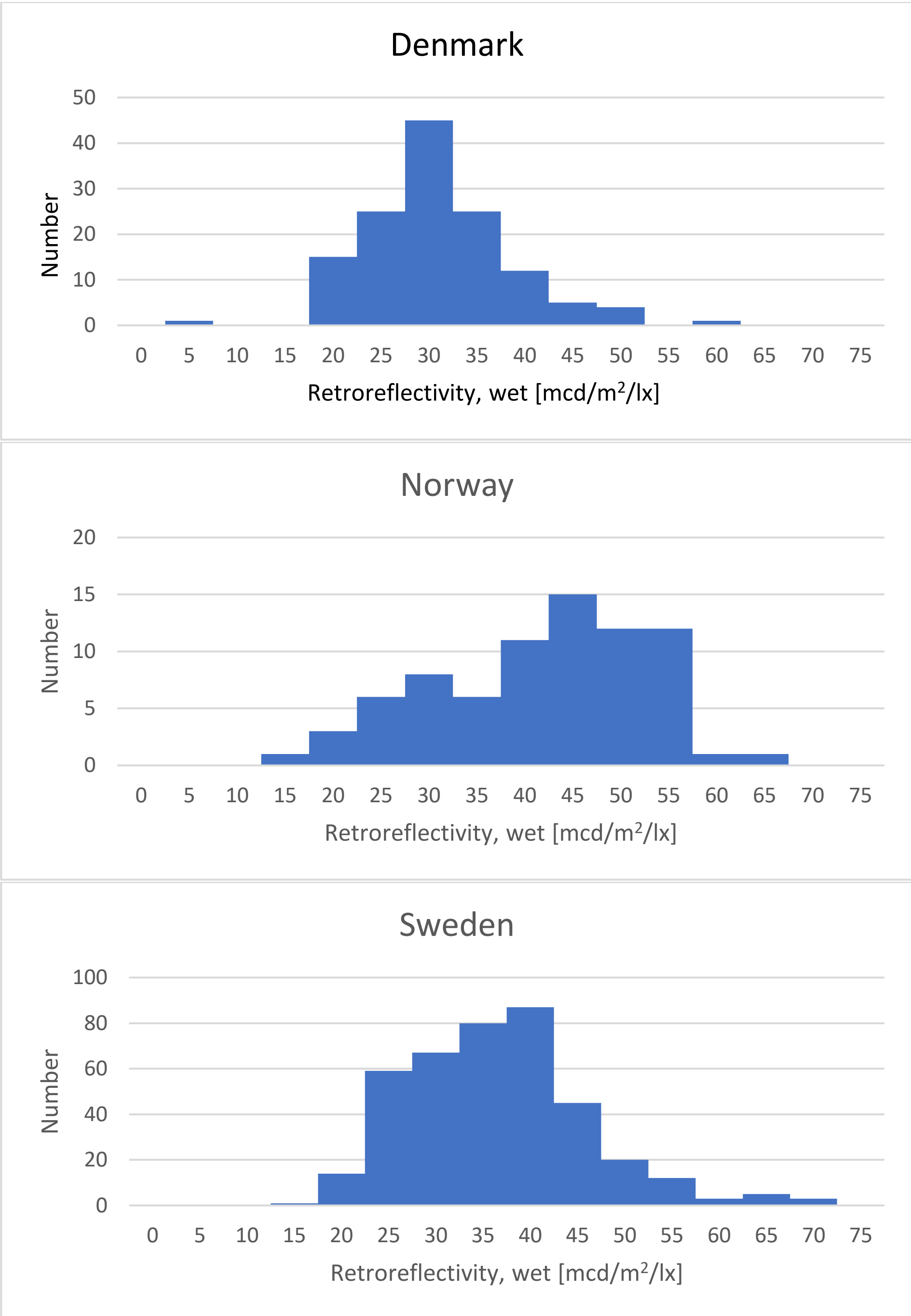

Figure 23. Distribution of wet road marking retroreflectivity for Denmark, Norway and Sweden. Wet road markings.

The mean performance of retroreflectivity on wet road markings, studied by an ANOVA is shown in Table 19. There is a significant difference between the retroreflectivity in the different countries, between road classes, as well as a significant interaction effect (country*road class). Table 20 shows mean levels and standard error of wet road marking retroreflectivity for Denmark, Norway and Sweden. The mean levels are estimated marginal means and adjusted for unbalance in the design. In Table 20, the mean levels are compared between countries. Bonferroni adjustment for multiple comparisons are made. Norway has the highest mean value and Denmark the lowest, all three differences are significant. Note that Sweden and Denmark have only white permanent road markings, while Norway has both white and yellow (centre line).

Table 18. Results from ANOVA, retroreflectivity all road markings, wet road markings.

Dependent variable	Independent variable	Degrees of freedom	F-ratio	p-value
Retroreflectivity (wet road markings)	Country	2	34.409	0.000
	Road class	5	7.654	0.000
	Country*road class	6	3.041	0.006

Table 19. Mean levels and standard error of wet road marking retroreflectivity for Denmark, Norway and Sweden, all road markings.

Country	Mean [mcd/m²/lx]	Standard error [mcd/m²/lx]
Denmark	29	0.8
Norway	38	1.2
Sweden	34	0.5

Table 20. Comparison of mean levels of wet road marking retroreflectivity, all road markings between countries.

Comparison	Difference (95% CI) mcd/m²/lx
Sweden - Denmark	4.8 ± 2.3
Sweden - Norway	-4.5 ± 3.1
Norway - Denmark	9.2 ± 3.4

In Figure 24, the retroreflectivity for all wet road markings are compared for different road classes. Note that Denmark has no measurements in road class F (rural roads with AADT<2000) and Norway has no measurements in road class A (motorways with AADT>50 000). For all road classes, Norway has the highest mean retroreflectivity for wet road markings.

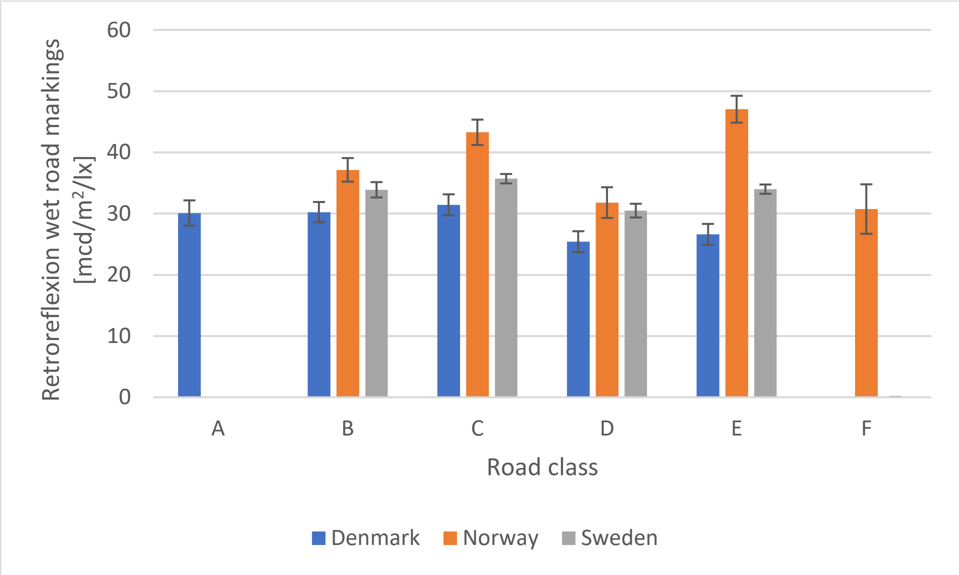

Figure 24. Retroreflectivity for wet road markings. All road markings.

In Figure 25 the retroreflectivity for wet right edge lines are shown. The pattern is similar as in Figure 24, with somewhat higher levels for Norway.

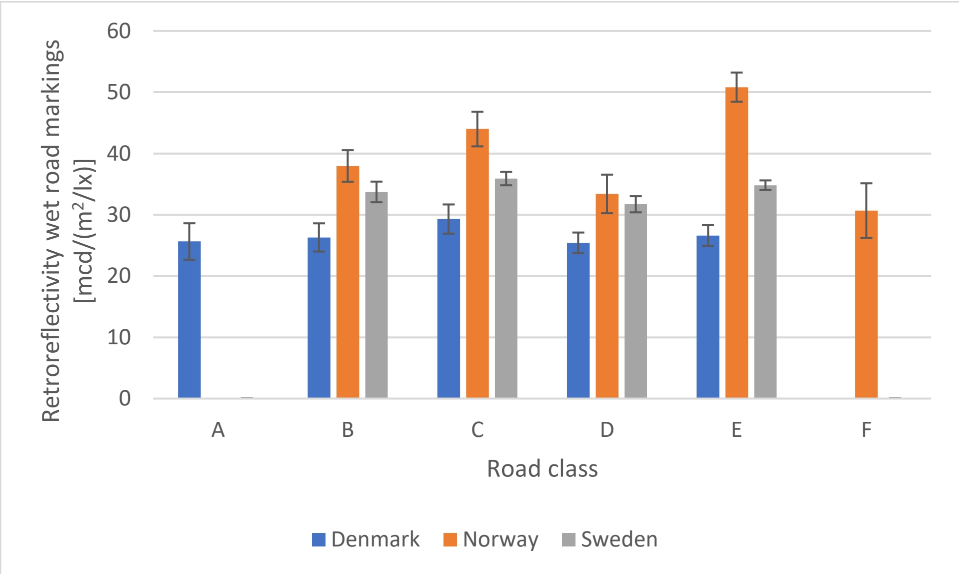

Figure 25. Retroreflectivity for wet road markings. Right edge line.

3.2.2 Relative visibility

In Figure 26, the relative visibility for right edge lines are compared for different road classes. Note that in Denmark there are no measurements in road class F (rural roads with AADT<2000) and in Norway there are no measurements in road class A (Motorways with AADT>50 000). For all road classes, Norway has the highest mean relative visibility, but the differences are rather small. The relative visibility for wet right edge road markings is particularly low for Sweden in road class E.

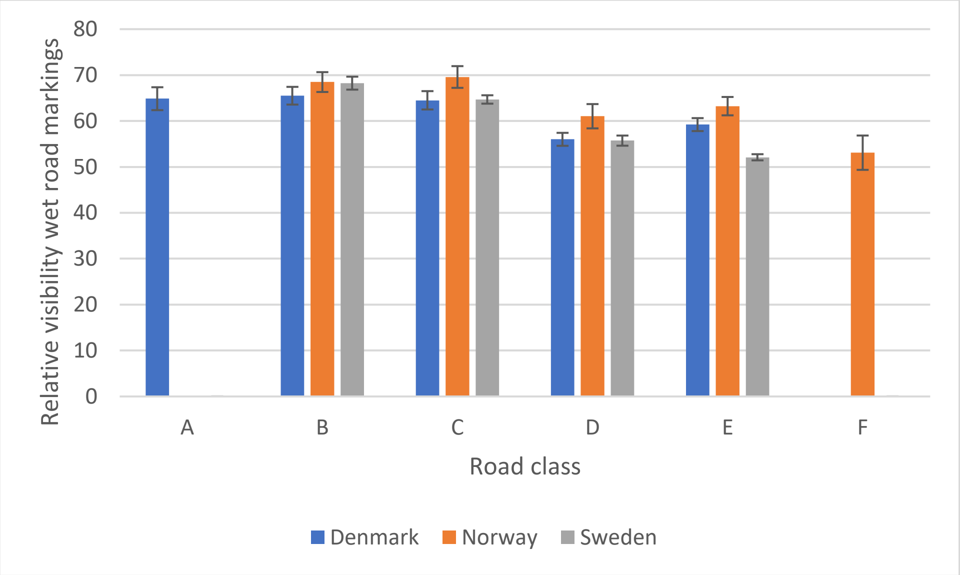

Figure 26. Relative visibility of wet road markings. Right edge line.

3.2.3 Relative pre-view-time

In Figure 27, the relative pre-view-time for wet right edge road markings are compared for different road classes. Note that in Denmark there are no measurements in road class F (rural roads with AADT<2000) and in Norway there are no measurements in road class A (motorways with AADT>50 000). Similar to Figure 26, Norway has the highest values for relative pvt in all road classes where there are measurements.

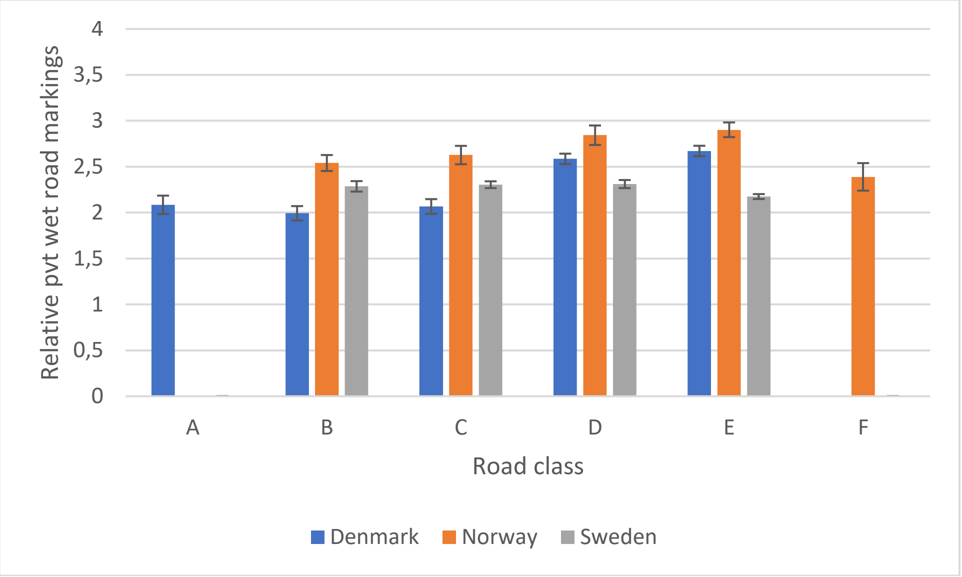

Figure 27. Relative pvt for wet road markings. Right edge line.

3.3 TEN-T road network

In total, about 30 % of the measured objects belong to the TEN-T network. The distribution is somewhat different between the three countries which is shown in Table 21. In Denmark the share is 52 %, in Norway 37 % and in Sweden 27 %.

Table 21. Share of measured TEN-T roads in Denmark, Norway and Sweden.

Country	Share TEN-T roads (%)
Denmark	52
Norway	37
Sweden	27
All	**31**

In Figure 28, a comparison between retroreflectivity for dry road markings for the TEN-T road network and the non-TEN-T road network is done. There are only minor differences between the TEN-T and other roads in Denmark and Norway, while in Sweden there are somewhat higher levels for the TEN-T network with retroreflectivity 162 mcd/m^2/lx for non-TEN-T and 175 mcd/m^2/lx for TEN-T roads, and this difference in Sweden is significant.

The results for relative visibility are shown in Figure 29 and there the differences between TEN-T or non-TEN-T are larger. For Sweden the relative visibility on the TEN-T roads are 76 while the relative visibility for the non-TEN-T roads are 65. For Denmark the relative visibility is 76 (TEN-T) and 73 (non-TEN-T) and for Norway 73 (TEN-T) and 68 (non-TEN-T). For all countries, the difference between TEN-T and non-TEN-T is significant.

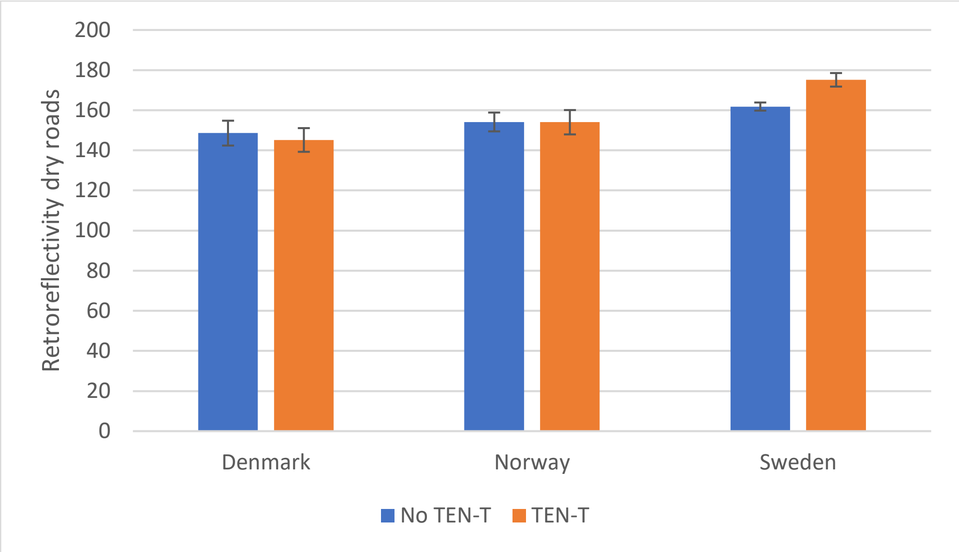

Figure 28. Retroreflectivity for dry road markings, all road markings. TEN-T and non-TEN-T.

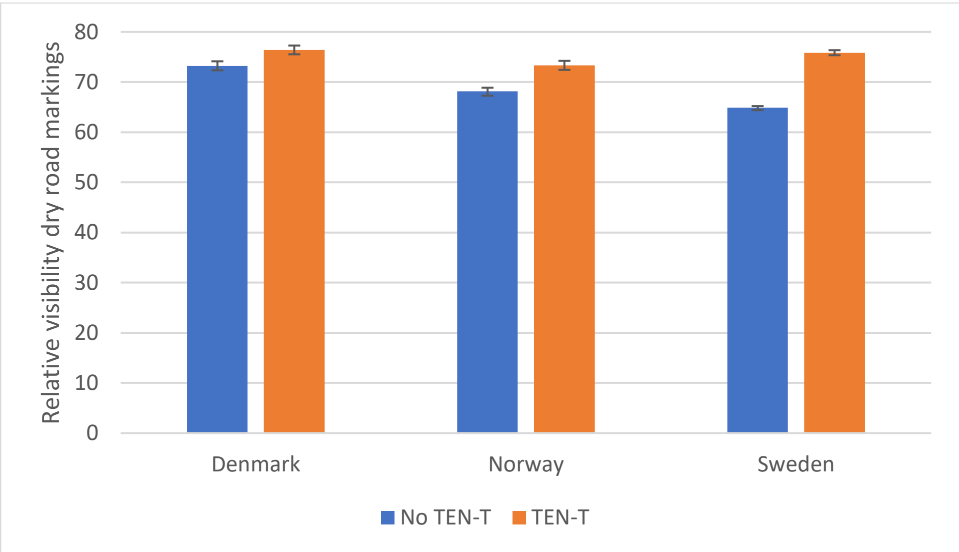

Figure 29. Relative visibility for dry road markings, all road markings. TEN-T and non-TEN-T.

In Figure 30, relative pre-view-time are shown for the measured TEN-T roads as well as for the other roads. In all countries, the relative pvt is lower on the measured TEN-T roads, probably due to higher speed limits on the TEN-T road network. In Table 22, the mean speed limits for the two types of road network are shown. For all countries, the mean speed limits are higher on the TEN-T roads than on other roads, but there are also differences between countries. In Denmark, the mean speed level on TEN-T roads is 114 km/h, in Sweden it is 102 km/h and in Norway 86 km/h.

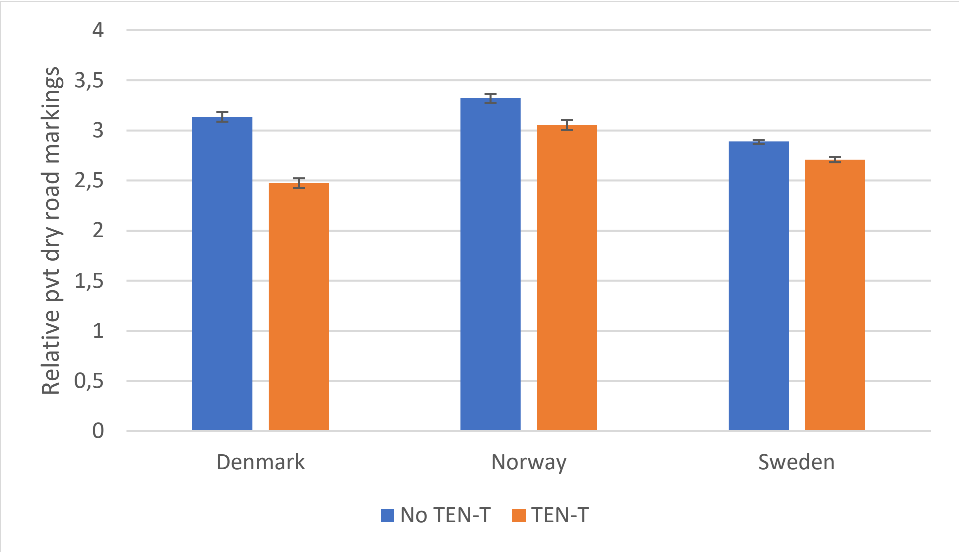

Figure 30. Relative pvt for dry road markings, all road markings. TEN-T and non-TEN-T.

Table 22. Mean speed limits on measured TEN-T roads and non-TEN-T roads.

	TEN-T (km/h)	**Non-TEN-T (km/h)**
Denmark	114	87
Norway	86	75
Sweden	102	82

3.4 Cover index

The cover index (%) is defined as the part of the road marking area that remains at the time of measurement. The measure is new and still under development. The ambition for the coming years is to relate the cover index to road marking type (i.e. whether the road marking is profiled or not). However, this information is not available yet.

The cover index is measured in % and can have values above 100 % if for example a new road marking overlap with an old road marking. Profiled markings might have values below 100 % even when they are new if the pattern contains unfilled parts, such as a chessboard pattern. Consequently, a cover index of 60 % can represent a partially worn road marking or a new profiled road marking.

3.4.1 All road markings

In Figure 31 and Figure 32, it is illustrated how the cover index is distributed among all measured road objects for all countries. In Denmark about 85 % of the measured objects have a cover index above 60 %, while in Norway the share of measured objects with cover index above 60 % is about 80 % and in Sweden that share is 86 %. It is not known whether the road markings are profiled or not.

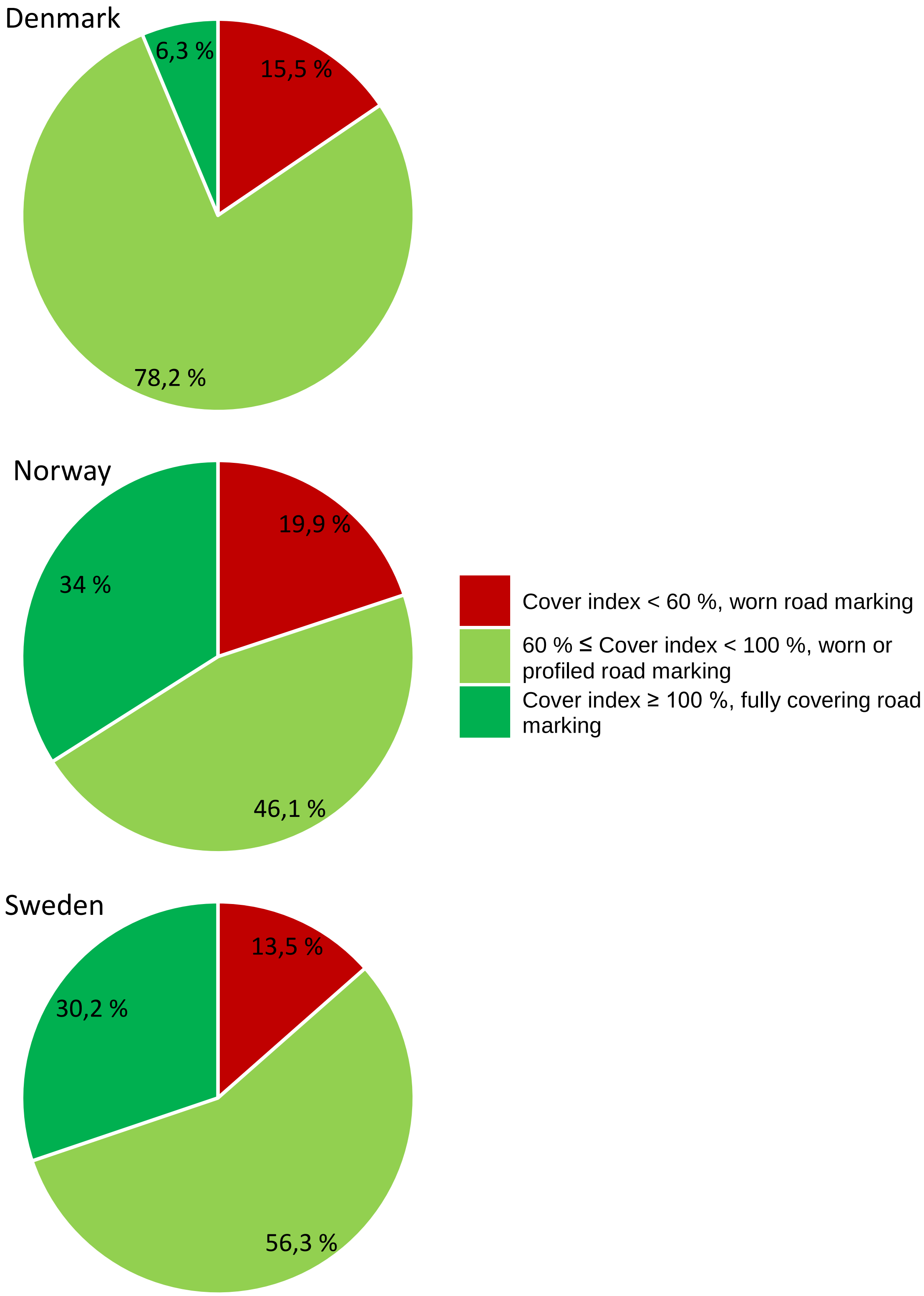

Figure 31. Cover index for Denmark, Norway and Sweden, all road markings.

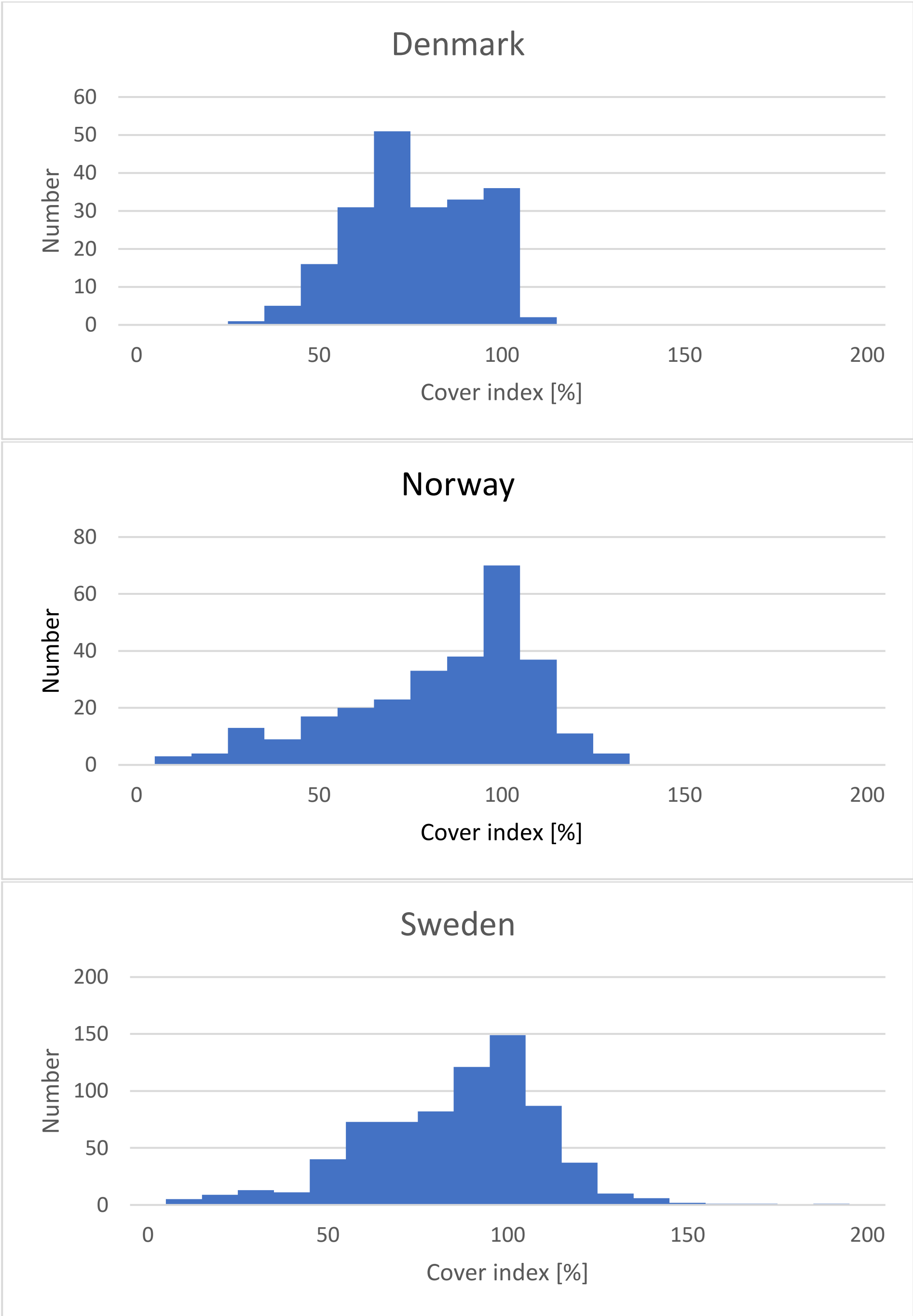

Figure 32. Distribution of cover index for Denmark, Sweden and Norway. All road markings.

In Table 23, the result of the ANOVA is shown for cover index for all dry road markings. There is a significant difference between the different countries and between road classes, as well as a significant interaction effect (country*road class).Table 23 shows mean levels and standard error of dry road marking cover index for Denmark, Norway and Sweden. In Table 25, the mean levels are compared between countries. Sweden has the highest mean value and Denmark the lowest, all differences between countries are significant.

Table 23. Results from ANOVA, cover index for all road markings, dry road markings.

Dependent variable	Independent variable	Degrees of freedom	F-ratio	p-value
Cover index	Country	2	6.996	0.001
	Road class	5	4.541	<0.001
	Country*road class	8	2.284	0.02

Table 24. Mean levels and standard error of cover index for Denmark, Norway and Sweden.

Country	Mean (%)	Standard error (%)
Denmark	71	1.7
Norway	77	1.5
Sweden	80	1.2

Table 25. Comparison of mean levels of cover index between countries. All road markings, white and yellow.

Comparison	Difference (95% CI)
Sweden - Denmark	8.4 ± 4.9
Sweden - Norway	2.6 ± 4.6
Norway - Denmark	5.8 ± 5.5

In Figure 33 the cover index for all dry road markings are compared for different road classes. Note that in Denmark there are no measurements in road class F (rural roads with AADT<2000) and in Norway there are no measurements in road class A (motorways with AADT>50 000).

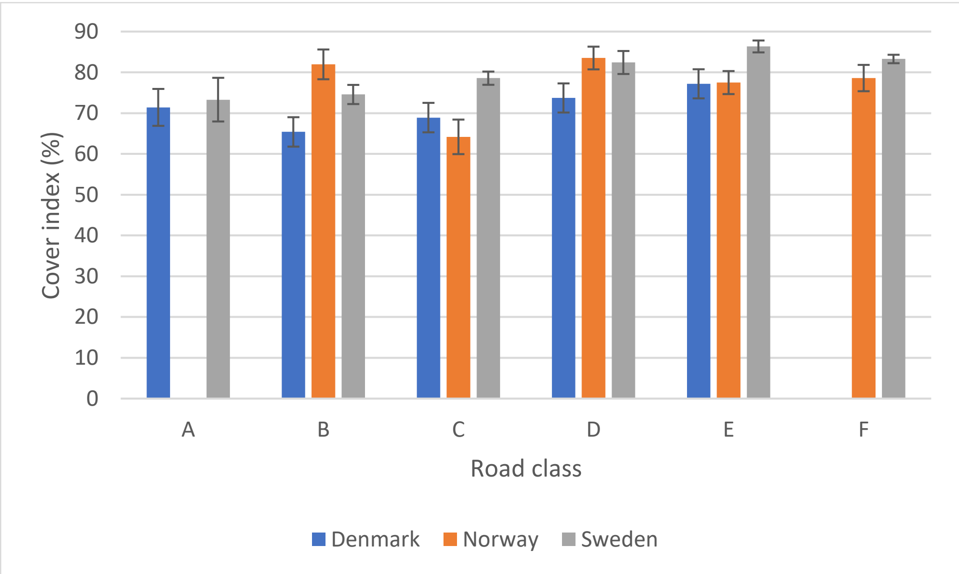

Figure 33. Cover index for all road markings (white and yellow).

3.4.2 Right edge line

In Table 26, results from the ANOVA is shown for cover index for right edge road markings. There is a significant difference between the different countries and between road classes, but not a significant interaction effect (country*road class). Table 27 shows mean levels and standard error of dry road marking cover index for Denmark, Norway and Sweden. In Table 28, the mean levels are compared between countries. Sweden has the highest mean value and Denmark the lowest, all differences between countries are significant. Compared to the mean levels in Table 24, the cover index for the right edge line is lower for all countries.

Table 26. Results from ANOVA, cover index right edge line, dry road markings.

Dependent variable	Independent variable	Degrees of freedom	F-ratio	p-value
Cover index	Country	2	6.447	0.002
	Road class	5	4.683	<0.001
	Country*road class	8	1.74	0.085

Table 27. Mean levels and standard error of cover index for Denmark, Norway and Sweden, right edge line.

Country	Mean (%)	Standard error (%)
Denmark	63	2.8
Norway	74	2.3
Sweden	77	1.9

Table 28. Comparison of mean levels of cover index between countries. Estimated marginal means, adjusted for unbalance in the design. Right edge line, 95% confidence interval.

Comparison	Difference (95% CI)
Sweden - Denmark	14.3 ± 8.0
Sweden - Norway	2.5 ± 7.0
Norway - Denmark	11.8 ± 8.6

In Figure 34 the cover index for right edge lines are compared for different road classes. Note that in Denmark there are no measurements in road class F (rural roads with AADT<2000) and in Norway there are no measurements in road class A (motorways with AADT>50 000).

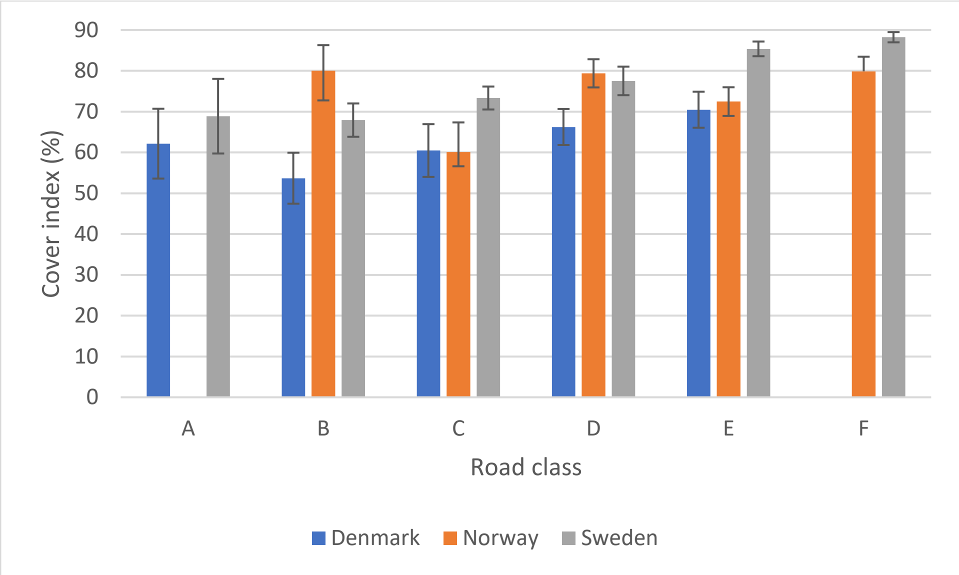

Figure 34. Cover index for right edge lines.

3.4.3 Lane and centre line

In Table 29, the result of the ANOVA is shown for cover index for lane line (class A, B and C) and centre line (class D, E and F). There is a significant difference between the different road classes, but not a significant difference between countries or a significant interaction effect (country*road class). Table 30 shows mean levels and standard error of dry road marking cover index for Denmark, Norway and Sweden. In

Table 31, the mean levels are compared between countries. Compared to the mean levels of right edge lines in Table 27, the cover index on right edge line is lower compared to lane and centre line, this applies for all countries.

Table 29. Results from ANOVA, cover index right edge line, dry road markings.

Dependent variable	Independent variable	Degrees of freedom	F-ratio	p-value
Cover index	Country	2	0.254	0.775
	Road class	5	5.209	<0.001
	Country*road class	8	0.262	0.978

Table 30. Mean levels and standard error of cover index for Denmark, Norway and Sweden, right edge line.

Country	Mean (%)	Standard error (%)
Denmark	89	2.5
Norway	86	2.5
Sweden	88	1.8

Table 31. Comparison of mean levels of cover index between countries. Lane and centre line centre lane (class D, E and F). Denmark and Sweden white markings and Norway yellow centre line.

Comparison	Difference (95% CI)
Sweden - Denmark	-0.9 ± 7.4
Sweden - Norway	2.3 ± 7.3
Norway - Denmark	3.1 ± 8.4

In Figure 35 the cover index for lane lines (class A, B and C), centre lines (class D, E and F) are compared for different road classes. Note that in Denmark there are no measurements in road class F (rural roads with AADT<2000) and in Norway there are no measurements in road class A (motorways with AADT>50 000). It is in general a high cover index for lane and centre lines, about 90 % for all road classes except for class F where the level is about 70 %.

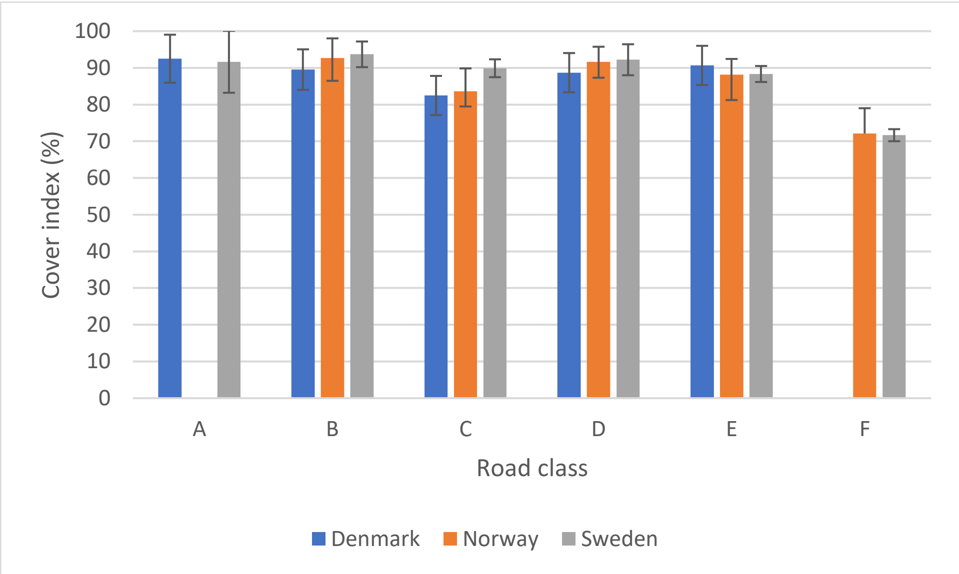

Figure 35. Cover index for lane line (class A, B and C) and centre line (class D, E and F). Denmark and Sweden white markings and Norway yellow centre line.

4 Discussion

The main aim of the Nordic state assessment of road markings 2017 is to study the road marking quality before introduction of the certification requirements and the results from the study are discussed below.

4.1 General

The colour of the permanent road markings is always white, except in Norway where the centre line on two-lane roads and the left edge line on multi-lane roads are yellow. When drawing general conclusions regarding **retroreflectivity** from the measurements in Denmark, Norway and Sweden, it is important to have in mind that yellow road markings (Norway) in general have about 30 % lower retroreflectivity than white ones. Therefore, when comparing the results in Chapter 3, the overall values in Norway in total are expected to be lower by approximately 15 - 20 % than for Denmark and Sweden. As an example, this probably explains some of the differences in retroreflectivity between Denmark/Sweden and Norway in Figure 12 and Figure 13.

The **relative visibility** of a road marking is dependent on the retroreflectivity multiplied by the area of the marking as Eq. (1) shows. Below the observed area (based on measured width, type and standard length of the road marking) as well as the typical area (based on country-standards) of the edge line on a road length of 60 m is shown:

Table 32. Observed area (based on measured width, type and standard length of the road marking) and typical area (based on country-standards) of the edge line on a road length of 60 m.

Road class	Country	Observed mean area (60 m^2)	Typical area (60 m^2)
A	Denmark	17.2	18 (6 on 3-lane roads)
	Sweden	14.7	18 (12 on 3-lane roads)
B	Denmark	16.5	18 (6 on 3-lane roads)
	Norway	14.1	12
	Sweden	17.0	18 (12 on 3-lane roads)
C	Denmark	14.2	18 (6 on 3-lane roads)
	Norway	14.0	12
	Sweden	12.8	18 (12 on 3-lane roads)
D	Denmark	7.3	6
	Norway	6.5	6
	Sweden	7.0	6
E	Denmark	10.2	6
	Norway	6.2	6

	Sweden	4.0	2-3 (possibly 6)
F	Norway	3.8	6 (possibly 3)
	Sweden	2.6	2-3
Total	Denmark	11.5	
	Norway	6.8	
	Sweden	5.1	

From the figures in Chapter 3 one understands that although the retroreflectivity values of dry road markings in Sweden were somewhat higher than in Denmark and Norway, the product of retroreflectivity and area may be low in Sweden. This is discussed further below.

The retroreflectivity of wet road markings is always lower than in the dry condition. This implies also shorter relative visibility distance in the wet condition. Typically, the relative visibility is 55 – 65 metres in the dry condition, while in wet condition, it is 40 – 50 metres.

Regarding lane and centre lines, the area difference in the three countries is less than for edge lines. In Denmark the lane and centre lines are 10 cm wide while in Norway and Sweden they are 10 – 15 cm.

In the analyses of visibility, the light condition used has always been high beam. The reason for this is that in dipped headlight illumination, the visibility distance will be influenced by the cut-off, which means that the visibility is almost independent of the retroreflectivity of the road marking at distances beyond cut-off.

In the sections below, centre line always refers to the configuration on a straight road. This means 5+10 metres (5 metres line and 10 metres gap) in Denmark, and 3+9 metres in Norway and Sweden.

The **relative pre-view-time, pvt,** is closely related to the relative visibility distance as shown in Eq. (2). The pre-view-time is often used as a safety measure in night-time traffic; several studies have shown that the driver needs a pvt more than 2 - 3 s for safe driving, see Fors and Lundkvist (2009). In 80 km/h this means a visibility distance of approximately 45 - 65 metres. However, for reasons mentioned in Section 2.3, the measure used in this study is the relative visibility distance and pre-view-time. Therefore, the pvt values shown in Sections 3.1.3 and 3.2.3 should not be related to the desirable 2 – 3 s.

For practical reasons, the speed used in Eq. (2), , is the speed limit of the road. It would have been more appropriate to use the space mean speed of the section of the road where measurements have been carried out, as the actual speed may differ from the speed limit. Actual speed, and consequently pvt, may also vary along the road, depending on e.g. road geometry. Pvt can also, independently of vehicle speed, be influenced by road geometry. Pvt may for example be lower on hilly or curvy roads, simply because the road marking isn't visible beyond the hilltop or curve. However, space mean speed data are not available, which means that the speed limit is the best available measure to use. Furthermore, road geometry is not considered when calculating pvt, which means that the actual pvt for a specific road section may differ from the values presented in this report. When “pvt” is used below, it always refers to the relative pre-view-time.

4.2 Dry road markings

Figure 13 - Figure 15 and Table 7 - Table 9 in Chapter 3 indicate that dry road markings in Sweden have higher retroreflectivity than road markings in Denmark, while the other differences are not significant at a risk level of 5 %. Furthermore, there are retroreflectivity differences between the road classes. However, the interaction effect is not significant, which means that the differences between road classes are approximately equal in the three countries. This is shown in Figure 13; the retroreflectivity is higher in every road class, A – F, in Sweden than in Denmark and Norway. The retroreflectivity difference between road markings in Denmark and Norway is small in the road classes that can be compared, B – E.

Figure 14 shows the result for **edge lines**, only. Still, on average road markings in Sweden have somewhat higher retroreflectivity than those in Denmark and Norway. White edge lines in every road class in Denmark have lower values than those in both Norway and Sweden.

Figure 15 is comparable to Figure 14, but refers to **lane (classes A - C) and centre (classes D - F) lines**, white markings in Denmark and Sweden, yellow centre lines in Norway. The figure shows that lane lines on multi-lane roads in Denmark have lower values than in Norway and Sweden. On two-lane roads the retroreflectivity of the centre line is lower in Norway than in Denmark and Sweden, which probably can be explained by the yellow colour of that line.

Figure 19 indicates that the relative visibility distance to the **dry right edge line** is approximately the same on multi-lane roads in the three countries. On most multi-lane roads, the edge line is wider in Denmark and Sweden compared to Norway, but this is to a large extent compensated for by higher retroreflectivity in Norway (see Figure 14). Furthermore, Figure 19 shows that the visibility distance on two-lane roads is longer in Denmark than in Norway and Sweden, especially in road class E. The reason for this is both that the edge line in those road classes may be intermittent in Sweden and Norway, but always continuous in Denmark and that Denmark has wider observed road marking width (see Table 32). Thus, Figure 19 reflects the loss in visibility caused both by the use of an intermittent edge line instead of a continuous one and differences in road marking width.

On multi-lane roads, Figure 20 shows no large difference in visibility distance of **dry lane lines** in the three countries. However, on two-lane roads, the visibility distance of the **centre line** is shorter in Norway than in Denmark and Sweden. Of course, this is explained by the lower retroreflectivity of the Norwegian yellow centre line.

When comparing the relative visibility (Figure 19) and the relative pvt (Figure 21) of **dry edge lines**, some differences can be seen: Denmark has relatively low pvt-values on multi-lane roads and Norway has high pvt values on multi-lane roads in class B and C. This is explained by the high speed-limit on motorways in Denmark, up to 130 km/h, while it is lower in Norway and Sweden. In the same way, the relatively poor pvt on Swedish two-lane road is explained by the fact that many such roads in Sweden have a speed limit of 80 or 90 km/h, while it generally is 80 km/h in Denmark and 70 – 80 km/h in Norway.

Regarding **lane and centre lines**, the differences in pvt between the countries are rather small. The only clear result is shown for lane lines on Danish motorways: they show a shorter pvt than lane lines in Norway and Sweden.

4.3 Wet road markings

Figure 24 - Figure 27 and Table 18 - Table 20 show the result for wet road markings. The significant interaction effect (country * road class) shows that the differences in retroreflectivity is not homogeneous over the road classes, which can be seen in Figure 24. In every road class, the retroreflectivity of wet road marking is higher in Norway than in Denmark and Sweden, which is especially pronounced for road class E. This is remarkable as yellow road markings are included in class E. As for dry road markings, wet road markings in Denmark have lower values in every road class than in Norway and Sweden.

Regarding edge lines, the results are shown in Figure 25. In every road class, wet road markings in Norway have higher retroreflectivity than those in Denmark and Sweden. The difference in retroreflectivity between Denmark and Sweden is small.

Figure 26 shows that profiled edge lines in Norway have longer visibility distances than in the other two countries. This is to a large extent explained by higher retroreflectivity. On two-lane roads the edge lines in Sweden have worse visibility than edge lines in Denmark, although the retroreflectivity is higher in Sweden. The explanation for this matter is probably the Swedish intermittent edge line but can also reflect differences in road marking width (see Table 32).

Figure 27 indicates that pvt of wet edge markings in Norway is higher than in Denmark and Sweden. The explanation is quite simple: High retroreflectivity, large edge marking area and low speed limit means high pvt. However, it should be noted that Norway has fewer measured road markings than Sweden and Denmark and that the results therefore might be uncertain.

4.4 TEN-T road network

A comparison is also done between the Trans-European Transport Network (TEN-T) and other roads. The TEN-T is a network which comprises roads, railway lines, inland waterways, inland and maritime ports, airports and rail-road terminals throughout the 28 Member States. In total, about 30 % of the measured objects in this study belong to the TEN-T network.

Comparing retroreflectivity for dry road markings on the TEN-T road network and the non-TEN-T road network it is shown that there are only minor differences between the TEN-T and other roads in Denmark and Norway, while in Sweden there are somewhat higher levels for the TEN-T network with retroreflectivity 175 mcd/m^2/lx compared to 162 mcd/m^2/lx for non-TEN-T roads. The difference in Sweden is significant.

The results for relative visibility show larger differences between TEN-T and non-TEN-T. For Sweden the relative visibility on the TEN-T roads are 76 while the relative visibility for the non-TEN-T roads are 65. For Denmark the relative visibility is 76 (TEN-T) and 73 (non-TEN-T) and for Norway 73 (TEN-T) and 68 (non-TEN-T). For all countries, the difference between TEN-T and non-TEN-T is significant.

Studying the relative pre-view-time it is shown that in all countries, the relative pvt is lower on the measured TEN-T roads, probably due to higher speed limits on the TEN-T road network. For all countries, the mean speed limits are higher on the TEN-T roads than on other roads, but there are also differences between the countries.

4.5 Cover index

The measure is new and under development. The cover index is measured in % and can have values above 100 % if for example a new road marking overlap with an old road marking. Profiled markings might have values below 100 % even when they are new if the pattern contains unfilled parts, such as a chessboard pattern. Consequently, a cover index of 60 % can represent a partially worn road marking or a new profiled road marking. The ambition for the coming years is to relate the cover index to road marking type (i.e. whether the road marking is profiled or not) to make the results easier to interpret, but this information is not available yet.

Although the cover index is not included in the Danish regulations, it was measured in all three countries and the results are shown in Figure 31 - Figure 35. The cover index is significantly smaller in Denmark than in Norway and Sweden. This fact may be explained by the use of studded tyres in the two last mentioned countries which might lead to that the road markings are reconditioned more often. Another explanation can be different proportions of profiled and non-profiled road markings in the three countries.

Figure 35 shows a higher cover index for lane and centre lines than for edge lines (Figure 34). This is difficult to explain, but maybe the reason is that the first-mentioned road markings are reconditioned almost every spring, due to many wheel roll-overs. If so, measurements would have been carried out on almost new lane and centre lines, while the edge lines might have been applied long ago.

5 Conclusions

In Sections 4.1. - 4.3, the retroreflectivity, relative visibility, relative pre-view-time and cover index have been discussed. One should have in mind that the only two parameters which can be found in any regulation are retroreflectivity and, in Norway and Sweden, also cover index.

The retroreflectivity requirement of **dry** road markings is roughly fulfilled in 50 % of the measured objects. The values are a little bit higher for lane and centre lines, which may be explained by that those lines can have been quite new at the time of measurement. In all, there are no large differences in road marking performance between countries. Some retroreflectivity values are low, e.g. edge lines on motorways in Denmark. However, this is compensated for by a large area, which nevertheless means good relative visibility. The opposite: Edge lines on Swedish two-lane roads have high retroreflectivity, which would imply good visibility. However, the road marking area is small, thus reducing the relative visibility to shorter distance than for both Danish and Norwegian edge lines.

There are no requirements for visibility or pvt in any regulations. It would be desirable to include pvt in the regulations, as it with high probability is a measure related to traffic safety. As mentioned before, many studies have been accomplished, but maybe the study within COST 331 is the most reliable (COST 331, 1999). This study consisted of two parts, one carried out in a driving simulator and one as a field study. Both studies showed similar results: when driving conditions are good and simple, the driver needs a pvt value of approximately 2 s. However, a short time must be added, since in a real situation the driver may be disturbed by the surroundings, e.g. oncoming vehicles. A central question appears: How large is that “short time”? This is a tricky but very essential question to answer. As mentioned in Chapter 2.3.2, the model for calculation of visibility is under revision and this work will provide a basis for further research on drivers’ needs under various conditions. With better knowledge it will be possible to take visibility and pvt into account when formulating regulations. For each type of road and for a given speed limit, the requirements on retroreflectivity and road marking area (width and broken/continuous line) can be selected so that the desired levels of visibility and pvt are achieved. Further research on the relationship between drivers’ needs and road marking area and retroreflectivity is thus urgent.

Generally, there is no large difference in road marking performance in the three countries. The only significant differences are the poor visibility of edge lines on two-lane roads in Sweden (especially in class E) and the good performance of wet road markings in Norway. Other differences are of no or small importance.

Today, it is not possible to study any effect of the Nordic certification system for road markings, as 2017 was the first year of ROMA. However, in the coming years, some effect, hopefully positive, would be possible to register.

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NordFoU

Annex A Results Denmark

Dry road markings

Retroreflectivity

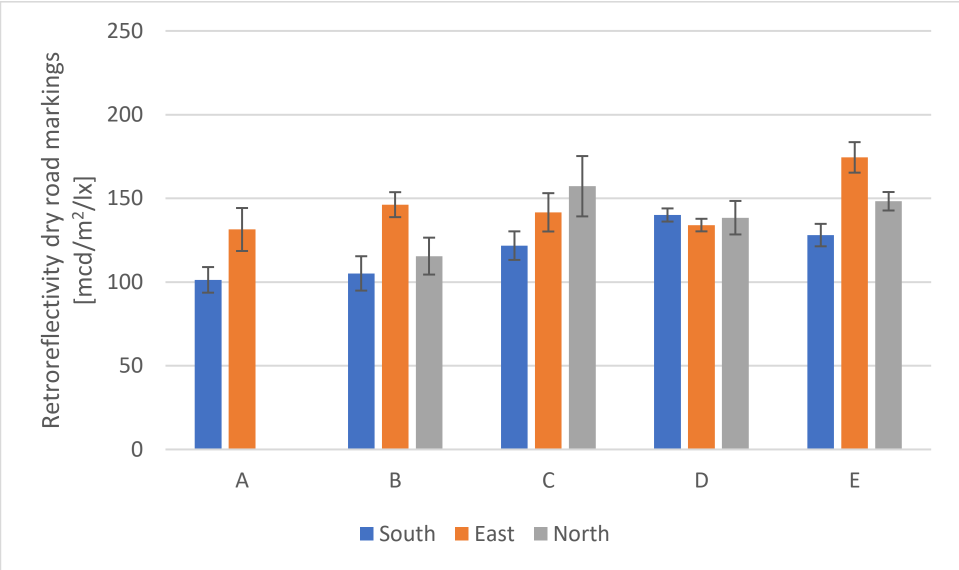

Figure 36. Mean of retroreflectivity right edge line on dry road markings for each region and road class in Denmark.

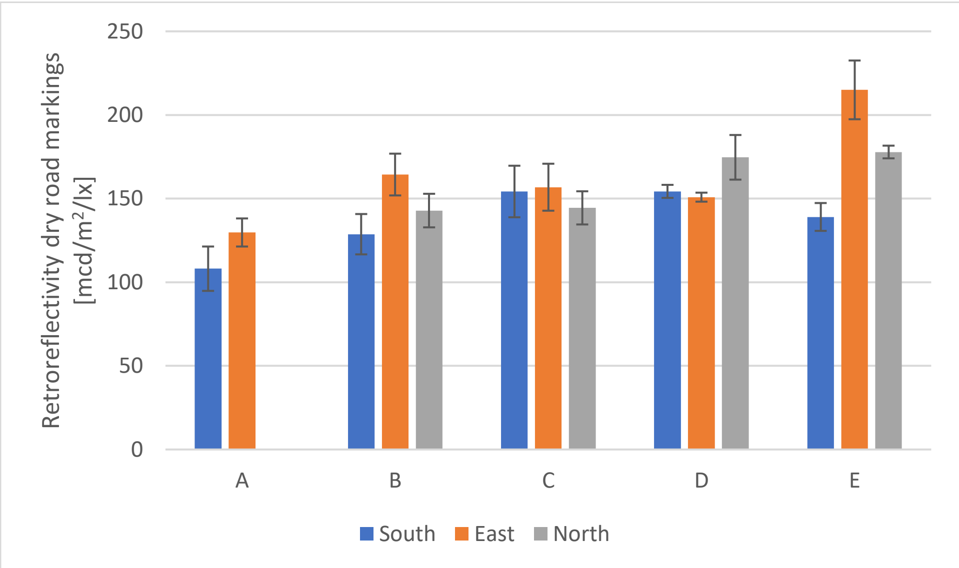

Figure 37. Mean of retroreflectivity in Denmark. Lane line (class A, B and C), centre line (class D, E, and F). Dry road markings for each region and road class in Denmark.

Relative visibility

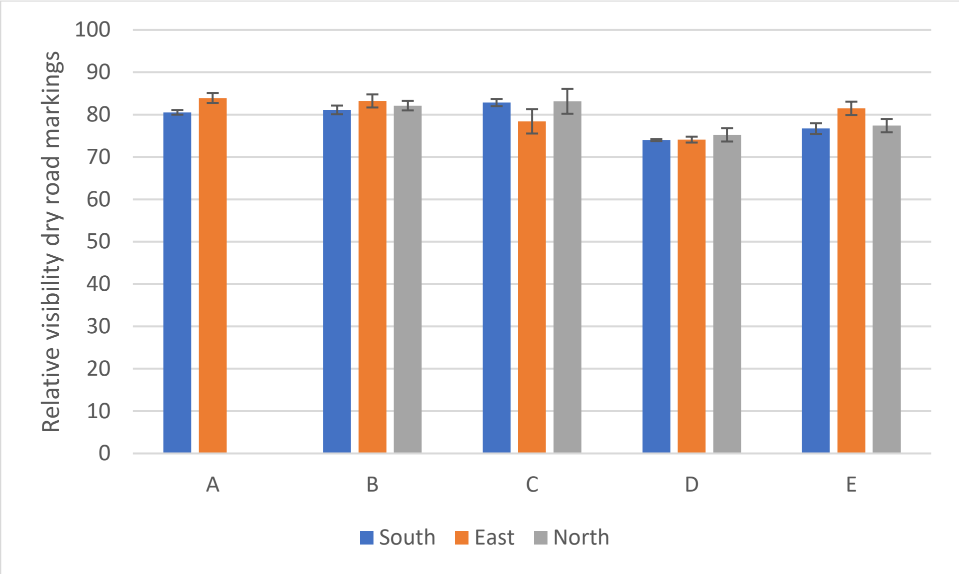

Figure 38. Relative visibility for right edge line for each region and road class in Denmark. Dry road markings.

Relative pre-view-time (pvt)

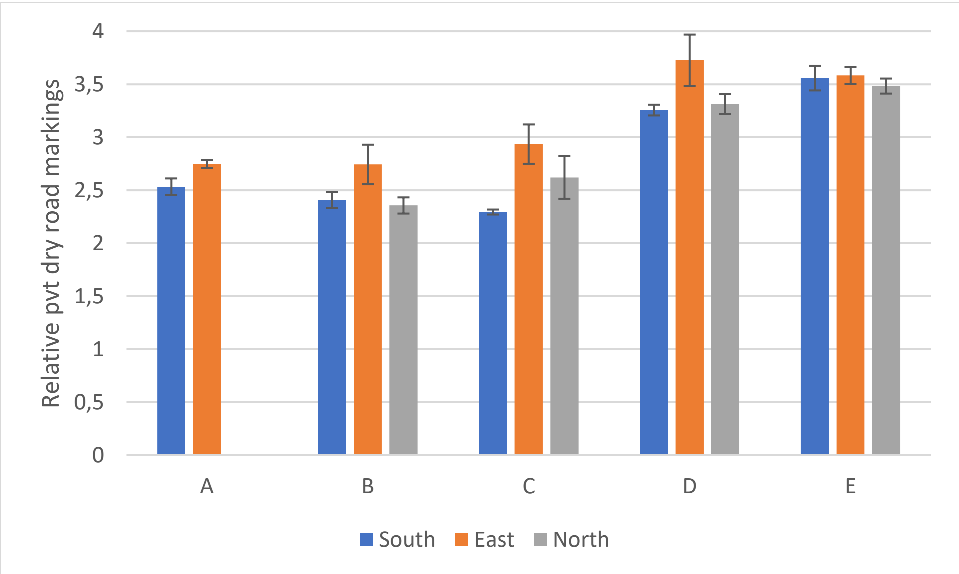

Figure 39. Relative pre-view-time for right edge line for each region and road class in Denmark. Dry road markings.

Wet road markings

Retroreflectivity

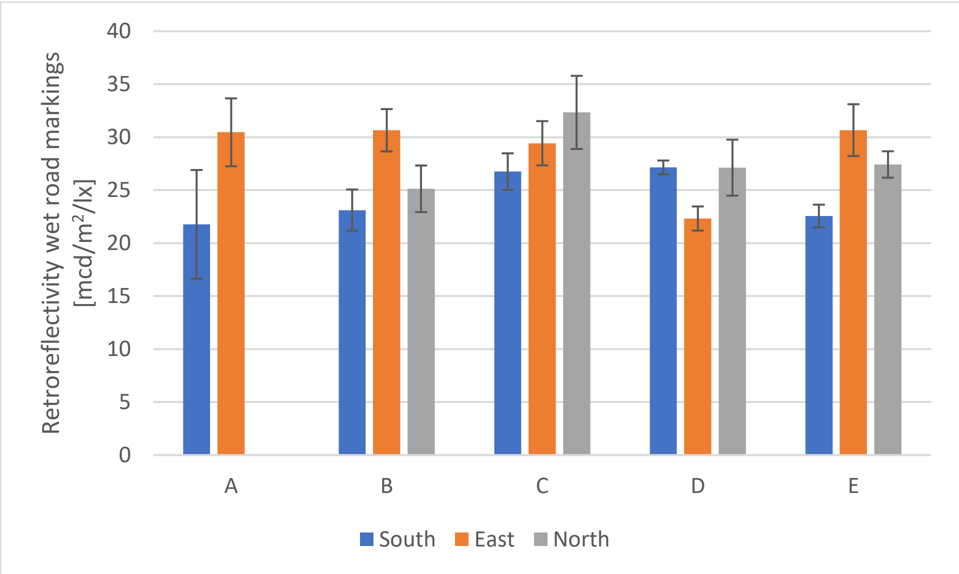

Figure 40. Mean of retroreflectivity right edge line on wet road markings for each region and road class in Denmark.

Relative visibility

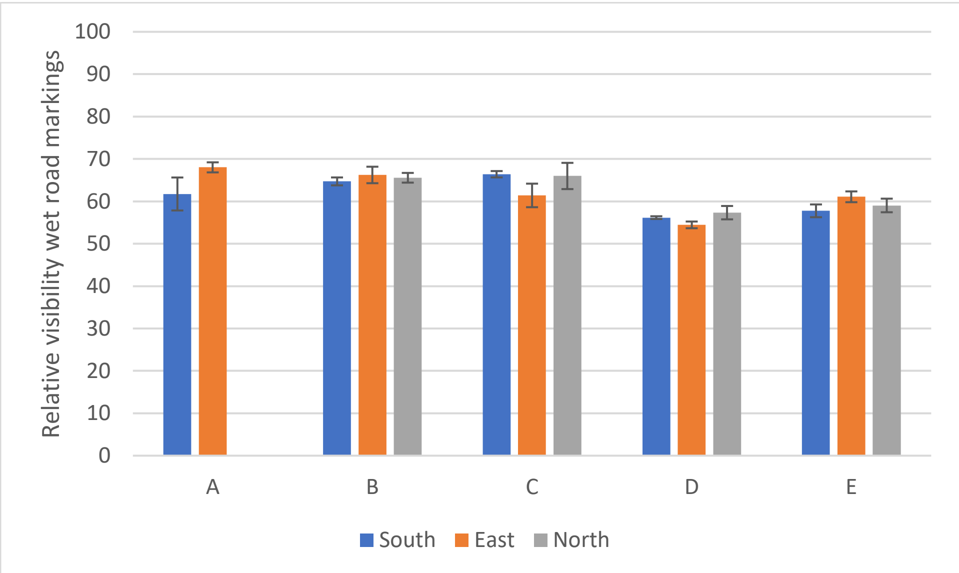

Figure 41. Relative visibility for right edge line for each region and road class in Denmark. Wet road markings.

Relative pre-view-time (pvt)

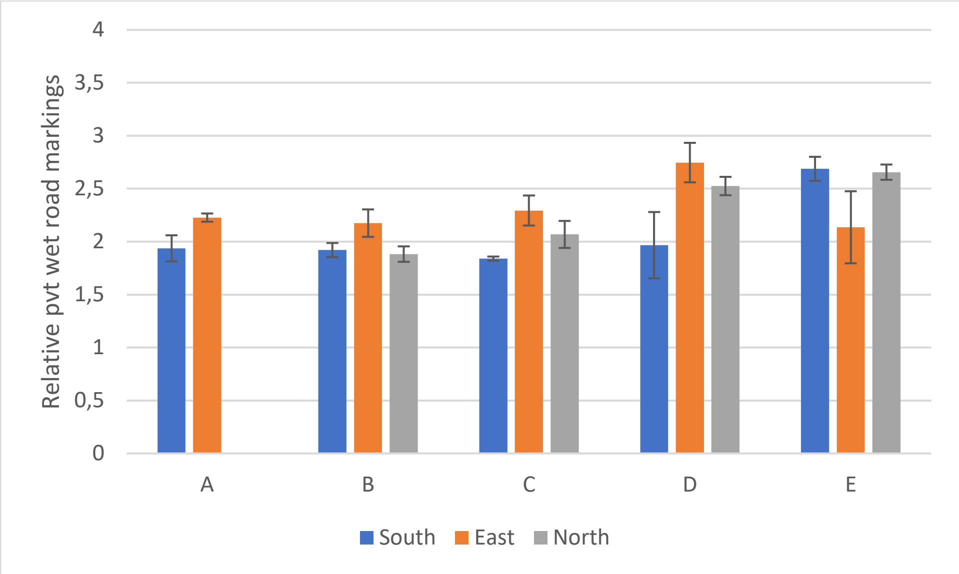

Figure 42. Relative pre-view-time for right edge line for each region and road class in Denmark. Wet road markings.

Cover index

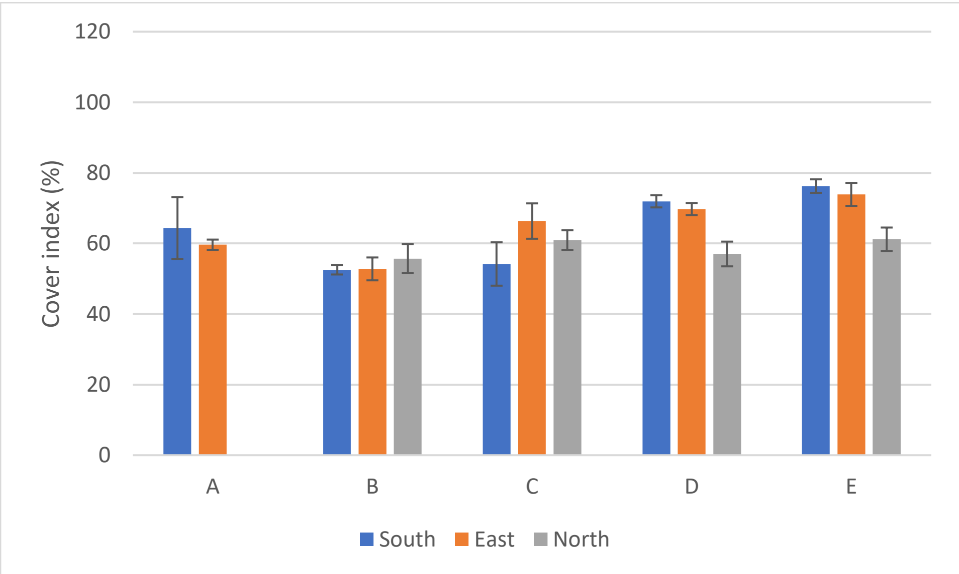

Figure 43. Cover index for each region and road class in Denmark. Right edge line markings.

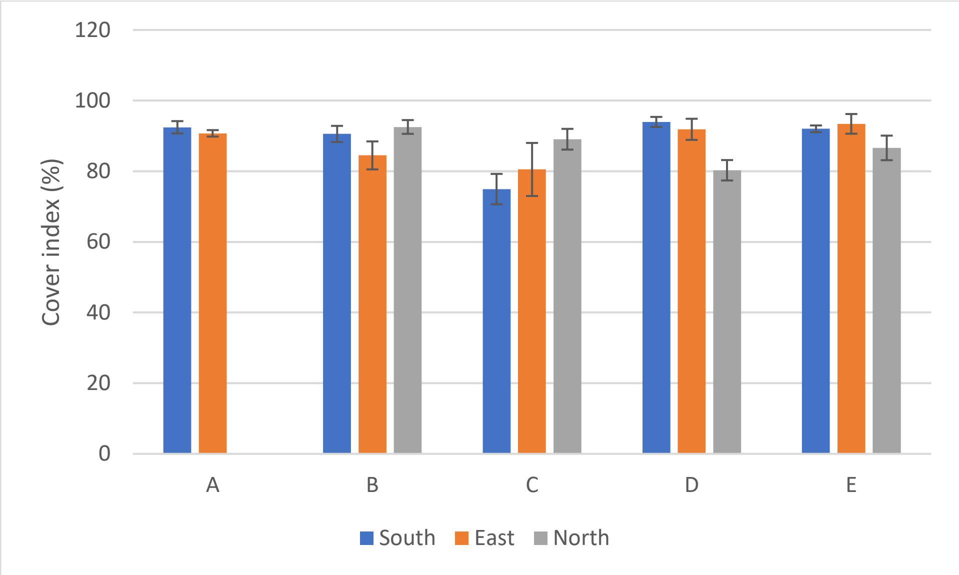

Figure 44. Cover index for each region and road class in Denmark. Lane line (class A, B and C), centre line (class D, E, and F).

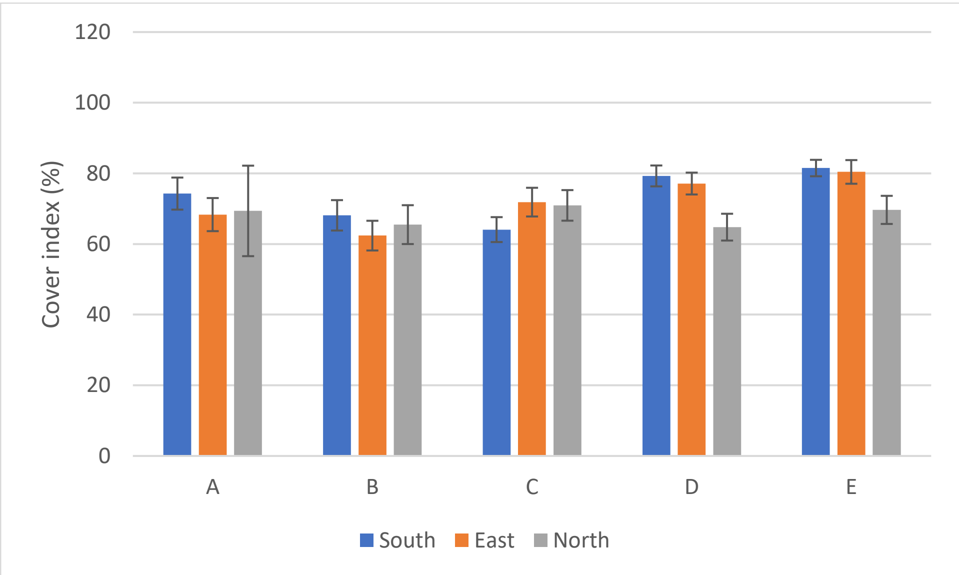

Figure 45. Cover index for each region and road class in Denmark. All road markings (white).

NordFoU

Annex B Results Norway

Dry road markings

Retroreflectivity

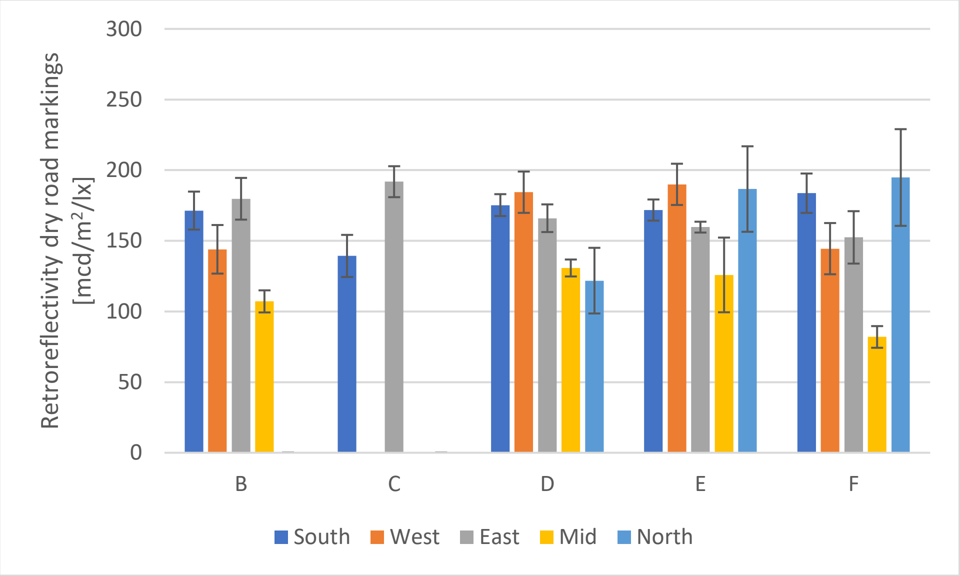

Figure 46. Mean of retroreflectivity right edge line on dry road markings for each region and road class in Norway.

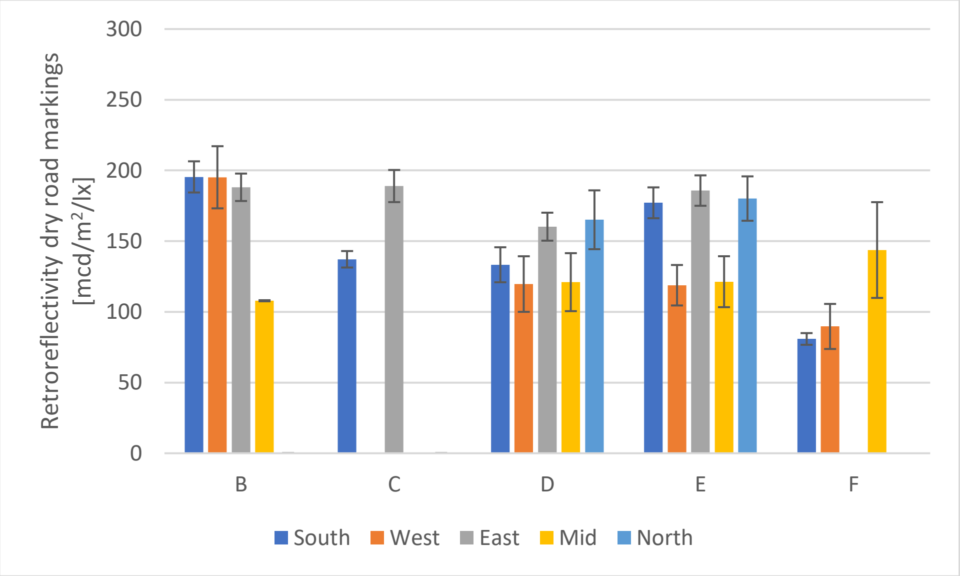

Figure 47. Mean of retroreflectivity in Norway. Lane line (class A, B and C), centre line (class D, E, and F). Dry road markings for each region and road class in Norway.

Relative visibility

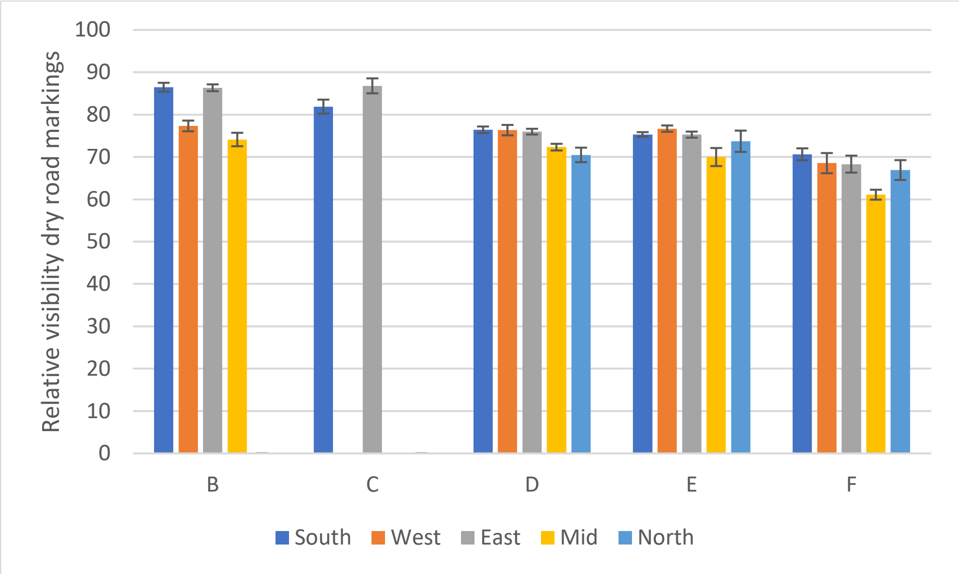

Figure 48. Relative visibility for right edge line for each region and road class in Norway. Dry road markings.

Relative pre-view-time

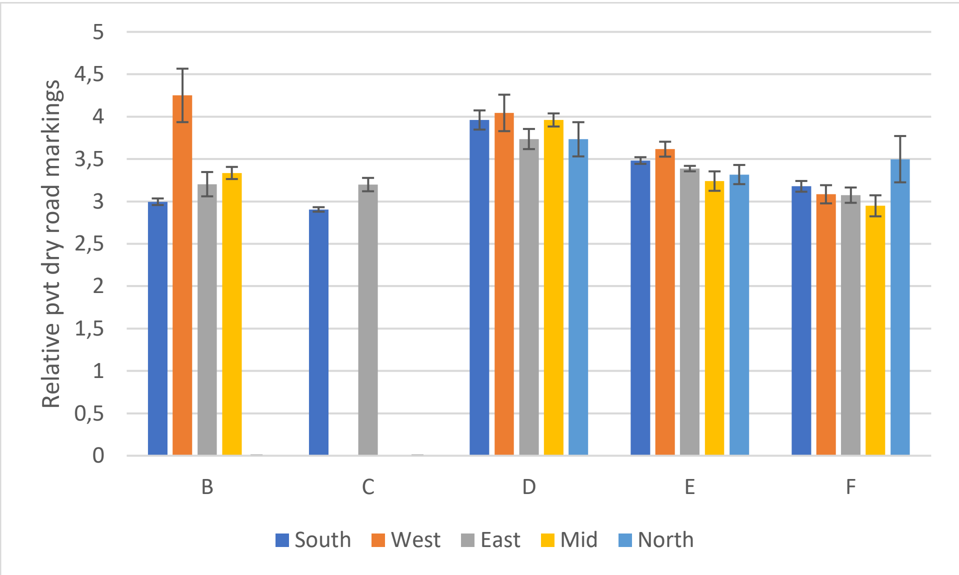

Figure 49. Relative pre-view-time for right edge line for each region and road class in Norway. Dry road markings.

Wet road markings

Retroreflectivity

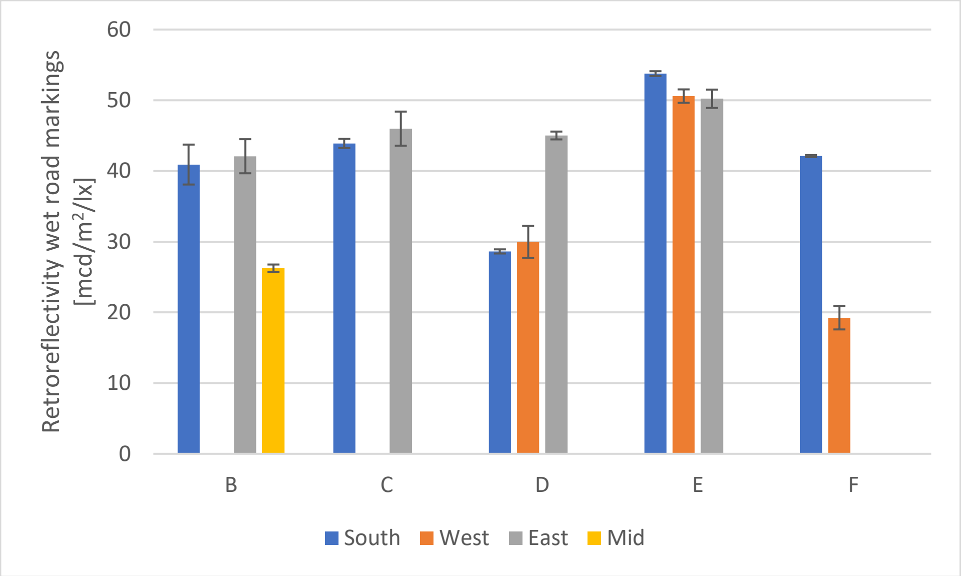

Figure 50. Mean of retroreflectivity right edge line on wet road markings for each region and road class in Norway.

Relative visibility

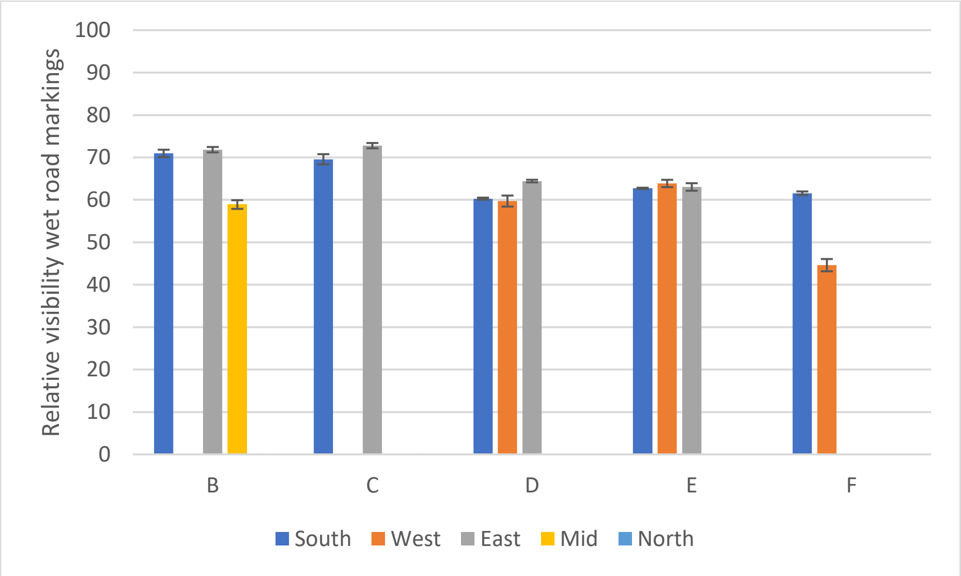

Figure 51. Relative visibility for right edge line for each region and road class in Norway. Wet road markings.

Relative pre-view-time

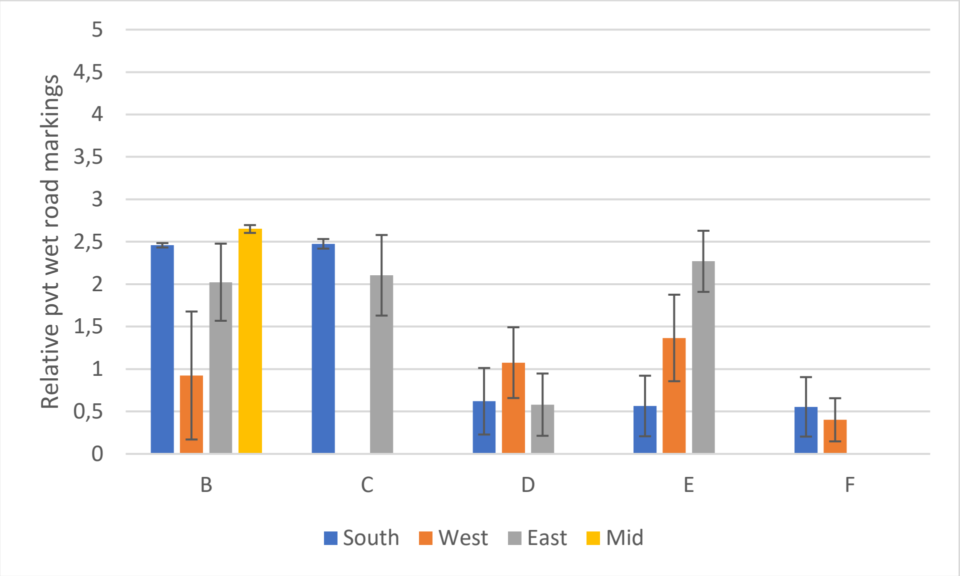

Figure 52. Relative pre-view-time for right edge line for each region and road class in Norway. Wet road markings.

Cover index

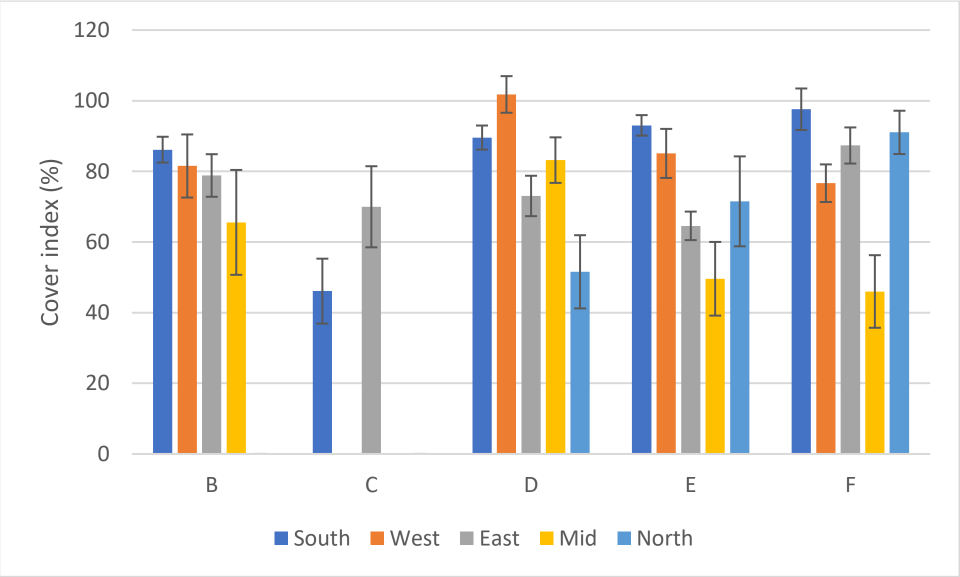

Figure 53. Cover index for each region and road class in Norway. Right edge line (white).

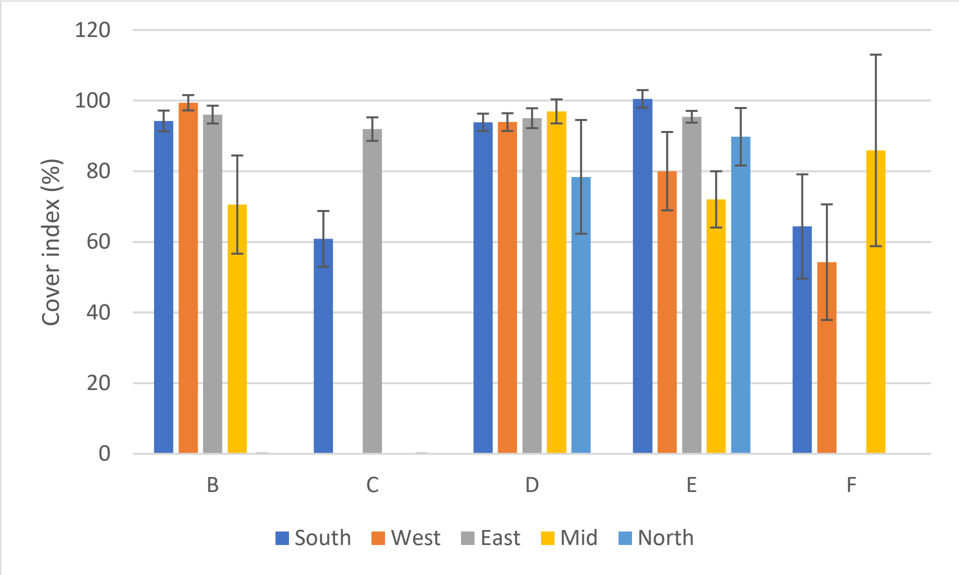

Figure 54. Cover index for each region and road class in Norway. Lane line (class A, B and C), centre line (class D, E, and F).

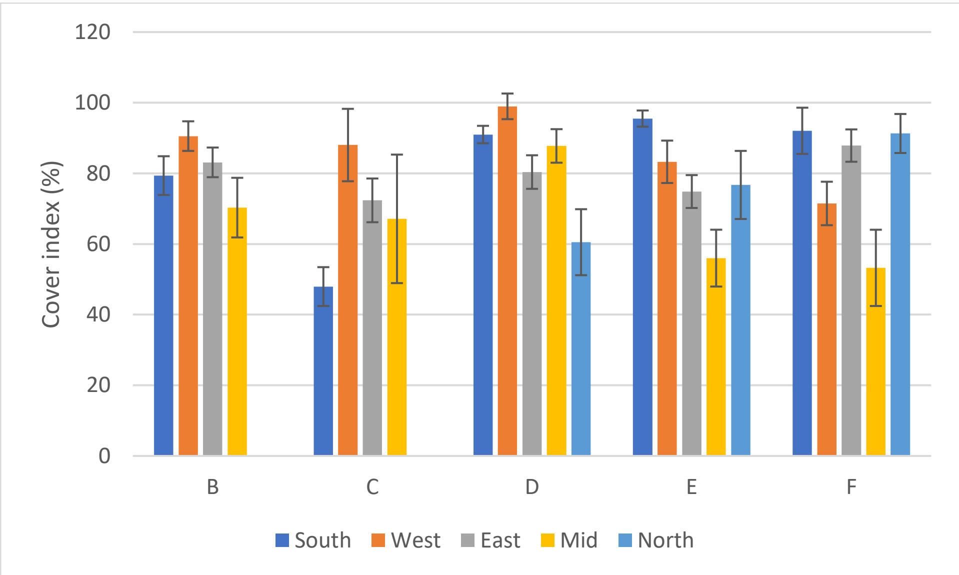

Figure 55. Cover index for each region and road class in Norway. All road markings (white and yellow).

County roads and national roads

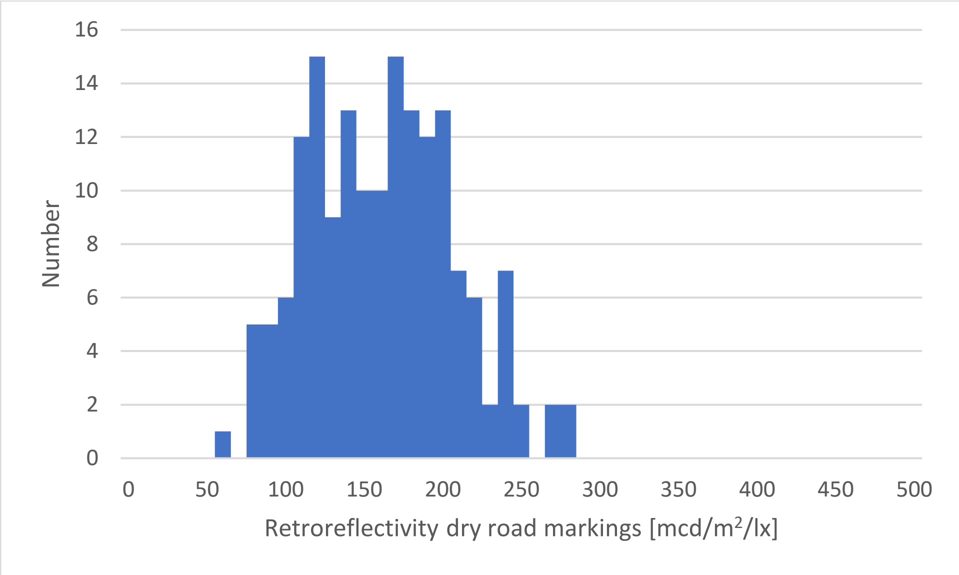

Figure 56 Retroreflectivity for dry road markings in Norway. All road markings, national roads.

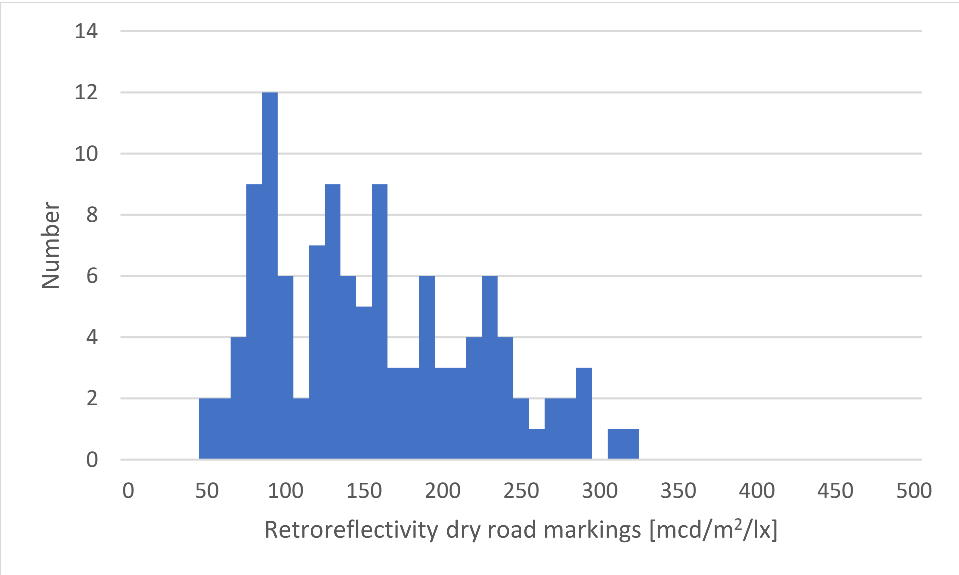

Figure 57. Retroreflectivity for dry road markings in Norway. All road markings, county roads.

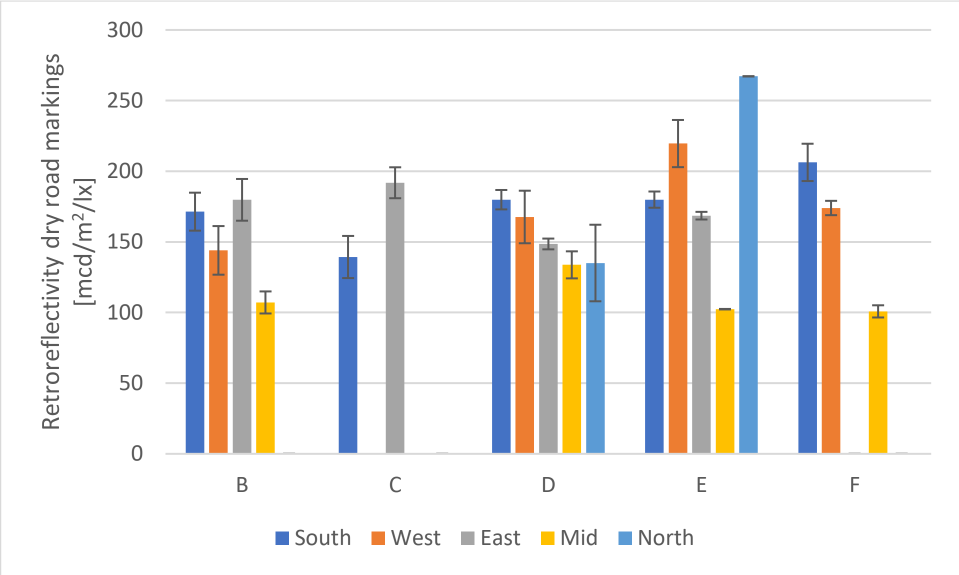

Figure 58. Retroreflectivity for dry road markings in Norway. Right edge line, national roads.

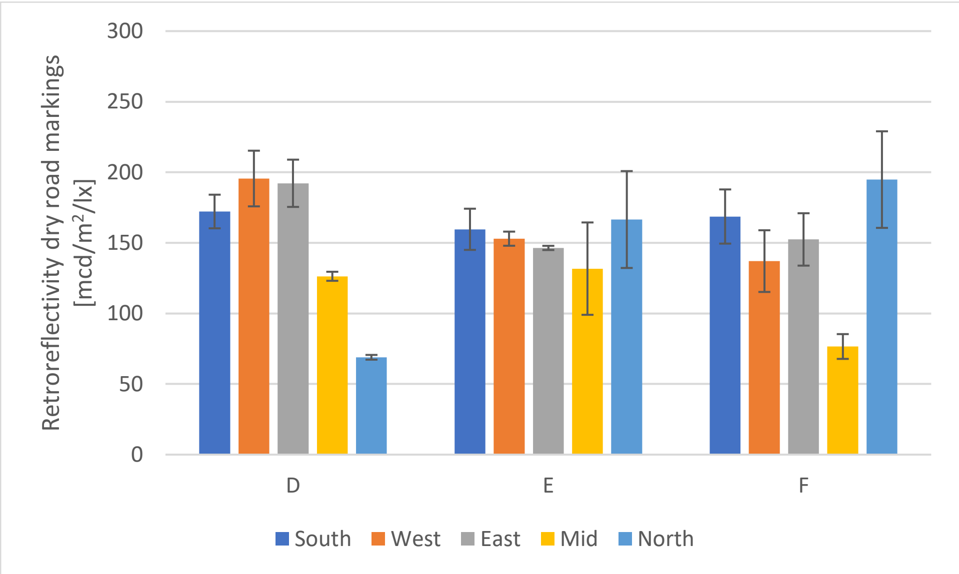

Figure 59. Retroreflectivity for dry road markings in Norway. Right edge line, county roads.

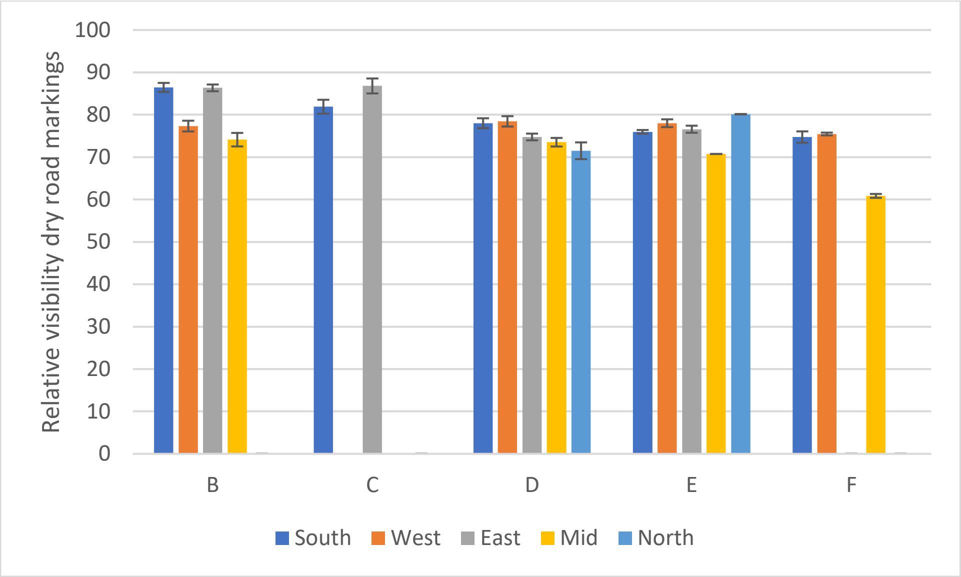

Figure 60. Relative visibility for dry road markings in Norway. Right edge line, national roads.

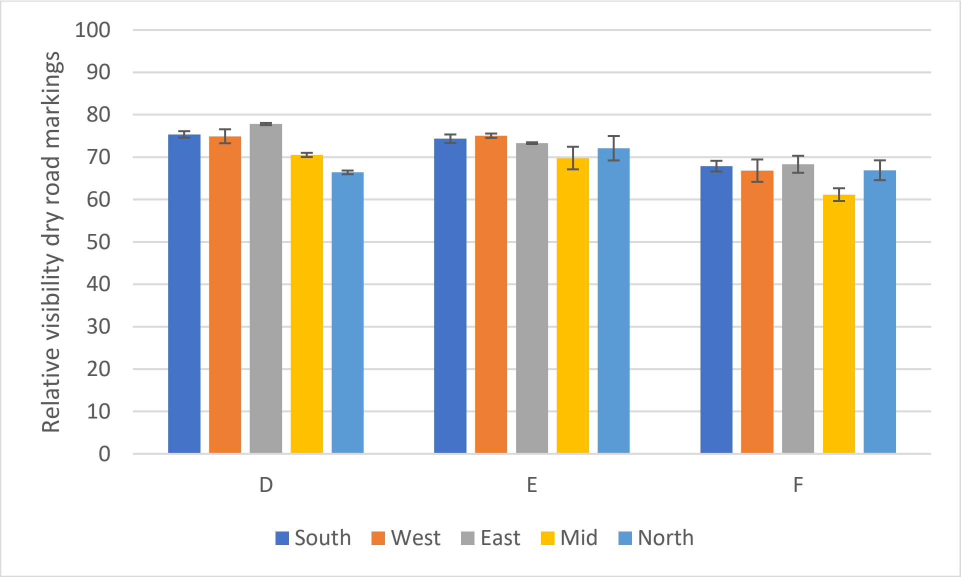

Figure 61. Relative visibility for dry road markings in Norway. Right edge line, county roads.

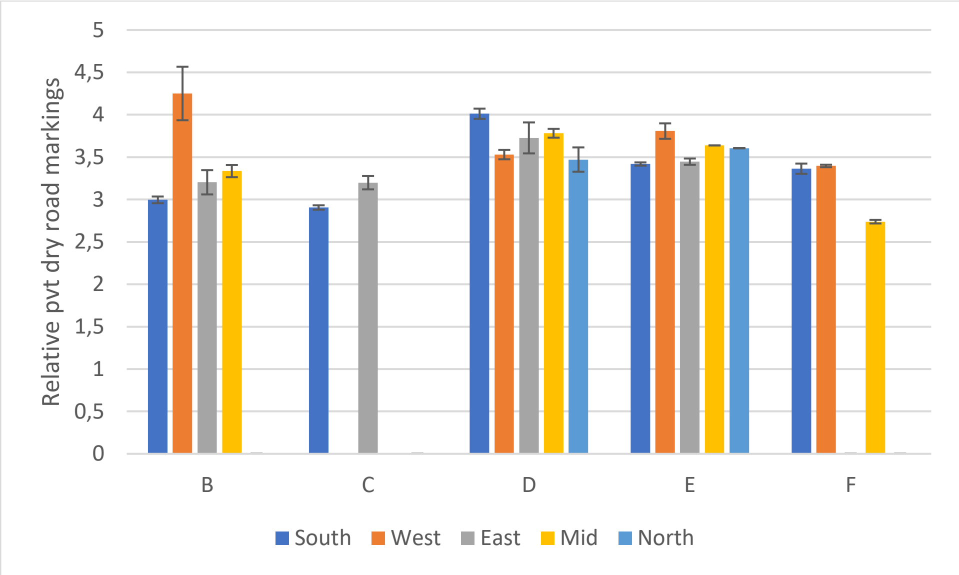

Figure 62. Relative pvt for dry road markings in Norway. Right edge line, national roads.

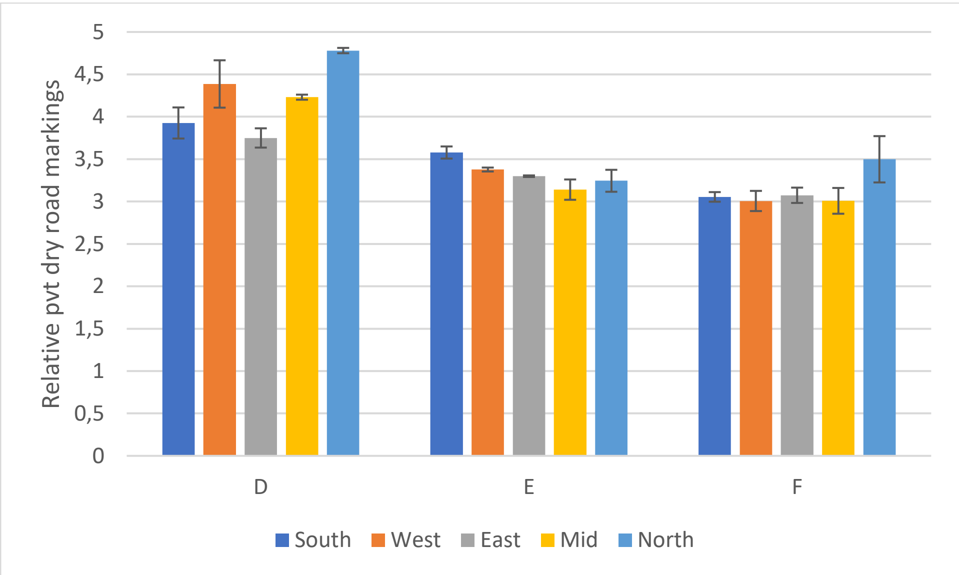

Figure 63. Relative pvt for dry road markings in Norway. Right edge line, county roads.

Annex C Results Sweden

Dry road markings

Retroreflectivity

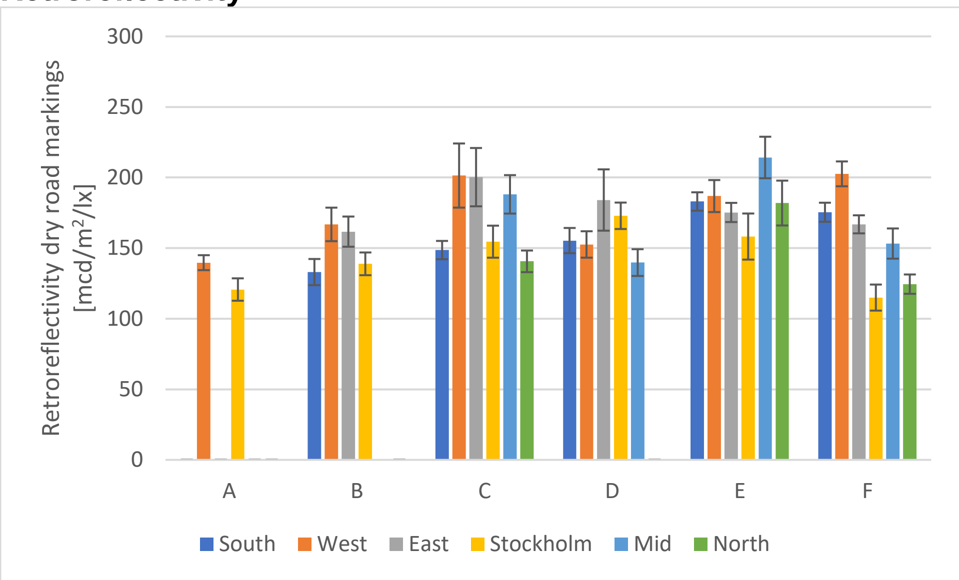

Figure 64. Mean of retroreflectivity right edge line on dry road markings for each region and road class in Sweden.

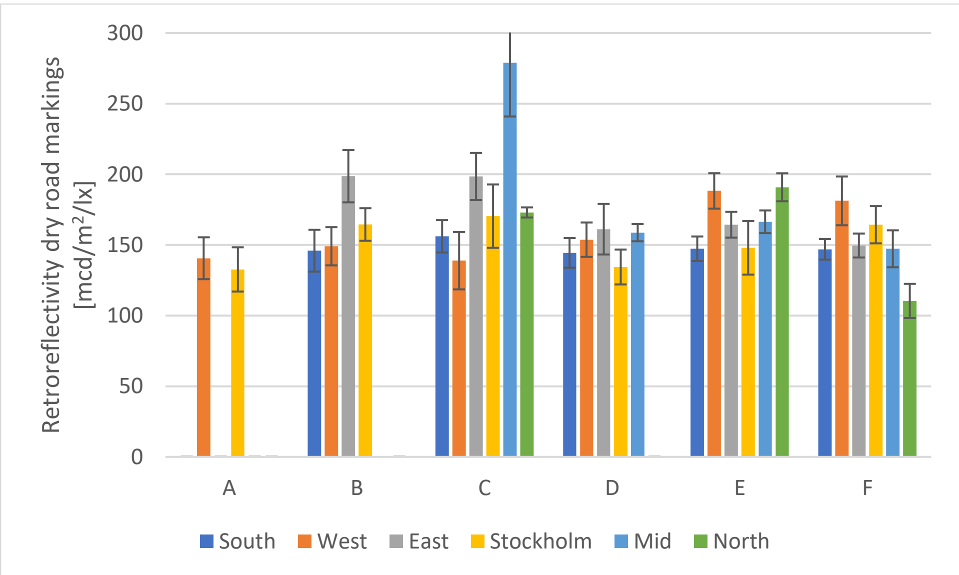

Figure 65. Mean of retroreflectivity in Sweden. Lane line (class A, B and C), centre line (class D, E, and F). Dry road markings for each region and road class in Sweden.

Relative visibility

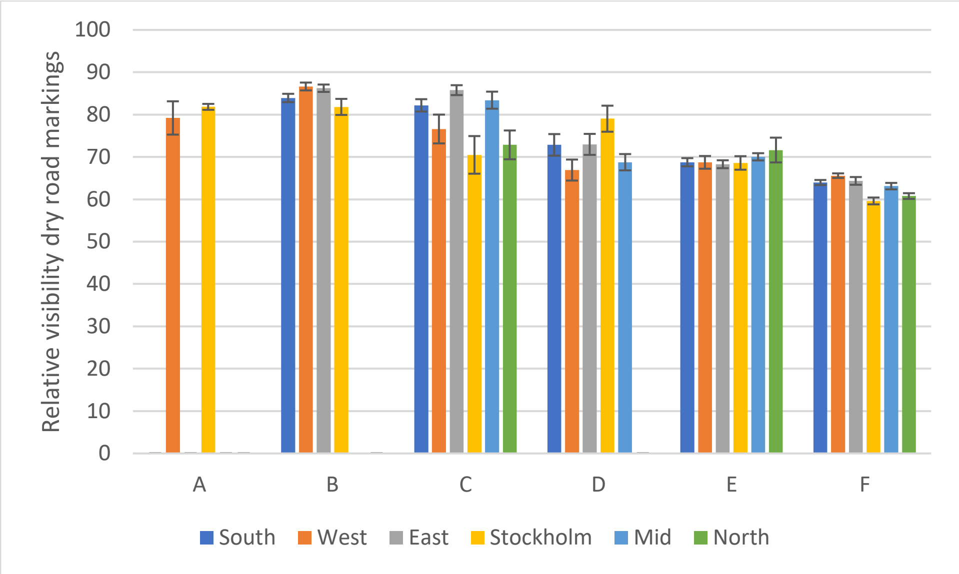

Figure 66. Relative visibility for right edge line for each region and road class in Sweden. Dry road markings.

Relative pre-view-time

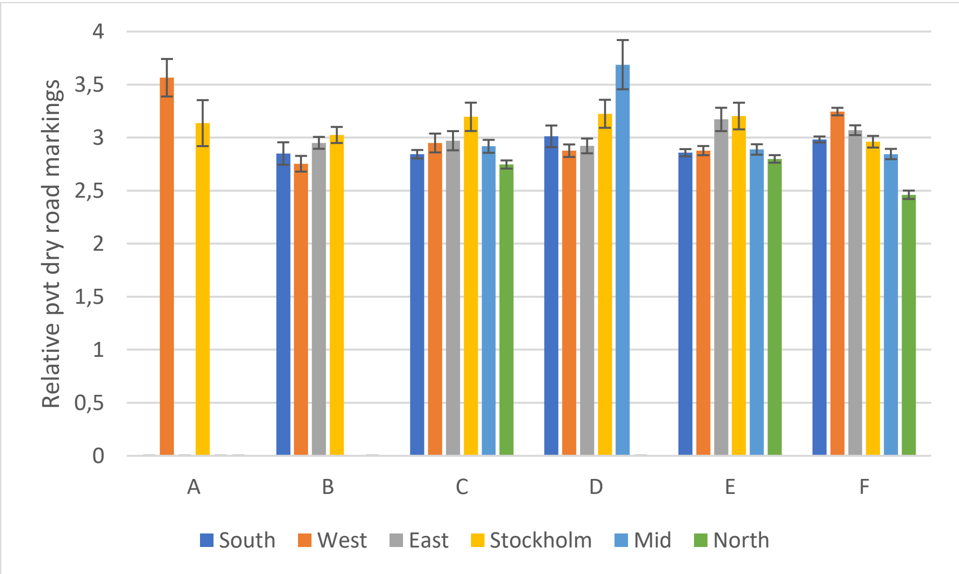

Figure 67. Relative pre-view-time for right edge line for each region and road class in Sweden. Dry road markings.

Wet road markings

Retroreflectivity

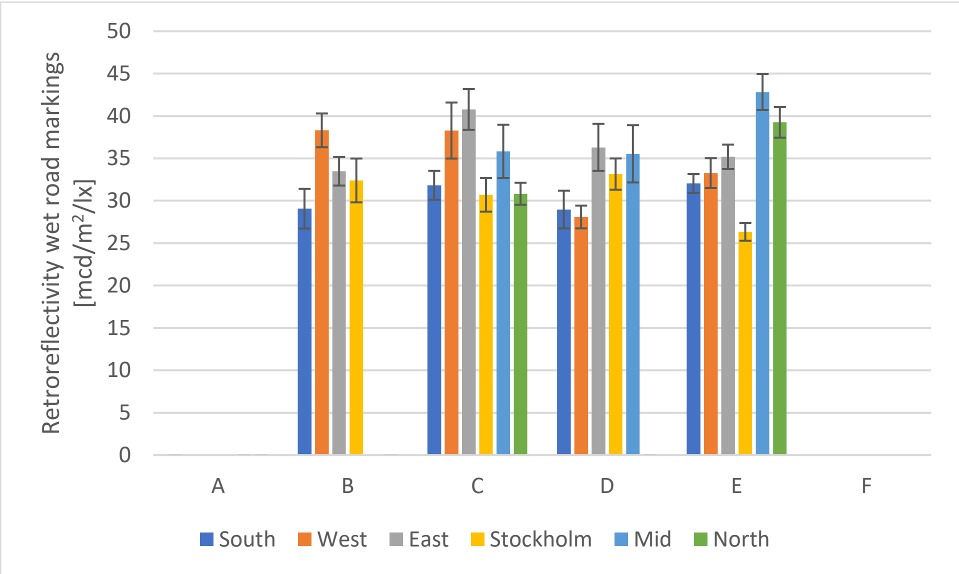

Figure 68. Mean of retroreflectivity right edge line on wet road markings for each region and road class in Sweden.

Relative visibility

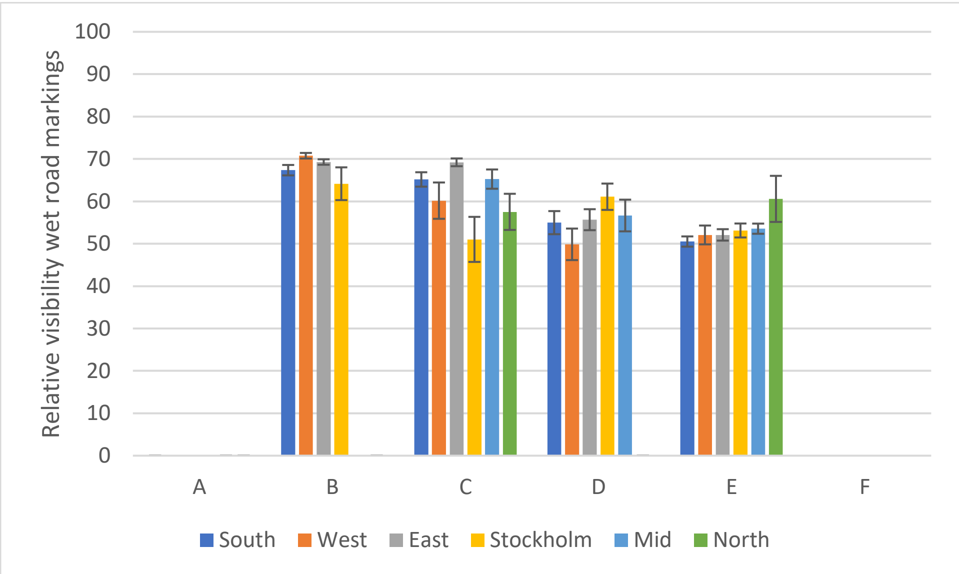

Figure 69. Relative visibility for right edge line for each region and road class in Sweden. Wet road markings.

Relative pre-view-time

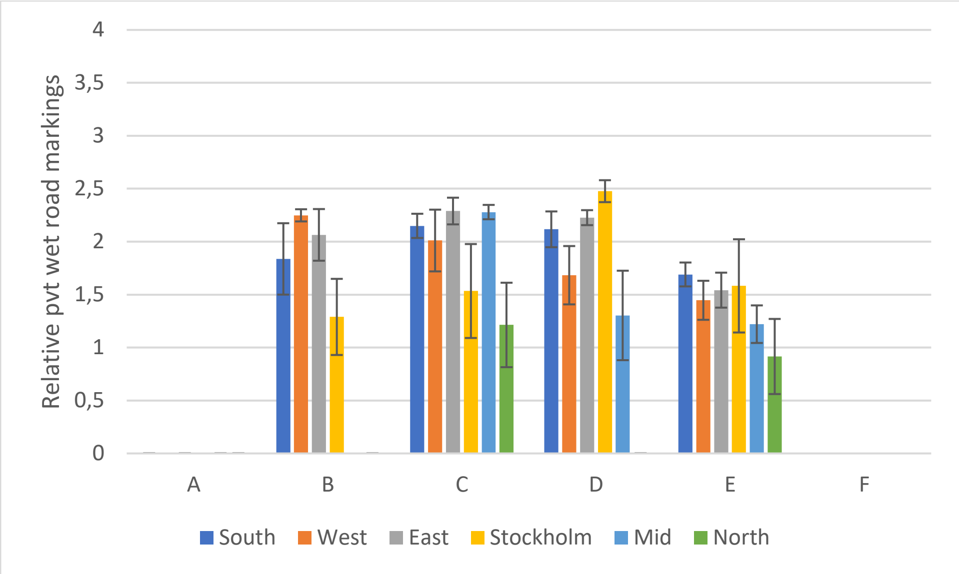

Figure 70. Relative pre-view-time for right edge line for each region and road class in Sweden. Wet road markings.

Cover index

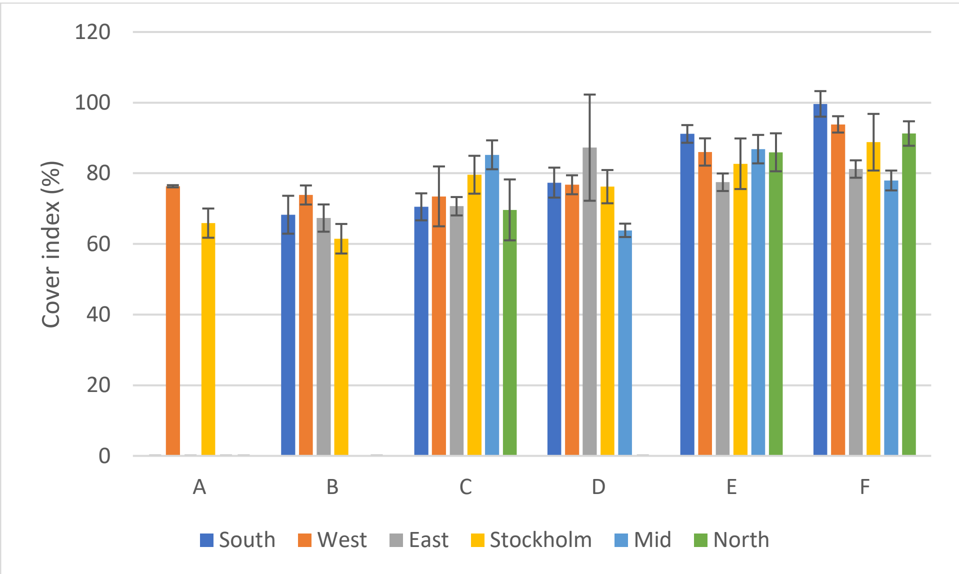

Figure 71. Cover index for each region and road class in Sweden. Right edge line road markings.

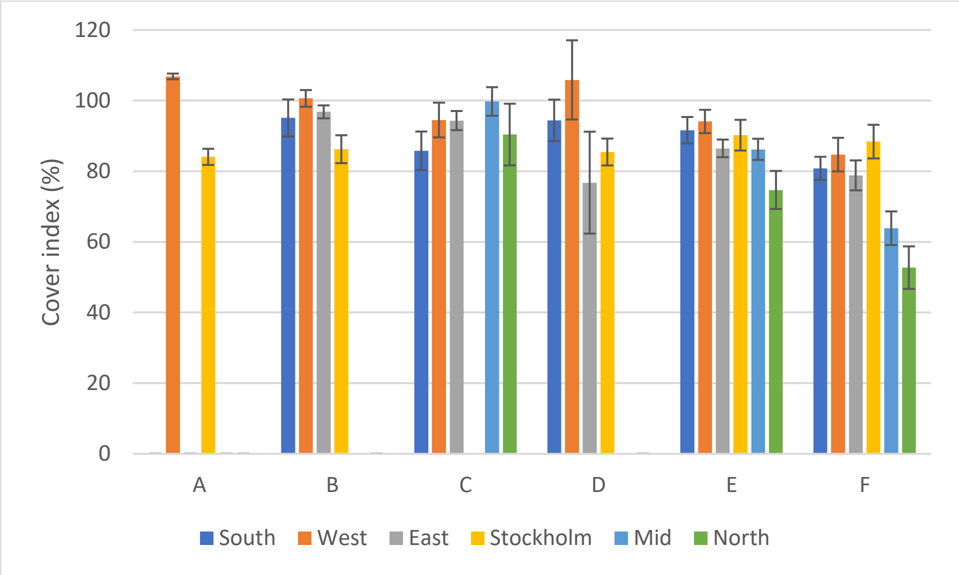

Figure 72. Cover index for each region and road class in Sweden. Lane line (class A, B and C), centre line (class D, E, and F).

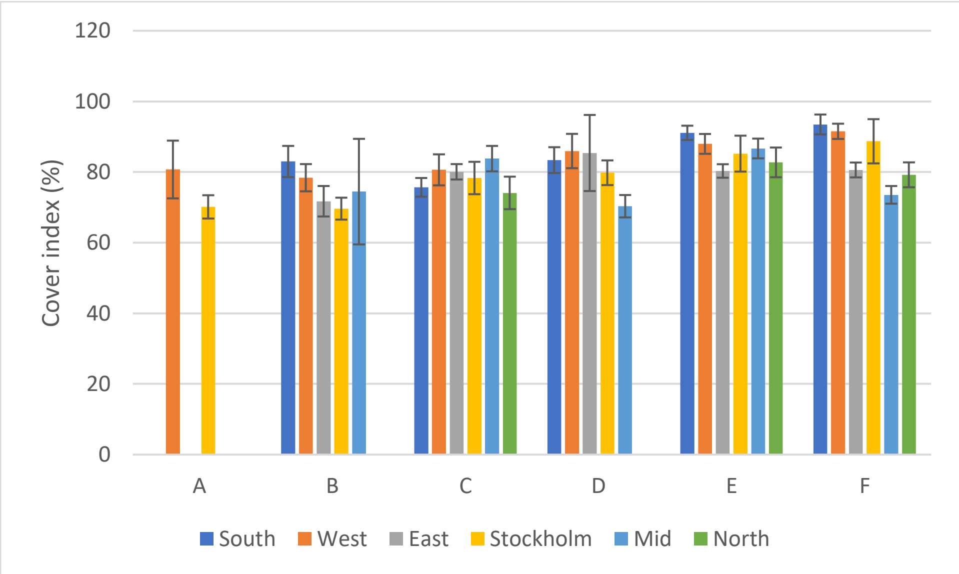

Figure 73. Cover index for each region and road class in Sweden. All road markings (white).

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Annex D Results ANOVA

Table 33. Results from ANOVA.

Dependent variable	Independent variable	Degrees of freedom	F-ratio	p-value
Retroreflectivity [mcd/m²/lx] All road markings Dry road markings	Country	2	7.103	0.001
	Road class	5	4.240	0.001
	Country*road class	8	0.428	0.905
Retroreflectivity [mcd/m²/lx] Right edge line Dry road markings	Country	2	4.485	0.012
	Road class	5	2.850	0.015
	Country*road class	8	0.370	0.937
Retroreflectivity [mcd/m²/lx] Lane/centre line Dry road markings	Country	2	1.675	0.188
	Road class	5	3.187	0.008
	Country*road class	8	1.159	0.322
Retroreflectivity [mcd/m²/lx] All road markings Wet road markings	Country	2	34.409	< 0.001
	Road class	5	7.654	< 0.001
	Country*road class	6	3.041	0.006
Retroreflectivity [mcd/m²/lx] Right edge line Wet road markings	Country	2	38.323	< 0.001
	Road class	5	6.137	< 0.001
	Country*road class	6	2.798	0.011
Relative visibility [m] Right edge line Dry road markings	Country	2	5.5	0.004
	Road class	5	81.057	< 0.001
	Country*road class	8	4.668	< 0.001
Relative visibility [m] Lane/centre line Dry road markings	Country	2	10.015	< 0.001
	Road class	5	7.16	< 0.001
	Country*road class	8	2.713	0.006
Relative visibility [m] Right edge line Wet road markings	Country	2	9.068	< 0.001
	Road class	5	18.454	< 0.001
	Country*road class	6	3.889	0.001
Relative pvt [s] Right edge line Dry road markings	Country	2	36.633	< 0.001
	Road class	5	32.042	< 0.001
	Country*road class	8	11.663	< 0.001
Relative pvt [s] Lane/centre line Dry road markings	Country	2	6.252	0.002
	Road class	5	24.669	< 0.001
	Country*road class	8	2.762	0.005
Relative pvt [s] Right edge line Wet road markings	Country	2	39.693	< 0.001
	Road class	5	11.97	< 0.001
	Country*road class	6	13.206	< 0.001
Cover index [%] All road markings	Country	2	6.996	0.001
	Road class	5	4.541	< 0.001
	Country*road class	8	2.284	0.02
Cover index [%] Right edge line	Country	2	6.447	0.002
	Road class	5	4.683	<0.001
	Country*road class	8	1.74	0.085
Cover index [%] Lane/centre line	Country	2	0.254	0.775
	Road class	5	5.209	<0.001
	Country*road class	8	0.262	0.978

Table 34. Mean levels and standard error for Denmark, Norway and Sweden. The mean levels are estimated marginal means and adjusted for unbalance in the design.

Variable	Denmark	Norway	Sweden
Retroreflectivity, all road markings, dry [mcd/m²/lx]	146 (4.3)	154 (3.9)	162 (2.9)
Retroreflectivity, right edge line, dry [mcd/m²/lx]	133 (7.3)	159 (6.0)	160 (4.9)
Retroreflectivity, lane/centre line, dry [mcd/m²/lx]	150 (6.9)	155 (6.8)	160 (4.7)
Retroreflectivity, all road markings, wet [mcd/m²/lx]	29 (0.8)	38 (1.2)	34 (0.5)
Retroreflectivity, right edge line, wet [mcd/m²/lx]	27 (1.0)	39 (1.4)	34 (0.6)
Relative visibility [m], right edge line, dry	80 (0.7)	76 (0.6)	75 (0.5)
Relative visibility [m], lane/centre line, dry	64 (0.7)	60 (0.7)	64 (0.5)
Relative visibility [m], right edge line, wet	62 (0.8)	63 (1.2)	60 (0.5)
Relative pvt [s], right edge line, dry	2.9 (0.05)	3.4 (0.04)	3.0 (0.03)
Relative pvt [s], lane/centre line, dry	2.4 (0.05)	2.7 (0.05)	2.6 (0.04)
Relative pvt [s], right edge line, wet	2.3 (0.03)	2.7 (0.05)	2.3 (0.02)
Cover index [%], all roads	71 (1.7)	77 (1.5)	80 (1.2)
Cover index [%], right edge line	63 (2.8)	74 (2.3)	77 (1.9)
Cover index [%],lane/centre line	89 (2.5)	86 (2.5)	88 (1.8)

Annex E Distribution of retroreflectivity and relative visibility right edge line

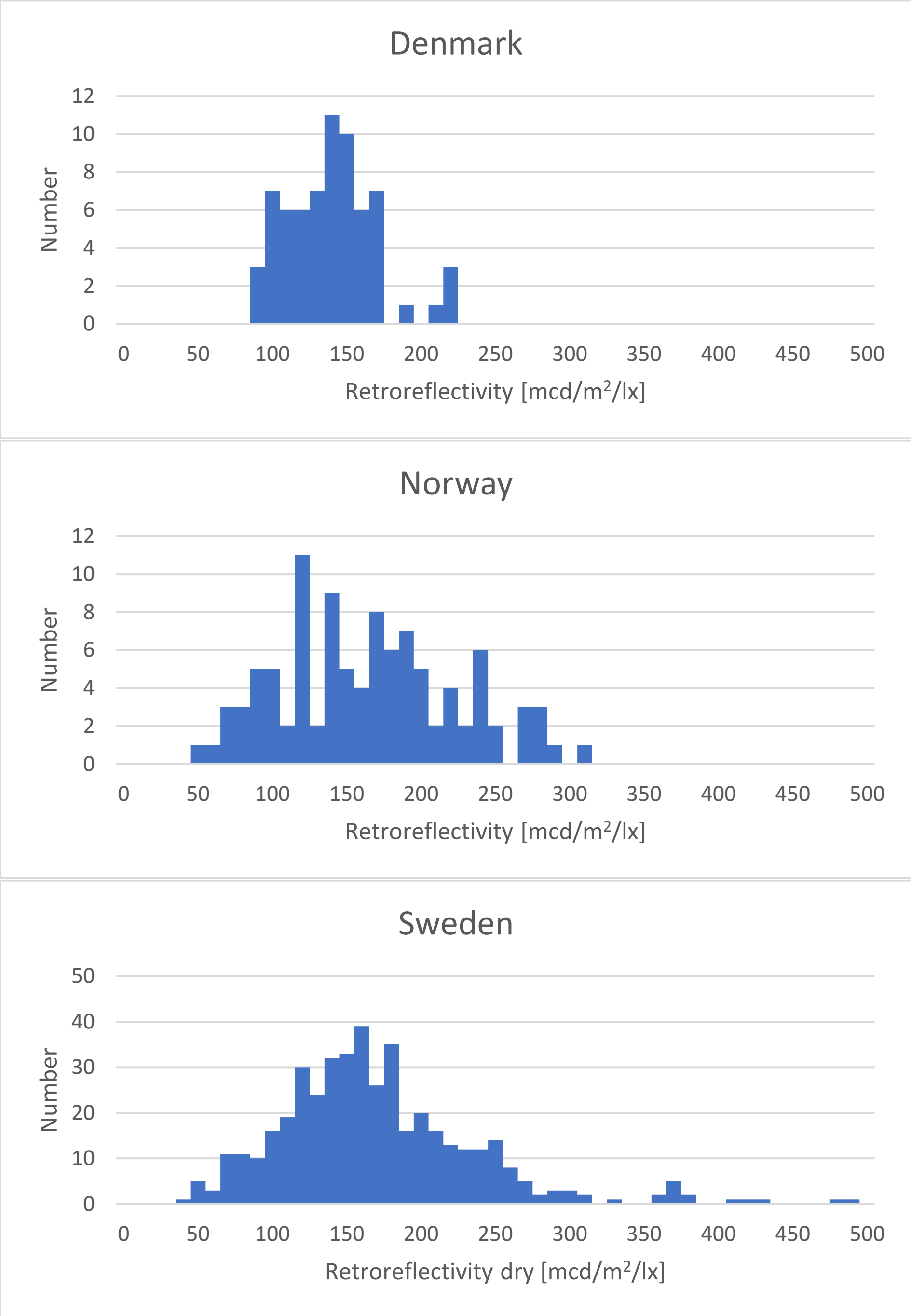

Figure 74. Distribution of dry right edge line retroreflectivity [mcd/m²/lx].

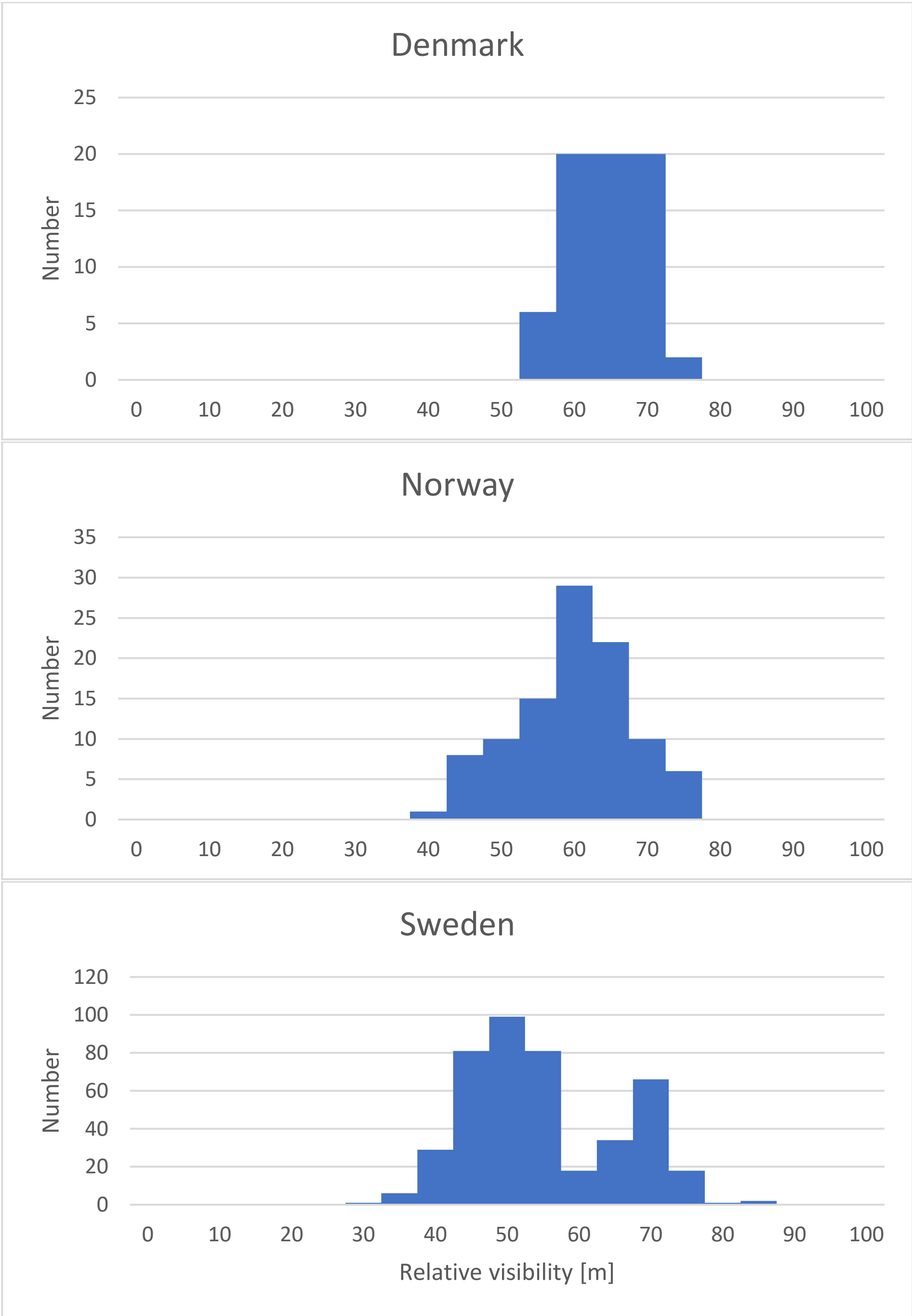

Figure 75. Distribution of relative visibility of dry right edge lines.

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