WESTERN NORWAY RESEARCH INSTITUTE
VESTLANDSFORSKING
www.vestforsk.no

Vestlandsforsking-rapport nr. 1/2013

Energi- og miljøbesparende tiltak i Lerum Frakt BA

- En rapport fra Transnova-prosjektet

Av Morten Simonsen

Vestlandsforsking rapport

Tittel Energi- og miljøbesparende tiltak i Lerum Frakt BA	**Rapportnummer** 1/2013 **Dato** 15.01.2013 **Gradering** Open
Prosjekttittel Vidareføring av energi- og miljøbesparende tiltak - Lerum Frakt	**Tal sider** 105 **Prosjektnr** 6277
Forskar(ar) Morten Simonsen	**Prosjektansvarleg** Morten Simonsen
Oppdragsgivar Statens Vegvesen – Transnova-programmet	**Emneord** Transport, miljø. energi
Samandrag	
Andre publikasjonar frå prosjektet	
ISBN: 978-82-428-0332-0	**Pris:** Kan lastast ned gratis på www.vestforsk.no

Innholdsfortegnelse

Summary

What factors are most important for fuel consumption in heavy duty vehicles? We have analysed this by using a multivariate regression model with fuel consumption per 10 km as the dependent variable. The independent variables are different factors that we assume have an impact on fuel consumption. These are weight load, use of torque, cruise control, rolling without engine load, running idle, automated gear shifts, average speed, vehicles' break horsepower, seasonal variations and a dummy for whether the vehicle is a semitrailer or a truck with an independent trailer. In addition location of first delivery is taken into consideration since road quality and terrain will differ on different routes.

The data used in the analysis comes from the fleet management system, Dynafleet, developed by Volvo. In November 2012 Dynafleet was installed in 18 vehicles operated by the freight company Lerum Frakt BA. The system registers fuel consumption and distance travelled by each vehicle each day. In addition, values for use of cruise control, running idle etc. is registered on a daily basis. The weight of the freight load is taken from the freight company's booking system. This is matched manually with data from Dynafleet on a daily basis where this is possible. All known trips from the booking system that has a match in the daily Dynafleet report within a maximum deviance of 10% are included in the data material. This means that the results are valid for heavy duty vehicles with approximately full load.

The results from the model estimation show that weight load has a significant effect on fuel consumption. If this load is increased by 10 tonnes, the expected fuel consumption increases with 0,11 litre per 10 km. Average speed has the expected significant effect. If it is increased from 30 to 40 km an hour the average fuel consumption falls with 0,5 litre per 10 km. If average speed is increased from 50 to 60 km an hour the same effect is much less, 0,2 litre. The effect of increased speed is therefore highest when speed level is low. Overall average speed is 63 km an hour.

If relative time spent using more than 90% of maximum torque is increased by 10 percentage points, average fuel consumption increases by 0,7 litre per 10 km. On average, vehicles spend 20% of driving time with this torque use.

If a vehicle has 200 more horsepower than another vehicle and they are equal in all other aspects, the one with more horsepower will have 0,57 litre higher fuel consumption. In the winter season the vehicles use about 0,14 litre more than in summer and the average fuel consumption for a vehicle with an independent trailer is 0,3 litre higher than the average for a semitrailer.

If relative time spent rolling without engine load is increased by 10 percentage point, fuel consumption is reduced by 0,12 litre per 10 km on average. A similar increase in relative time spent running idle means fuel consumption goes up by 0,12 litre. The effects of these two indicators are roughly equal in opposite directions.

For all interpretations of effects in the multivariate model we assume constant values for all independent variables except the one we are studying the effect of.

An analysis of mean elasticities from the regression model shows that four independent variables have much larger effects than the others. These are in decreasing order of absolute magnitude horsepower, use of engine load of more then 90% of maximum torque, average speed and time spent driving in highest gear. These are variables that describe the effect of terrain and road standard more than drivers' behaviour. We can therefore conclude that road standard and terrain are the most important factors for determining fuel consumption. Driving behaviour does still matter, but road standard and vehicle properties such as horsepower, engine load and weight load matter much more.

An analysis of fuel consumption shows that the positive trend towards reduced fuel consumption is levelling off and reversing towards the end of 2012. The consumption in January 2012 is 0,4 litre per 10 km lower than the same month a year before. In February and March the corresponding figures are 0,1 and 0,2 litre lower per 10 km than the corresponding months a year before. However, in September, October and November the difference is 0,3 litre *higher* per 10 km in 2012 compared to the same months a year before.

In summer 2011 seven drivers at Lerum Frakt BA took part in a driving course. The aim of the course was to teach driving behaviour beneficial for lower fuel consumption. Eighteen of the vehicles used by the company had the fleet management system Dynafleet[1] installed before the driving course. These vehicles constitute the sample used in the analysis in this report.

The overall research question is: Are there any significant differences in driving behaviour after the driving course for each individual driver and for different groups of drivers? The drivers are divided into two groups, one consist of the drivers who took the course and the other of the drivers who did not. The first is referred to as the treatment group and the second as the control group.

Nine different driving behavioural indicators are included in the analysis. These are use of cruise control, use of running idle, use of rolling without engine load, use of highest gear, of automatic gear shift and of use of more than 90% of maximum torque. All these indicators are measured as use in percentage of total driving time per day. In addition, number of brake applications and number of stops, both per 100 km, are included in the analysis as well as fuel consumption per 10 km.

We have made three different tests for each driver in order to determine whether there are any differences before and after the driving course. We perform a t-test for independent samples with assumed unequal variance for each driver where the two samples tested are the days before the driving course and the days after. We then use binomial tests to determine whether there are more significant differences between drivers from the treatment group and the control group than what would be expected from pure chance alone. In addition we use Wilcoxon's signed rank test in order to determine whether there is any change among all drivers before and after the course and Mann-Whitney test to determine whether the median difference is different in the treatment group and in the control group. Both the Wilcoxon tests and the Mann-Whitney tests use the means from the t-tests as measurement of driving behaviour before and after the driving course.

Both the last two tests are non-parametric which means they do not assume any underlying normal distribution for the behavioural indicators. The t-tests are based on he normal distribution, but

[1] Dynafleet is a fleet management system developed by Volvo.

according to the central limit theorem a sum of independent non-normal variables can itself be normal. Since a mean is a sum of independent variables, this means the assumption of normality is made about the means we are testing, not about any individual indicator distribution.

For cruise control, we find that drivers have significantly altered their use of cruise control after the driving course measured by the Wilcoxon's test. At the same time, we do not find any significant difference between the drivers who participated in the course and those who did not by use of the Mann-Whitney test. The t-tests also reveal no significant difference between the treatment group and the control group.

The conclusion for use of automatic gear shift is that we cannot find any evidence to suggest that its use has changed as an effect of the driving course. Consequently, there is also no difference between drivers in the treatment group and the control group.

For use of more than 90% of maximum torque we cannot find any effect of the driving course. A decreasing use of this indicator is beneficial for fuel consumption, but its use has rather increased after the driving course though this change is not significant as measured by the Wilcoxon's signed rank test.

The conclusion for application of brakes per 100 km is that there is not evidence enough to reject the null hypothesis of no change in its use. The same is true for indicator number of stops per 100 km.

For running idle we find a significant change in use of it among all drivers. We do not find significant differences between the treatment group and the control group in use of running idle. Looking at driving in highest gear, we find that we cannot reject the null hypothesis of no change in this indicator, neither for all drivers nor for the treatment group compared to the control group.

The conclusion for rolling without engine load is that we find evidence of more use of this indicator for all drivers after the driving course. We also find evidence to support the claim that drivers from the treatment group use this indicator more than drivers from the control group. So there is positive change among all drivers and the positive change is largest among drivers in the treatment group.

We find a significant reduction in fuel consumption after the driving course, but the course itself seems to have had no effect since all drivers reduce their consumption regardless of whether they participated or not.

We do find significant change among all drivers for use of cruise control, running idle and fuel consumption, but not between the treatment group and the control group. How can that be? The drivers who participated in the course may have spread information about measures to reduce fuel consumption (more cruise control, more rolling without engine load, less running idle) to the drivers that did not attend it. The ones that did take the course acted as information agents for the ones who did not. Therefore, useful information and experiences from the driving course may also have an influence on drivers who did not participate. The two groups do not act independent of each other, they have daily contact and the control group is not "blind" about the positive experiences and knowledge acquired by drivers who participated in the driving course.

All of the 9 behavioural indicators also may not be equally valid as indicators of driving behaviour. Several of them are more determined by external factors than by drivers' intention. Use of maximum torque, driving in highest gear, number of brake applications and number of stops may be more dependent on attributes like road quality, the vehicles drivers use and variations in driving conditions and cargo. These indicators may not describe drivers' behaviour at all. On the other hand, indicators like use of running idle, rolling without engine load and cruise control may be more valid indicators since the values on these indicators are more determined by driver's choice and intention.

Since we find evidence of systematic change for these indicators among all drivers, it may be that the driving course and its attention on benign driving behaviour for reduced fuel consumption did have an effect on the behavioural indicators that drivers have the largest potential of changing. We find this effect also among drivers who did not participate, maybe because discussions among drivers helped to spread information about how to best achieve lower fuel consumption.

The ANOVA analysis with Scheffe's post hoc test did not reveal any significant differences between drivers who participated in the driving course and those who did not.

Looking at trends in use of selected behavioural indicators, we find that for use of cruise control there is a clear increase in use of it after the driving course in mid June 2011. Except for a dip in September 2011, there is an upward trend all up to January 2012. After that use of cruise control has gone gradually down. One interpretation of this trend is that the driving course created an awareness about use of cruise control that has decreased over time.

The variation in use of cruise control increases as the use of it also increases. Therefore, the trend towards more use of cruise control is not a common trend among all drivers.

For use of running idle, we find a clear downward trend. For this behavioural indicator, there is also an obvious seasonal trend. Use of running idle is lowest in the summer months and increases in the winter months December, January, February and March.

We also find that the variation in use of running idle increases as the use of it decreases. Not all drivers are therefore reducing their use of running idle to the same degree.

For rolling without engine load, we find a clear upward trend. But also for this indicator we find a weakening effect over time. The level of using rolling without engine load is higher in September and October 2012 as compared to the same months one year earlier measured by the moving average. For November 2012 though, the trend is the opposite, the level of use of rolling without engine load is lower compared to the same month one year earlier.

The variation in use of rolling without engine load increased the most just after the driving course in June 2011. The awareness of the benign effects of rolling without engine load on fuel consumption increased just after the course but it has levelled off over time.

For fuel consumption we find a clear seasonal trend but not a linear one, We therefore find no indications that suggest lower fuel consumption over time for all drivers.

Both the developments of driving behavioural indicators and fuel consumption suggest that positive effects from a change in driving behaviour must be actively supported by the freight company in order to be sustained over time. If focus on positive driving behaviour is relaxed, the effects will gradually subside. We also think it will be beneficial for change in driving behaviour if the partners in the project (the freight company, the drivers, lorry owners, the companies that demand transport services) have a shared conception of how potential economic benefits from this change should be distributed among them.

We have analysed the environmental impact of using different transport means to transport a given freight from the transport company Lerum Frakt's location to a given destination. In order to make this comparison, we analyse energy use and emissions in two energy chains, the direct and the indirect one. The direct energy chain consists of energy use for propulsion of the transport mean including the energy use for production and distribution of that energy. The indirect energy chain consists of energy use for construction, maintenance and running of the infrastructure a transport mean uses in addition to energy use for production and maintenance of the transport mean itself. In order to compare energy use and emissions for production of one tonne-km by different transport means we take both the direct and indirect energy use into consideration. This allows for the most complete and consistent comparison of environmental effects between different transport means.

We have analysed the environmental effect of using different transport modes for transporting 1000 tonnes from Lerum Fabrikker in Sogndal to a large warehouse in Vestby close to Oslo. If only semitrailers are used for the transport, as opposed to ship in combination with semitrailer, the energy use is 1,9 times higher and emissions of CO2-equivalents are more than twice as high. Emissions of SO2-equivalents are half the emissions from ship in combination with semitrailer while emissions of TOPP-equivalents are about the same. All emissions are calculated per tonne-km. SO2-equivalents measures the potential for acidification from a set of components while TOPP-equivalents measures contribution to creation of ground-level ozone from a set of gases.

We have also analysed the effect of using railway in combination with semitrailer in order to transport the same freight on the same distance. If we compare with sea transport in combination with semitrailer the total use of energy is 1,4 times higher with the combination railway-semitrailer. Emissions of CO2-equivalents are 1,3 times higher. If we look at emissions of SO2-equivalents and TOPP-equivalents the emissions are under half the amount of corresponding emissions from combination ship-semitrailer.

Compared to the alternative with only semitrailer, the alternative with railway-semitrailer has 76% of the energy use and 62% of total emissions of CO2-equivalents. We should note that emissions of CO2-equivalents from railway freight transport is high because of the emissions required to build and maintain the infrastructure which needs a lot of cables and masts in order to distribute electricity for the trains.

We analysed the same combination of transport means on two other routes with the same load. For the route Sogndal-Blomsterdalen outside Bergen the alternative with ship and semitrailer had 23% of total energy use compared to the alternative with semitrailer alone. The corresponding figure for CO2-emissions was 22%. Emissions of SO2-equivalents and TOPP-equivalents were about the same for the two alternatives.

If we look at the combination railway-semitrailer on the same route, the energy use for this combination was 3,3 times higher than the ship-semitrailer alternative while the emissions of CO2-equivalents were 3,2 times higher. Still, the alternative with railway-semitrailer had 79% of the energy use from semitrailer alone while the corresponding figure for emissions of CO2-equivalents was 69%.

The last route analysed was Sogndal-Heimdal outside Trondheim. Again, the load is assumed to be the same. The energy use for the combination ship-semitrailer had 29% of the energy use from semitrailer alone. The corresponding figure for emissions of CO2-equivalents was 26%. On the other hand, emissions of SO2-equivalents was 1,2 times higher for the ship-semitrailer alternative compared to semitrailer alone while emissions of TOPP-equivalents were 60% of the corresponding emissions from the semitrailer alone alternative.

Finally, the alternative with railway-semitrailer had an energy use that was 2,7 times higher than the alternative with ship-semitrailer on this route. The corresponding figure for emissions of CO2-equivalents was 2,5 times higher. The emissions of SO2-equivalents and TOPP-equivalents are lower from the railway-semitrailer alternative than the ship-semitrailer alternative.

The overall conclusion is that the ship-semitrailer alternative is the most environmentally friendly one measured by emissions of climate gases. Measured by local and regional emissions, the alternative railway-semitrailer is the most environmentally friendly since emissions of SO2-equivalents and TOPP-equivalents are lower.

Oversikt over endringer i prosjektets andre fase

Prosjektet "Miljøbesparende tiltak i Lerum Frakt BA" er gjennomført i to faser. I første fase ble det presentert analyser som viste hvilke faktorer som påvirker drivstofforbruk og utslipp av klimagasser. Analysene viste omfang av drivstofforbruk og bruk av kjøreindikatorene cruise kontroll, tomgangskjøring, utrulling, automatisk gearskift, motorbelastning, kjøring i høyeste gear samt gjennomsnittsfart pr lastebil og pr sjåfør i selskapet Lerum Frakt BA. Analysene viste også hvilken effekt kjøreindikatorer og veistandard har på drivstofforbruket. Data for analysene ble hentet fra flåtestyringssystemet Dynafleet som er installert i til sammen 21 lastebiler fra desember 2010.

En svakhet med analysene i første fase var at vektregistreringene i Dynafleet ikke er tilfredsstillende. Det ble kun registrert om kjøretøyet kjørte med lav, middels eller høy vekt. Vekten inkluderte kjøretøyets egenvekt. Når høy vekt inklusive egenvekten defineres som vekt over 28 tonn havnet stort sett alle turer i denne kategorien siden kjøretøyene veier 15-20 tonn uten last inklusive henger.

Analysene i andre fase bruker derfor data fra ordesystemet til Lerum som viser hvor mye last kjøretøyene kjører med på konkrete ruter. Regresjonsanalysene er gjennomført med data pr tur med kjent last i stedet for pr dag slik vi gjorde i første runde. For å beregne effekten av kjøreindikatorer som bruk av cruise kontroll, utrulling, gjennomsnittsfart osv må data fra oversiktstabellen i Dynafleet pr dag matches med konkrete ruteopplysninger med kjent last fra ordresystemet. Kjøretøyene utfører imidlertid ofte flere turer pr dag eller en tur kan strekke seg over flere dager. Data for kjøreindikatorene lagres i Dynafleet dag for dag, men ikke tur for tur. For å vite om kjøreindikatorer pr dag er representativt for en tur har vi derfor matchet data fra ordresystemet manuelt med oversiktstabellene og tracking-rapportene i Dynafleet tur for tur. I i de tilfelle hvor avviket fra oversiktsrapporten er mindre enn 10% av distansen med kjent last er kjøreindikatorer pr dag benyttet for denne turen. Dette gir et mye bedre datagrunnlag for å beregne effekt av veistandard og kjøreindikatorer enn i første runde.

I analysene er 11 kjøretøy brukt. For de andre kjøretøyene mangler vi enten data fra Dynafleet eller vi klarer ikke å kople data fra Lerum's ordresystem med data fra Dynafleet for de aktuelle kjøretøyene. Dynafleet virker heller ikke tilfredsstillende i andre lastebiler enn Volvo.

I tillegg er det gjennomført analyser av drivstofforbruk langs ulike ruter. Rutene omfatter alle viktige leveringssteder for Lerum's transport som Oslo, Stavanger og Trondheim. For disse rutene er det laget to alternative ruteanalyser som vil gi sjåførene bedre grunnlag for å foreta valg av rute. Rute til Bergen omfattes av den ene ruten til Stavanger.

Det er utarbeidet sjåførrapporter og lastebilrapporter for hver sjåfør og lastebil som er registrert i Dynafleet. Disse rapportene er overlevert Lerum.

Det er også gjort analyser av bruk av alternative transportmiddel, det vil si sjøtransport og jernbane i tillegg til transport med lastebil, på konkrete ruter. For hver av rutene er sjøtransport og godstransport med tog analysert i kombinasjon med semitrailer for levering til sluttbruker. Forbruk av drivstoff og utslipp sammenliknes for de ulike kombinasjoner på de konkrete rutene.

Til slutt er det foretatt en oppdatering av analysene av effekt av kjørekurset som ble gjennomført på Lerum Frakt sommeren 2011. De oppdaterte analysene viser utvikling i bruk av kjøreindikatorer som cruise kontroll, tomgangskjøring, utrulling osv helt fram til og med november 2012. Analysene viser hva slags effekt kurset i økonomisk kjøring som ble avholdt 18 juni 2011 har hatt på drivstofforbruk og bruk av kjøreindikatorer i et lengre tidsperspektiv. Resultatene tyder på at positive effekter av kurset avtar over tid.

Formidlingsaktiviteter

Det er gjennomført følgende aktiviteter i prosjektets andre fase:

- Møte med sjåfører og ledelse Lerum Frakt 23 juni 2012. Presentasjon av foreløpige funn regresjonsanalyse og ruteanalyse.
- Møte med sjåfører og ledelse Lerum Frakt 13 oktober 2012. Presentasjon av regresjonsanalyser, ruteanalyser og sjåførrapporter/lastebilrapporter.
- Oversendt data for spesifikke ruter til Grønn Godstransport (GG) den 4/11/2012 for videre analyse med deres modell. GG har utarbeidet et notat som viser forskjeller i energibruk med deres modell sammenlignet med registreringer i Dynafleet.
- Vi har tatt kontakt med Norsk Lastebileierforbund og NHO Transport for å presentere prosjektet. Vi har dessverre ikke fått noen respons fra disse aktørene.

Media:

- Kronikk Sogn Avis 10/10/2012
- Kronikk Firda. 11/12/2012
- Artikkel i Logistikk & Ledelse, november 2012 (http://www.logistikk-ledelse.no/2012/tr/tr1103.htm)
- Artikkel sendt Transportforum 28 januar 2013.

Oppsummering av prosjektet

Prosjektets andre fase gir ny kunnskap når det gjelder hvilken kjøreadferd som kan påvirke drivstofforbruket i positiv retning. Denne kunnskapen er forbedret i forhold til første fase siden vi kan kontrollere for kjent lastevekt med datamateriale som er brukt i andre fase. Dette datamateriale er unikt siden det er en kopling mellom flåtesystemet Dynafleet og Lerums ordresystem. Vi kan derfor analysere forbruk og effekt av kjøreindikatorer og veistandard med kjent last. Registrering av vekt i Dynafleet er for utilstrekkelig og upresis til å brukes til en slik kontroll.

Konklusjonene fra prosjektet viser at dagens veistandard setter klare grenser for hva som kan oppnås av reduksjoner i energibruk og utslipp. Nyere og bedre veier er derfor en forutsetning for lavere energibruk og utslipp på lang sikt. Kjøreatferd har likevel betydning, mer bruk av utrulling og mindre tomgangskjøring gir lavere forbruk. Sjåførene kan derfor påvirke drivstofforbruket også med dagens veistandard.

Kunnskapen fra prosjektet viser også at tiltak som kjørekurs for å stimulere til økonomisk kjøring må følges opp aktivt for å hindre at positive endringer avtar over tid. Det er en klar tendens til at positive endringer i bruk av cruise kontroll, tomgangskjøring og utrulling rett etter gjennomføringen av et slik kurs blant Lerums sjåfører i juni 2011 har avtatt med tiden.

Lerum har heller ikke klart å få til nedgang i drivstofforbruket på 5-10 prosent som var målet med prosjektet. Det er kun i januar 2012 at vi finner en slik endring i forhold til samme måned året før. I seks av de elleve siste måneder i 2012 var forbruket høyere enn i samme periode året før. Det er derfor viktig for et transportselskap å ha en aktiv strategi for å opprettholde og videreutvikle positive endringer.

Vestlandsforsking mener at prosjektet har større sjanse for å gi positive effekter over tid dersom fordeling av en eventuell økonomisk gevinst er avklart før prosjektet starter opp.

Analyser i prosjektets andre del viser at skip i kombinasjon med semitrailer er det mest miljøvennlige alternativt til godstransport med bare semitrailer om en legger energibruk og utslipp av klimagasser til grunn. Om en legger lokale og regionale utslipp til grunn er transport med jernbane i kombinasjon med semitrailer det beste alternativet.

I prosjektets andre fase er det utarbeidet ruteanalyser som viser hvilke ruter som er mest energikrevende samt hvilke strekninger langs en rute som har størst potensial for økonomisk kjøring. Disse analysene bygger på målinger av spesifikke turer i Dynafleet med kjent last hentet fra Lerums ordresystem.

Vestlandsforsking er av den oppfatning at datamateriale fra prosjekts andre del er et viktig bidrag til transportforskningen. Andre forskere kan med andre modeller og med andre erfaringer ha nytte av materiale og produsere ny kunnskap med utgangspunkt i det. Data tilhører imidlertid Lerum Frakt som må frigi disse data for andre brukere.

Vestlandsforsking vil anbefale at det holdes jevnlige kurs i økonomisk kjøring for transportselskap. Det bør vurderes om Statens Vegvesen kan stå for organiseringen av slike kurs som et tilbud til alle sjåfører. Vestlandsforsking ser det som viktig at kursene holdes regelmessig og at sjåfører gjerne deltar flere ganger for at oppmerksomheten omkring økonomisk kjøring ikke svekkes.

Does driving behaviour matter?

Lerum Fabrikker is a company in Sogndal, Western Norway, that makes jam and lemonade. The company uses a freight company, Lerum Frakt, to transport goods from Sogndal to markets around major Norwegian cities like Oslo, Bergen, Stavanger and Trondheim. Lerum Frakt operates 17-18 heavy duty vehicles, most of them are semitrailers. Some of them have 700 break horsepower engines but most have around 500 break horsepower. In June 2012 the fleet management system Dynafleet, developed by Volvo, was installed in 14 of their vehicles.

Western Norway Research Institute, in collaboration with Lerum Frakt, has carried out a project financed by the Norwegian research programme Transnova. The project's goal was to answer the following questions: Is it possible to transport the same amount of goods equally long distances with lower fuel consumption? What is the potential for reducing fuel consumption in heavy duty vehicles and what are the determining factors for achieving this? Does driving behaviour matter? This analysis describes the major conclusions from the project.

Constructing the data set for the analysis

The result presented here are obtained by using data from Dynafleet coupled with data from Lerum's order management system. The data cover the time period from January 2012 to July 2012. Dynafleet has different reports per vehicle, among them are the tracking report and the the daily overview report. The last one reports the distance travelled, the fuel consumed and the use of driving behavioural indicators like cruise control, rolling without engine load, idle running, use of automated gear shifts, all measured as percentages of total driving time per day. In addition, use of engine load more than 90% of maximum torque, average speed and percentage of driving time spent in highest gear are also registered in this report. The tracking reports track each vehicle every ten minute and show fuel consumption, distance travelled and geographical location in this time span.

The vehicles from Lerum Frakt usually travel over mountain passes to get to the big cities in Norway. There are two alternative mountain passes in the Oslo direction, the highest point on both these mountain passes are around 1000 meter above sea level. The vehicles start climbing at sea level when they depart from the the ferry that crosses the Sognefjord. If vehicles are travelling to Trondheim in summer months they have to cross a mountain pass where the highest point is 1400 meter above sea level. They start climbing at the end of the Sognefjord. In winter months vehicles travelling to Trondheim must make a detour around Western Norway and cross two mountain passes, the highest of them reaches 950 meter above sea level. Again, vehicles start climbing from sea level. All these mountain passes are characterized by steep hill climbing on winding roads. Vehicles with a full load of almost 30 tonnes must travel with slow speed in low gears and use close to maximum torque to overcome gravity. That is why indicators speed, time spent in highest gear and torque use reflect road standard and terrain more than driving behaviour in this context.

The route to Bergen do not include any mountain passes, but even here the vehicles have to overcome height differences in the order of 2-300 meters. This is also the case for routes to Stavanger which are extensions of the route to Bergen.

The tracking report in Dynafleet registers the distance travelled and fuel consumed between different triggers. Start driving is one trigger. Every time a vehicle starts up, its location, the distance it has travelled and the fuel it has used since last time it started driving is registered. These reports therefore give information about where the vehicles have travelled, a piece of information that is not available in the overview reports. In order to find out on which route the driving behaviours are applied we therefore have to merge the two reports from Dynafleet.

The third data source is the order management system used by Lerum Frakt. This system keeps track of which customers the vehicles deliver goods to on a specific trip and the total load the vehicle is travelling with. A trip can last part of a day, a whole day or several days. On the other hand, information about fuel consumption, distance travelled, indicators for road standard and driving behaviour are registered per day and not per trip. We can therefore only match pieces of information from the three different reports for trips that last a whole day. If a trip lasts only part of a day or more than one day it cannot be matched with indicators from the overview reports.

Information about route destination and weight load carried is essential since different weights on different routes will have different fuel consumptions and different potentials for application of driving behaviours. Consequently, without controlling for destination and weight load we cannot obtain unbiased estimates of the effect of driving behaviour on fuel consumption.

In order to match information from different reports we have followed this procedure: We start with a specific trip for a vehicle in the order management system. The next step is to identify this trip in the tracking report for that vehicle and obtain the distance travelled on it. We then locate the day the trip is made in the overview report. If the distance travelled is about the same in the two reports, we consider information from the overview report to be valid for that trip. Deviances of more than 10% are not accepted. We now have a trip with a known weight load to a specific destination with information about indicators for road standard and driving behaviour.

Some trips to the Oslo region and to Trondheim do not start in Western Norway since drivers may take rest stops during these trips. If a rest stop is made in Eastern Norway and the trip continues to Oslo the next day, this trip on the second day will have a known weight load but will only take place inside Eastern Norway in a terrain that does not include any mountain passes. The same is true for trips to Trondheim from Eastern Norway. There is one mountain pass, Dovrefjell, on that trip but it is far less demanding on fuel consumption than mountain passes in Western Norway.

Model specification and hypothesis

The data set described above contains 283 observations that can be used to analyse effects of road standard and driving behaviour on fuel consumption. We design a multivariate regression model for this purpose. Only trips longer than 100 km are included in the analysis. The dependent variable in the model is fuel consumption in litre per 10 km. The independent variables are:

- The weight load in tonnes.
- Percentage of driving time per day spent with more than 90% of maximum torque.
- Percentage of driving time per day spent using cruise control.
- Percentage of driving time per day spent rolling without engine load.
- Percentage of driving time per day spent running idle.
- Percentage of driving time per day spent driving in highest gear.

- Percentage of driving time per day spent using automated gear shifts.
- Average speed in km per hour per day.
- Location of first delivery. This is represented by 8 dummy variables, one for Bergen, one for Stavanger region, one for Trondheim, one for Ålesund/Molde region, one for Hedmark region (Eastern Norway North) and one for Southern Norway (Lillesand). The reference case is the Oslo region, this effect is measured by the model's constant term. In addition, there is one dummy for trips inside Eastern Norway, one for trips from Eastern Norway to Trondheim and one for trips from Eastern Norway to Southern Norway.
- The vehicles' break horse power.
- A dummy variable indicating whether the vehicle is a semitrailer (0) or a truck with an independent trailer (1).
- A dummy indicating whether the trip was made in the winter season which is the months from December to, but not including, April. Driving conditions are believed to be more difficult in the winter allowing for higher fuel consumption in these months.

The data set contains trips made with approximately full load. Empty vehicles without any weight load are not included in the analysis. A fully loaded vehicle will carry 30 tonnes, the average load for the vehicles included in the analysis is 25,7 tonnes. The maximum is 30 tonnes while the minimum is 3 tonnes.

The data are analyzed by using a OLS multivariate regression model. We assume that all effects in the model are linear except for average speed. This effect is assumed to be asymptotical which means that the effect of increasing speed is largest when the average speed is low. When it is near the average, an identical increase, say 10 km more per hour, will not have the same effect. The effect of increasing speed is therefore approaching a threshold value, and the closer average speed is to this threshold value, the smaller is the effect of an additional increase. We capture this effect by assuming an inverse functional form for the effect of average speed. Since increased speed is assumed to lower fuel consumption, we expect the sign of that effect to be positive.

In general, increasing speed will not lower fuel consumption but rather increase it since more speed can only be achieved by using more engine power. In this setting, however, low speed means that vehicles are travelling on curved roads climbing steep hills with heavy loads. Therefore, higher speed in this context indicates that the vehicles are travelling on better roads in terrains more beneficial for lower fuel consumption.

The multivariate regression model gives us the direct effects of all independent variables. In addition, there are indirect effects of each of them. If we increase weight load, that will also affect the value of other independent variables such as rolling without engine load, average speed, use of maximum torque, time spent in highest gear, use of cruise control and use of automated gear shifts. We do not know the value of all these indirect effects. But we do know the total effect of weight load which is equal to the sum of all direct and indirect effects. This is the bivariate effect of weight load on fuel consumption which is 0,47 litre more per 10 km if weight load is increased by 10 tonnes. The difference between this value and the direct effect is the sum of all indirect effects.

The hypothesis for each independent variable in the model is stated under the assumption of all other things being equal. This means that when we analyse the effect of one specific independent variable we assume that the values for all the others are held constant. We may visualize the effect of one specific independent variable, say average speed, as follows: Imagine two vehicles that are completely identical in all relevant aspects except for one, they have different speeds. With relevant aspects we mean properties described by the other independent variables. We assume that the two hypothetical vehicles also have different fuel consumption. Since they have equal values on all other independent variables except for speed, we can safely assume that the difference in fuel consumption can be related to the difference in speed.

For driving behavioural indicators such as use of cruise control, use of rolling without engine load and use of automated gear shifts we expect the effects on fuel consumption to have a negative sign, more use of these indicators will lower the fuel consumption. We expect that more time spent running idle will increase fuel consumption, hence its effect will have a positive sign. If time spent driving in highest gear increases we expect fuel consumption to be reduced, its effect should therefore have a negative sign. We have chosen a linear functional form for this effect rather than the inverse one we chose for average speed even if they both are indicators of infrastructure and terrain. This is based on an inspection of the bivariate relationship between time spent in highest gear and fuel consumption.

The effect of a higher weight load is obvious, more weight means higher fuel consumption so the sign of its effect should be positive. We expect that fuel consumption goes up in winter months, hence an expected positive sign for the effect of that dummy variable. For horsepower we also expect a positive sign since more power implies more fuel consumption. Also, vehicles with an independent trailer are expected to have higher fuel consumption than semitrailers, we therefore expect this dummy to have a positive effect.

We expect that trips to Trondheim will use more fuel than trips to Oslo since more mountain passes must be traversed. We expect the same for trips to Bergen and Stavanger. For trips that are only made inside Eastern Norway we expect the fuel consumption to be lower compared to trips which go in the same destination but start in Western Norway since the former do not include mountain passes. We expect the same for trips to Trondheim starting in Eastern Norway for the same reason.

There are also some trips starting in Eastern Norway and going to Southern Norway. We expect these trips to have roughly the same average fuel consumption as trips going inside Eastern Norway, hence a negative sign for that dummy variable.

Results

Table 1 shows the estimated regression model. Statistically significant results with a two-sided test are marked with an asterisk. We have used a 0,05 significance level to determine whether one particular effect is significant or not. We also report the actual significance probability level (p-value). When an effect is significant, we reject the null hypothesis for that independent variable with a 5% maximum probability of being wrong. As can be seen, most of our hypothesis are justified.

For some independent variables though, we cannot reject the null hypothesis which means they do not have the expected effect. We find no effect of cruise control and no effect of increasing the time spent driving with automated gear shifts. Trips to Bergen do not have a different fuel consumption than trips to the Oslo region, neither have trips to northern part of Eastern Norway, to the Stavanger region, to the southern parts of Norway or to Ålesund/Molde. On the other hand, trips to Trondheim from Western Norway do indeed have a higher fuel consumption than trips to Oslo. The average for these trips is 0,17 litre higher per 10 km than the average for Oslo trips. Also, trips inside Eastern Norway have an average fuel consumption which is 0,16 litre less per 10 km than trips in the same direction starting in Western Norway. If we look at trips to Trondheim starting from Eastern Norway these trips have an average that is 0,27 litre less per 10 km than similar trips starting from Western Norway.

Table 1 Estimated multivariate regression model (OLS-estimates) [2].

	Regression coefficient	Standard error	t-value	p-value
Constant term	1,38792	0,52237	2,65698	0,00830 *
Weight load	0,01112	0,00270	4,12333	0,00005 *
Average speed	64,47491	18,62942	3,46092	0,00062 *
Use of more than 90% of max torque	0,07357	0,00374	19,65242	0,00000 *
Use of cruise control	-0,00179	0,00194	-0,91955	0,35854
Use of rolling without engine load	-0,01182	0,00220	-5,37360	0,00000 *
Use of running idle	0,01153	0,00241	4,79006	0,00000 *
Use of highest gear	-0,01527	0,00267	-5,72811	0,00000 *
Use of automated gear shift	-0,00012	0,00089	-0,13741	0,89080
Trips to Bergen	0,02523	0,05638	0,44755	0,65479
Trips to East Norway (North)	0,02463	0,04129	0,59649	0,55129
Trips to Southern Norway	-0,00693	0,03521	-0,19675	0,84415
Trips to Stavanger region	0,04358	0,04738	0,91982	0,35840
Trips to Ålesund/Molde	-0,08088	0,07609	-1,06295	0,28865
Trips to Trondheim	0,17362	0,03688	4,70822	0,00000 *
Trips inside East Norway	-0,15477	0,06664	-2,32235	0,02088 *
Trips from East Norway to Trondheim	-0,27270	0,11351	-2,40251	0,01688 *
Trips from East Norway to South Norway	-0,03322	0,09477	-0,35056	0,72616
Horsepower	0,00287	0,00028	10,22133	0,00000 *
Winter season	0,13778	0,02434	5,65965	0,00000 *
Truck with independent trailer	0,30104	0,03425	8,78963	0,00000 *

Weight load has a significant effect on fuel consumption. If this load is increased by 10 tonnes, the expected fuel consumption increases with 0,11 litre per 10 km.

Average speed has the expected significant effect. If it is increased from 30 to 40 km an hour the average fuel consumption falls with 0,5 litre per 10 km. Vehicles often travel in 30 km on the steepest parts of mountain passes. If average speed is increased from 50 to 60 km an hour the same effect is much less, 0,2 litre. Overall average speed is 63 km an hour, minimum average speed for one whole day is 42 km while the maximum is 73 km. Also, if relative time spent using more than 90% of maximum torque is increased by 10 percentage points, average fuel consumption increases by 0,7 litre per 10 km. On average, vehicles spend 20% of driving time with this torque use.

[2] Significant effects (p-value<0,05, two sided test) are marked with an asterisk.

If a vehicle has 200 more horsepower than another vehicle and they are equal in all other aspects, the one with more horsepower will have 0,57 litre higher fuel consumption. In the winter season the vehicles use about 0,14 litre more than in summer and the average fuel consumption for a vehicle with an independent trailer is 0,3 litre higher than the average for a semitrailer.

The effect of indicators for driving behaviour is of special interest in this paper. If relative time spent rolling without engine load is increased by 10 percentage point, fuel consumption is reduced by 0,12 litre per 10 km on average. A similar increase in relative time spent running idle means fuel consumption goes up by 0,12 litre. The effects of these two indicators are roughly equal in opposite directions.

Some of our independent variables are indicators of road standard and terrain, others are indicators of driving behaviour. In the first group we have average speed, time spent driving with more than 90% of maximum torque and time spent travelling in highest gear. In the second group we have time spent running idle and time spent rolling without engine load. When vehicles are going up steep hills on winding roads the range of possible speed values is very restricted, the same is true for use of maximum torque and highest gear. We believe values for indicators in the second group are more a result of driver's behavior. What then is most important for reducing fuel consumption, road standard or driver's behaviour?

To answer this question we have calculated mean elasticities for each independent variable. This value shows the expected percentage change in fuel consumption when the value of the independent variable in question changes by one percent. The idea is that by using elasticities we make the effects of the independent variables comparable. We cannot compare the regression coefficients directly since they have different units. How much more use of rolling without engine load is comparable to an increase in average speed of 10 km per hour? It's impossible to say. On the other hand, when the effects are expressed in percentage terms we can compare them directly.

Table 2 shows the mean values and elasticities for the independent variables in the multivariate regression model. The mean value for fuel consumption is 5,05 litre per 10 km. The equation for calculating elasticities is shown in Equation 1 where e_i, b_i and $\overline{X}_i$ denote elasticity, regression coefficient and mean for the i^{th} independent variable and $\overline{Y}$ is the mean fuel consumption.

Equation 1 Mean elasticities

$$e_i = b_i * \left(\frac{\overline{X}_i}{\overline{Y}}\right)$$

Table 2 shows that measured by their elasticities, four independent variables have much larger effects than the others. These are in decreasing order of absolute magnitude horsepower, use of engine load of more then 90% of maximum torque, average speed and time spent driving in highest gear. The effect of horsepower is about one and a half times grater than the effect of average speed and double the effect of time spent driving in highest gear while the effect of engine load is close to horsepower. The next independent variable in order of magnitude is weight load, but its effect is less than a fifth of the effect of horsepower. The variables indicating driving behaviour have elasticities that are about a tenth of that of engine load. We can therefore conclude that road standard and terrain are the most important factors for determining fuel consumption. Driving behaviour does still matter, but road standard and vehicle properties such as horsepower, engine load and weight load matter much more.

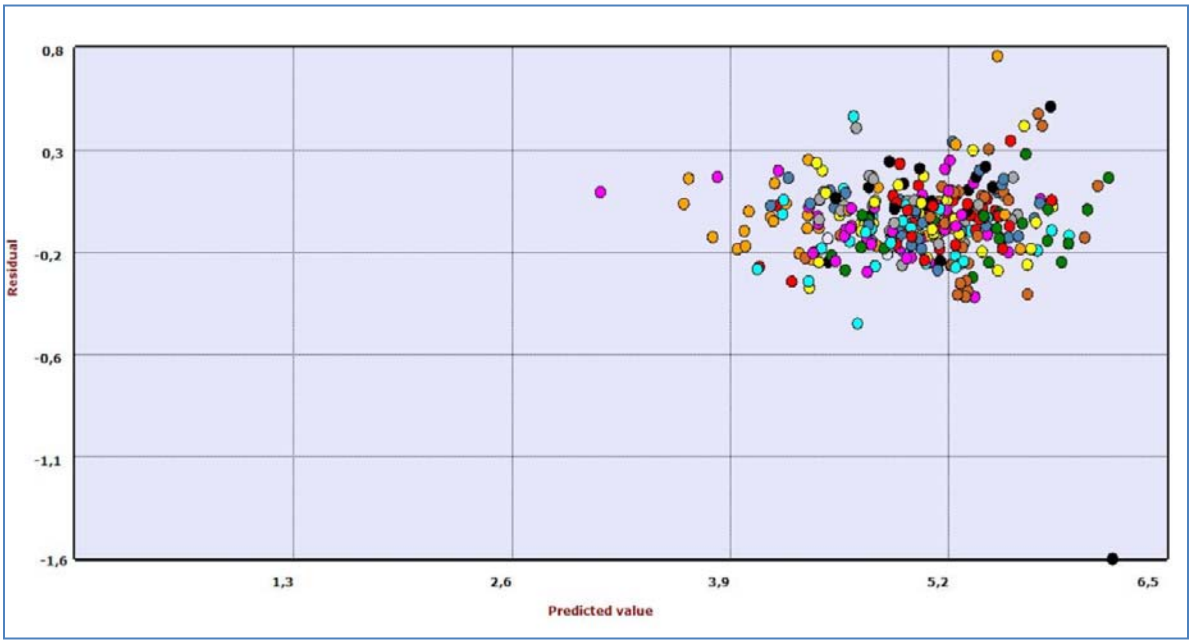
Table 2 Mean values and elasticities

	Mean value	Regression coefficient	Elasticity
Weight load	25,74	0,0111	0,0579
Average speed [3]	0,02	64,4749	0,2072
Use of more than 90% of max torque	20,17	0,0736	0,3000
Use of cruise control	4,02	-0,0018	-0,0015
Use of rolling without engine load	10,31	-0,0118	-0,0246
Use of running idle	9,49	0,0115	0,0221
Use of highest gear	50,77	-0,0153	-0,1567
Use of automated gear shift	54,73	-0,0001	-0,0014
Trips to Bergen	0,05	0,0252	0,0003
Trips to East Norway (North)	0,11	0,0246	0,0006
Trips to Southern Norway	0,14	-0,0069	-0,0002
Trips to Stavanger region	0,09	0,0436	0,0008
Trips to Ålesund/Molde	0,03	-0,0809	-0,0005
Trips to Trondheim	0,13	0,1736	0,0046
Trips inside East Norway	0,04	-0,1548	-0,0012
Trips from East Norway to Trondheim	0,01	-0,2727	-0,0006
Trips from East Norway to South Norway	0,02	-0,0332	-0,0001
Horsepower	538	0,0029	0,3119
Winter season	0,37	0,1378	0,0104
Truck with independent trailer	0,20	0,3010	0,0125

Figur 1 shows a residual plot from the estimated model. Values on the X-axis are predicted values from the regression model and values on the Y-axis are the corresponding residuals. There is no obvious trend in the figure which would suggest that some important variables are left out of the model or that the functional form for some effects are erroneously specified. There is one large residual for a 700 horsepower semitrailer that travelled to the Oslo area in June 2012. The vehicle had much lower fuel consumption than what is suggested by the model. The vehicle spent half the time in highest gear compared to the mean value for all vehicles (51%). Its use of running idle was about 10 percentage points higher than the mean for all vehicles (9,5%) while its average speed was almost 13 km lower than the mean for all vehicles (63 km per hour). All this suggests a higher predicted consumption from the model than what actually was the case. No other observation has a residual of that magnitude, still we have chosen to include it in the analysis.

Figur 1 Residual analysis

[3] The inverse of 62,9 which is the average speed.



Interaction terms

In the model estimated above the effect of an increase in weight load is supposed to be the same for all regions the vehicles travel to. An alternative interpretation could be that weight load has conditional effects in addition to its direct effect. These conditional effects will differ from destination to destination so that an increase in weight load would be different for, say, a trip to Oslo than for a trip to Bergen. We would then have an interaction between the dummy for the different regions and the weight load variable. The dummy variables for different destinations now become interaction terms.

Table 3 shows the results of a re-estimating of the regression model with interaction terms. There are no major differences in the effects of independent variables other than the interaction terms. The effect of indicators for driving behaviour and infrastructure do not change much. This suggests that we have robust models with an appropriate control for weight load in both and that we have unbiased estimates for the effects of behavioural indicators.

In order to assess the effect of interaction terms on fuel consumption we have to fix a weight increase. Let us assume an increase of 10 tonnes in weight load from 20 to 30 tonnes. The direct effect of weight load independent of all interaction terms is the effect for trips to the Oslo region. An increase in weight load of 10 tonnes will yield an increase in fuel consumption of about 0,1 litre pr 10 km for these trips.

We find that the same regional dummy variables have significant effects in both models. If we assume mean values for all other independent variables we can construct Table 4 which shows the effect of a 10 tonne increase in weight load from 20 to 30 tonnes for different regions. As the table shows, the effect of an increase in weight load is highest for trips to Trondheim. Fuel consumption for these trips would be up by 0,17 litre pr 10 km. We find the lowest effect for trips from Eastern Norway to Trondheim, the increase in fuel consumption is only 0,01 litre. For trips inside Eastern Norway the effect is an increase of 0,04 litre per 10 km.

Table 3 Estimated multivariate regression model (OLS-estimates) with interaction terms. Significant effects (p-value<0,05, two sided test) are marked with an asterisk.

	Regression coefficient	Standard error	t-value	p-value
Constant term	1,52320	0,52288	2,91309	0,00384*
Weight load	0,01016	0,00240	4,23312	0,00003*
Average speed	60,99781	18,67286	3,26666	0,00121*
Use of more than 90% of max torque	0,07300	0,00372	19,60076	0,00000*
Use of cruise control	-0,00187	0,00193	-0,96970	0,33297
Use of rolling without engine load	-0,01189	0,00221	-5,39148	0,00000*
Use of running idle	0,01133	0,00241	4,70280	0,00000*
Use of highest gear	-0,01578	0,00266	-5,92481	0,00000*
Use of automated gear shift	-0,00007	0,00088	-0,08294	0,93395
Trips to Bergen	0,00158	0,00249	0,63305	0,52718
Trips to East Norway (North)	0,00052	0,00157	0,33380	0,73876
Trips to Southern Norway	-0,00024	0,00131	-0,18163	0,85600
Trips to Stavanger region	0,00179	0,00185	0,96786	0,33388
Trips to Ålesund/Molde	-0,00285	0,00354	-0,80531	0,42127
Trips to Trondheim	0,00673	0,00142	4,73188	0,00000*
Trips inside East Norway	-0,00585	0,00249	-2,35199	0,01931*
Trips from East Norway to Trondheim	-0,00922	0,00384	-2,40003	0,01700*
Trips from East Norway to South Norway	-0,00125	0,00351	-0,35480	0,72299
Horsepower	0,00284	0,00028	10,18281	0,00000*
Winter season	0,13335	0,02432	5,48440	0,00000*
Truck with independent trailer	0,30013	0,03430	8,74972	0,00000*

Table 4 Effect of an increase of 10 tonne in weight load for different regions.

	Weight load 20 tonnes	Weight load 30 tonnes	Difference
Trips to Oslo region (East Norway)	4,98	5,08	0,10
Trips to Bergen	5,01	5,13	0,12
Trips to East Norway (North)	4,99	5,10	0,11
Trips to Southern Norway	4,98	5,08	0,10
Trips to Stavanger region	5,02	5,14	0,12
Trips to Ålesund/Molde	4,92	5,00	0,07
Trips to Trondheim	5,12	5,28	0,17
Trips inside East Norway	4,86	4,91	0,04
Trips from East Norway to Trondheim	4,80	4,81	0,01
Trips from East Norway to South Norway	4,96	5,05	0,09

Changes in fuel consumption during project phase

Has fuel consumption changed during the project phase? Dynafleet was first installed in some vehicles in december 2010. Table 5 shows statistical properties for fuel consumption during the project phase. Trips longer than 100 km both with and without weight loads are included. The table shows that mean consumption in winter months 2012 generally were lower than the corresponding ones in 2011. This is especially true for January, the fuel consumption that month was 0,4 litre lower in 2012 than in 2011. When a vehicle travels as much as 120 000 km a year, small variations in fuel consumption may have a great impact on a yearly basis. Emissions of CO_2 are affected in the same way. Per km the emissions were 1252 gram in January 2012 which was 106 gram lower than a year before. That is the equivalent of one small diesel car pr km[4]. The CV-values show that the variation in January 2012 was higher than in January 2011, suggesting that some vehicles reduced their consumption more than others.

Table 5 Fuel consumption by month during the project phase

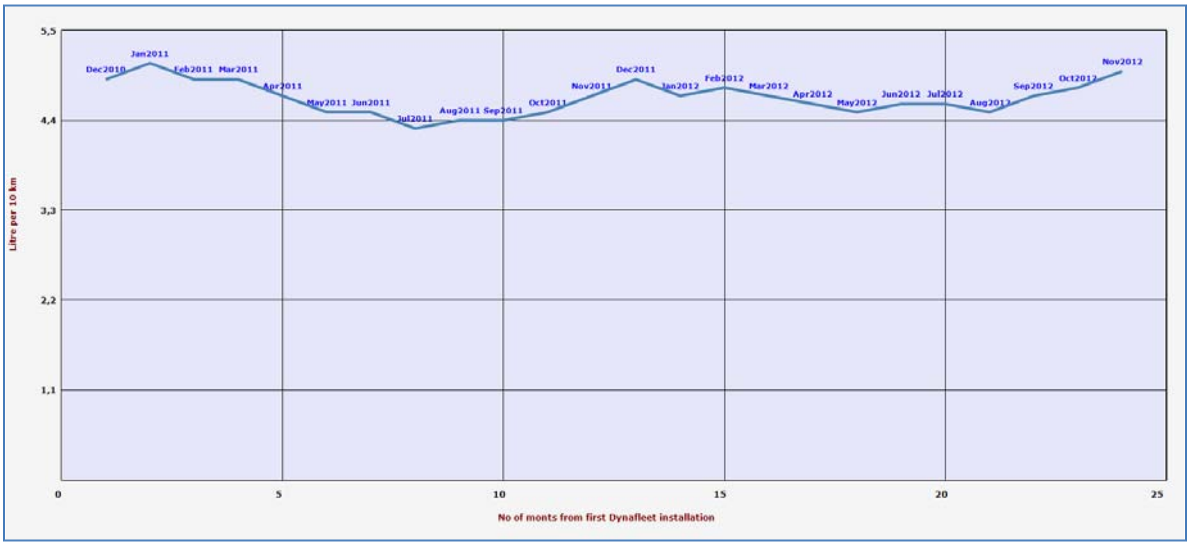
Year	Month	Count	Mean	Standard deviation	CV	Min	Max	Distance travelled in km
2010	December	88	4,9	0,092	1,9	3,3	6,8	40 030
2011	January	184	5,1	0,064	1,3	3,5	8,3	83 340
2011	February	189	4,9	0,055	1,1	3,4	6,9	90 802
2011	March	242	4,9	0,051	1	3,2	6,9	110 843
2011	April	210	4,7	0,054	1,2	2,2	7,4	95 579
2011	May	293	4,5	0,047	1	2,4	6,5	127 964
2011	June	295	4,5	0,049	1,1	2,2	7,8	133 818
2011	July	268	4,3	0,05	1,1	2,4	6,6	117 833
2011	August	292	4,4	0,048	1,1	2,3	7,7	136 829
2011	September	291	4,4	0,048	1,1	2,9	6,5	135 889
2011	October	289	4,5	0,047	1	2,8	6,7	132 330
2011	November	282	4,7	0,047	1	2,2	6,9	127 481
2011	December	252	4,9	0,049	1	3	7,1	112 268
2012	January	277	4,7	0,052	1,1	2,4	7,9	122 666
2012	February	240	4,8	0,058	1,2	2,4	7,8	106 437
2012	March	250	4,7	0,051	1,1	2,8	8,3	116 173
2012	April	220	4,6	0,05	1,1	2,4	6,7	96 229
2012	May	250	4,5	0,048	1,1	2,6	6,8	110 688
2012	June	247	4,6	0,045	1	2,5	6,7	107 392
2012	July	234	4,6	0,048	1,1	2,5	6,7	105 364
2012	August	231	4,5	0,052	1,2	2,3	7,3	103 908
2012	September	239	4,7	0,054	1,2	2,4	7,5	104 098
2012	October	245	4,8	0,049	1	3	6,7	111 521
2012	November	217	5	0,052	1	2,7	6,8	94 881

All in all, the vehicles travelled 2,2 million km during the project phase with a mean consumption of 4,6 litre pr 10 km. The total emissions of CO_2 were 2 741 tonnes.

[4] An emission factor of 2,6628 gram pr liter diesel is applied.

Figur 2 shows the fuel consumption trend from the first month of Dynafleet installation in Lerum Frakt vehicles up to November 2012. The figure shows that the positive trend towards reduced fuel consumption is levelling off and reversing towards the end of 2012. This is also apparent in Table 5. The consumption in August 2012 is 0,1 litre per 10 km higher than the same month a year before. In September, October and November that difference has increased to 0,3 litre higher per 10 km in 2012 compared to same months a year before. We have noted this trend in other analysis of driving behavioural indicators such as use of cruise control, running idle and rolling without engine load. These indicators have a positive development after a driving course that was held in June 2011, but these effects are weakening and partly reversing after the summer of 2012. This is both true for drivers who participated in the driving course and those who did not.

Figur 2 Fuel consumption trend from first Dynafleet installation



What are the general lessons from the model estimations?

Finally, in what ways are these results valid for other vehicles in other regions of Norway or even in other countries? Obviously the results are connected to road standard and terrain in Western Norway. Still, the model estimation shows that driving behaviour does matter when we apply the appropriate control for weight load and trip destinations. There is a potential for lower fuel consumption by modifying driving behaviour and a change in use of running idle and rolling without engine load, where possible, will be most beneficial to achieve this.

The results can also tell us the optimal size of a vehicle in terms of horsepower. A vehicle with 700 horsepower will on average use 0,57 litre more per 10 km than a vehicle with 500 horsepower, all other things being equal. When replacing old vehicles, freight companies should therefore consider whether this extra power is necessary to get the job done or if a vehicle with less horsepower will give a better balance between delivery and fuel consumption.

Conclusions

Average speed has the expected significant effect. If it is increased from 30 to 40 km an hour the average fuel consumption falls with 0,5 litre per 10 km. If average speed is increased from 50 to 60 km an hour the same effect is much less, 0,2 litre. Overall average speed is 63 km an hour.

If relative time spent using more than 90% of maximum torque is increased by 10 percentage points, average fuel consumption increases by 0,7 litre per 10 km. On average, vehicles spend 20% of driving time with this torque use.

If a vehicle has 200 more horsepower than another vehicle and they are equal in all other aspects, the one with more horsepower will have 0,57 litre higher fuel consumption. In the winter season the vehicles use about 0,14 litre more than in summer and the average fuel consumption for a vehicle with an independent trailer is 0,3 litre higher than the average for a semitrailer.

If relative time spent rolling without engine load is increased by 10 percentage point, fuel consumption is reduced by 0,12 litre per 10 km on average. A similar increase in relative time spent running idle means fuel consumption goes up by 0,12 litre. The effects of these two indicators are roughly equal in opposite directions.

An analysis of mean elasticities from the regression model shows that four independent variables have much larger effects than the others. These are in decreasing order of absolute magnitude horsepower, use of engine load of more then 90% of maximum torque, average speed and time spent driving in highest gear. These are variables describing the effect of terrain and road standard. We can therefore conclude that these are the most important factors for determining fuel consumption. Driving behaviour does still matter, but road standard and vehicle properties such as horsepower, engine load and weight load matter much more.

An analysis of fuel consumption shows that the positive trend towards reduced fuel consumption is levelling off and reversing towards the end of 2012. The consumption in January 2012 is 0,4 litre per 10 km lower than the same month a year before. In February and March the corresponding figures are 0,1 and 0,2 litre lower per 10 km than the corresponding months a year before. In September, October and November, on the other hand, that difference has increased to 0,3 litre higher per 10 km in 2012 compared to same months a year before.

Optimal driving behaviour - analysis of the effects of a driving course

The Dynafleet monitoring system is installed in 18 vehicles used by the transport provider Lerum Frakt . The company supplies Lerum Fabrikker, a manufacturer of jam and lemonade, with transport services. Lerum's customers are located mainly in the inner part of Oslofjord-region of Norway, an area around the capital Oslo. Lerum's production site is in Sogndal which is about 360 km from Oslo. The road from Sogndal to Oslo goes over a montain pass which peaks at about 1100 meter above sea level. The road has several sections where it is narrow and winding, and this far north the weather conditions can be challenging. Sogndal is a bit further north than Anchorage, Alaska.

As part of a research project, data for fuel consumption and driving behavioural indicators have been collected from 18 of the vehicles used by Lerum Frakt. Seven of the drivers also participated in a driving course on June 17th and 18th 2011. All in all, 55 drivers have driven one or more of the vehicles supplied with the Dynafleet system. The Dynafleet system was installed in the first vehicles in December 2010.

The purpose of the research project is to stimulate driving behaviour which reduces fuel consumption. A fuel friendly driving behaviour is expected to be characterized by more use of cruise control, more use of automatic gear shifts, less idle running, less use of maximum torque, more rolling without engine load, less application of brakes and less stops, the last two indicators measured per 100 km. The other indicators are measured in percentage of driving time.

In this document we will address these questions: Is the distribution of driving indicators for the drivers who participated in the driving course different before and after the course took place? Are the distribution of driving indicators after the course took place different for drivers who participated compared to drivers that did not? And is fuel consumption after the course took place lower for the drivers who participated compared to those who did not? For the last two questions, there is also the additional question whether the vehicle drivers are using have an impact on the distributions of driving indicators and fuel consumption. In other words, when we control for vehicles' power, are there any statistically significant differences in distribution of driving indicators for drivers who participated and those who did not?

Before we present results, we should warn against drawing too one-sided conclusions. Even for drivers who did not participate, the course can have an effect. The drivers who participate in the research project know that data are collected and there has been two meetings with drivers during the project where preliminary results have been presented. Consequently, there has been an attention on driving behaviour among drivers in general, whether they participated in the course or not. At the same day as the course was held, several drivers attended a information meeting where preliminary results from the project were presented. Most of the drivers therefore know from this meeting that results indicate i.e. that increased use of cruise control and more driving time spent in highest gear will have a positive impact on fuel savings. Therefore the course itself initiated attention about driving behaviour among a wider range of drivers than the ones who participated directly in the course.

Only trips longer than 100 km are included in the analysis.

Statistical tests

The sample consists of 18 drivers, seven of whom participated in the driving course. The drivers that did not participate in the driving course constitutes the control group. We want to test whether the drivers who took the driving course has another development in their use of driving behavioural indicators than drivers who did not participate.

In order to answer the question addressed above, we will perform a t-test for two samples with assumed unequal variances for each driver before and after the course took place for a set of driving behavioural indicators. The first sample is the period before the course and the second sample is the period after the course took place. We will also perform an analysis of variance (ANOVA) for the period after the course in order to investigate whether there are differences between drivers who took the course and the ones in the control group. The ANOVA analysis is performed by using regression analysis with drivers as dummy variables in the regression equation.

In addition to a ANOVA analysis we will also present two non-parametric tests, a Wilcoxon's test for paired sample and a Mann-Whitney test for difference in the median value between two independent samples. Both tests are performed for each driving behavioural indicator. The Wilcoxon's test is a test for changes in a specific behavioural value for all drivers, regardless of whether they followed the driving course or not. There is thus no control group in the Wilcoxon test, it is a test of whether any change has taken place when all drivers are taken as one group. Wilcoxon's test is a test for changes before and after some treatment of the research subjects. The treatment in this case is the driving course and the expected response of this treatment is behavioural change measured by changes in the driving behavioural indicators.

Wilcoxon's test is based on paired samples where each driver's driving behaviour is measured on some indicator before and after the driving course. This means that the same drivers are measured before and after the treatment which is the driving course. Since the measurement is done for the same drivers we indirectly control for other attributes that may influence the use of the indicator in question such as i.e. drivers' age and experience. Most of the time drivers use the same vehicle, therefore we also partly control for the vehicles they drive.

The measured response is the mean indicator value before the course took place minus the indicator value after. So more use of i.e. cruise control would mean a negative median difference if most drivers change their behaviour. The alternative hypothesis in each test for each indicator will state expectations about the median change. Sometimes we expect the difference to be negative, as for example with cruise control where we expect more use of it. For other indicators, i.e. for use of more than 90% of maximum torque, we expect less use of it so the alternative hypothesis would express an expectation of a positive median difference.

The Mann-Whitney test is a test for median difference between two independent groups, one being the drivers who followed the driving course (the treatment group) and the other group being the other drivers (the control group). This test thus tests the difference between the two groups. In the Mann-Whitney tests, we expect the behavioural indicator values for drivers in the treatment group to be more beneficial for fuel consumption than the corresponding values for drivers in the control group. Again, this means that sometimes we expect the values in the treatment group to be larger than values in the control group, as for i.e. use of cruise control. For other behavioural indicators we expect the values in the control group to be larger, as for i.e. use of more than 90% of maximum torque.

Both Wilcoxon and Mann-Whitney tests are non-parametric which means that they do not depend upon any specific probability distribution such as the normal distribution which the ANOVA tests depend on. Therefore these non-parametric test are a useful correction to the ANOVA test.

The assumption of normal probability distribution is on the other hand not so critical for the ANOVA test since it builds on the normal approximation rule which states that a sum of several independent variables itself can have a normal distribution even if the variables that the sum consists of do not. The mean is a sum of several independent variables since each observation used to calculate the mean can be considered a random variable consisting of two parts, the systematic part which is the mean plus random error which is each observation's deviance from that mean.

For each of the non-parametric tests the null hypothesis is that there is no difference, either in median use of some behavioural indicator between drivers before and after the course or no difference in median use of that indicator between different groups of drivers.

For each driving behavioural indicator we will present tables which show the change in use of the indicator for each driver before and after the driving course. The effects in the tables are calculated as mean value before the course minus mean value after. A positive sign therefore means that the driver has a higher mean value for the behavioural indicator before the driving course while a negative value means that the value has increased after the course.

For each driving behavioural indicator we will also present figures which show the change in use of it before and after the driving course. In these figures, change is calculated as mean use of the indicator after the course minus the use of it before. Note that this is the opposite of the direction used in calculations of the tables presenting each indicator. The reason for this is that the figures are easier to read if values are sorted in decreasing order.

In order to answer whether changes in all driving behaviour indicators for one individual driver has occurred by chance or by deliberate actions we need an overall test that builds on the test of each individual indicator for each driver. We will use the binomial probability distribution to perform such an overall test for each driver. Number of significant mean changes from the individual t-tests for each indicator for each driver is the test observator. The number of trials (n) will be all tests while number of successes (a) will be number of tests with significant changes. We assume that the chance of success in each trial p= 0.5, the probability for a statistical significant difference is just as large as the probability of non-significant one.

This binomial test is done for each driver. It is a single measurement of overall behavioural change for each driver. The null hypothesis in the binomial test is that number of statistically significant differences is no larger than what can be expected from pure chance. The test observator is number of significant mean differences and the binomial probability is the cumulative probability of obtaining at least as many significant differences as observed given that the null hypothesis is true.

Let p_0 be the probability that significant and non-significant differences are equally likely to occur, that is, the probability of success in each trial. Further, let p be the estimated probability of obtaining the number of significant differences that we are testing for given p_0, the probability of success at each trial or test. Then we have:

Table 6 Binomial probability tests

H_0 (null hypothesis)	p=p0
H1 (alternative hypothesis	p>p0
Number of differences	n
Number of observed statistically non-significant differences	a
Empirical probability (significance probability)	$p = 1 \sum_{i=0}^{a-1} binp(i, n, p_0)$
Significance level	α=0,05 (one sided)
Conclusion	if(p<α), reject H_0

where $binp(i, n, p_0)$ is the probability from the binomial probability distribution with i as number of successes (number of significant changes), n as number of trials and p_0 as the probability of success at each trial. In our tests p_0 is always 0,5.

We will also perform a second test based on the binomial probability distribution. The test observator is the number of significant changes from the t-tests for drivers who participated in the driving course relative to all significant changes for all drivers including the control group. Number of trials are all significant changes among all drivers while number of successes are the significant changes for the drivers who participated in the course. The chance of success in each trial is again assumed to be p=0.5.

When we perform tests based on the binomial probability distribution, we assume that if the estimated binomial probability p is less than 0,05, the results is not likely to have happen just by chance. That is, we can reject the null hypothesis that significant t-tests are just as likely to occur as non-significant ones for each driver. Or for the second test, we can reject the null hypothesis that change is just as likely to occur among drivers who did not participate as among those who did.

This decision criteria should be applied with some reasonable discretion. The point is that if probabilities from the binomial probability distribution are low, there is a less chance that results have occurred by pure chance and a greater chance that changes in driving behavioural indicators have been brought about by deliberate actions as an effect of the course. The criteria value of 0,05 is a heuristic limit, not an absolute one.

Analysis

Table 7 shows drivers included in the analysis. The table also shows first registration date for each driver, last registration date, number of registrations before the driving course took place and number of registrations after. The drivers that participated in the driving course are marked with an asterisk in the rightmost column. They belong to the treatment group. The other drivers belong to the control group.

Table 7 Drivers included in the analysis

	First registration date	Last registration date	Number of registrations before 18/6/2011	Number of registrations after 18/6/2011	Participation in driving course
AK	02-mai-11	08-sep-11	33	57	*
AT	01-mai-11	09-sep-11	12	30	
AY	08-mai-11	18-sep-11	29	50	*
B	23-mar-11	08-nov-12	30	59	
BA	01-mai-11	29-jul-11	39	35	*
D	14-feb-11	18-sep-11	78	56	
E	30-jan-11	07-june-12	114	90	*
F	18-apr-11	30-nov-12	7	55	
G	26-jan-11	05-oct-11	59	49	
H	20-feb-11	16-sep-11	11	18	
I	30-jan-11	27-sep-11	17	14	
J	26-jan-11	23-sep-11	89	47	
K	12-mai-11	16-nov-12	2	9	*
L	31-mai-11	21-nov-12	14	33	*
M	26-jan-11	05-oct-11	98	75	*

N	30-jan-11	02-des-12	99	63	
S	25-mai-11	18-sep-11	19	55	
X	01-mai-11	20-jul-11	31	19	

Cruise control

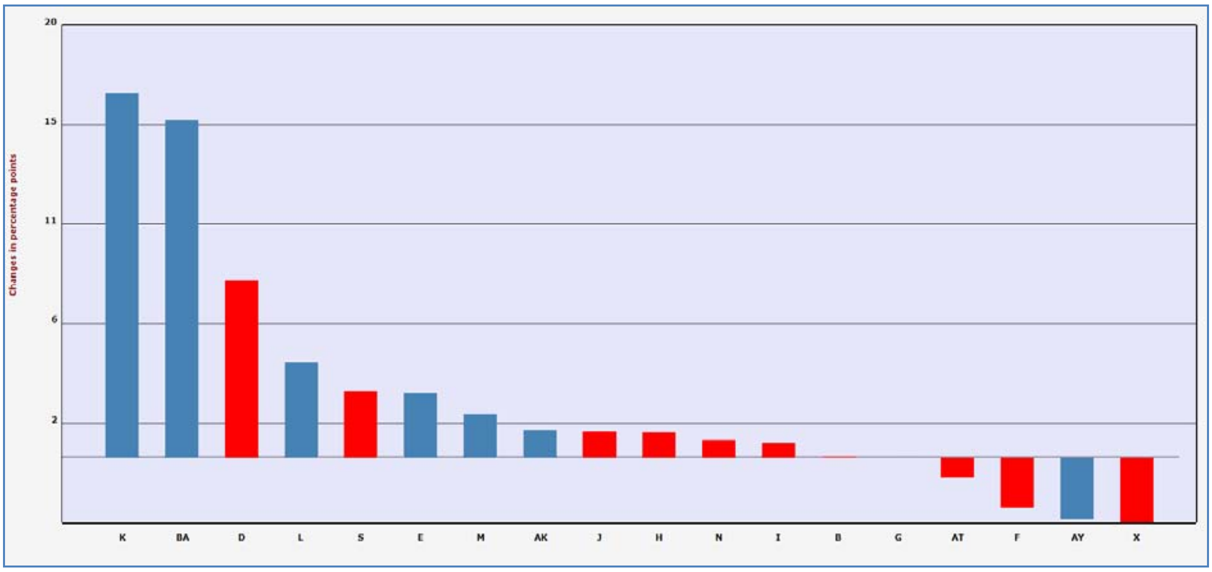
Table 8 Distribution of use of cruise control as percentage of total driving time before and after the driving course

Driver	Mean before	Mean after	t-value	degrees of freedom	p-value (two-sided)	p-value (one-sided)	Partici-pation	Signi-ficant change (one-sided)
AK	2,88	4,12	-0,863	71	0,3912	0,1956	*	
AT	5,63	4,68	0,371	14	0,7160	0,3580		
AY	9,02	6,18	0,697	54	0,4890	0,2445	*	
B	1,34	1,38	-0,056	61	0,9556	0,4778		
BA	10,76	26,37	-4,644	68	0,0000	0,0000	*	*
D	5,61	13,81	-5,135	123	0,0000	0,0000		*
E	2,05	5,00	-4,816	239	0,0000	0,0000	*	*
F	9,60	7,30	0,594	6	0,5744	0,2872		
G	0,10	0,09	0,124	105	0,9012	0,4506		
H	0,03	1,18	-1,786	17	0,0919	0,0459		*
I	0,00	0,66	-1,656	13	0,1216	0,0608		
J	2,21	3,40	-1,510	74	0,1352	0,0676		
K	6,95	23,79	-2,177	2	0,1614	0,0807	*	
L	0,26	4,67	-7,542	246	0,0000	0,0000	*	*
M	0,58	2,56	-3,299	90	0,0014	0,0007	*	*
N	4,90	5,71	-1,293	202	0,1975	0,0987		
S	1,98	5,05	-2,720	69	0,0082	0,0041		*
X	4,85	1,83	3,581	48	0,0008	0,0004		*

Table 8 shows the distribution of use of cruise control for drivers before and after the driving course. All in all we have data for 18 drivers.

Figur 3 shows changes in use of cruise control for the drivers before and after the driving course took place. In the figure a change is defined as the level of use of cruise control after the driving course took place minus the level before, therefore a positive change means more use of cruise control.

Figur 3 Changes in use of cruise control before and after driving course per driver



Drivers who participated in the course are marked with blue while drivers who did not participate are marked with red. These colour codes are used for all figures shown in this document. Five drivers use less cruise control after the course, only one of them participated in it. Three of the five drivers with largest increase in use of cruise control did participate in the driving course. Table 8 also shows that out of eight significant differences (one-sided) in use of cruise control, four came from drivers who participated in the course[5]. There are two conclusions to be drawn from these observations. First, the probability of getting at least 8 significant differences from a total of 18 differences by pure chance alone is about 76%. This suggests that we cannot reject the proposition that positive and negative changes in use of cruise control are just as likely, there is no systematic change in use of cruise control. Second, the probability of getting at least 4 significant differences out of a total of 8 by chance alone is about 64% which also suggests that the change in use of cruise control for drivers who participated in the driving course is not more than what pure chance alone allows for.

We perform two non-parametric test in order to test whether use of cruise control has changed. The first is a Wilcoxon test for all drivers regardless of participation in driving course. The test will tell us whether overall use of cruise control has changed before and after the driving course.

The null hypothesis in the Wilcoxon test is that there is no difference in use of cruise control before and after the driving course. The alternative hypothesis is that the driving course has led to increased understanding of the beneficial use of cruise control which leads to more use of it .

Table 9 shows the calculations for the Wilcoxon's signed rank test. For use of cruise control, we show all the calculations. For later tests, we only show the test statistics which are shown in Table 10.

Table 9 Calculations of Wilcoxon's signed rank test for use of cruise control

Driver	Mean Before	Mean After	Differ-ence	Absolute differ-ence	Rank ascen-ding	Rank descen-ding	Corrections	Negative rank	Positive rank
AK	2,88	4,12	-1,25	1,25	8	11	8	8	0
AT	5,63	4,68	0,95	0,95	5	14	5	0	5

[5] The largest change is not significant since there are very few observations for that driver.

AY	9,02	6,18	2,84	2,84	11	8	11	0	11
B	1,34	1,38	-0,04	0,04	2	17	2	2	0
BA	10,76	26,37	-15,61	15,61	17	2	17	17	0
D	5,61	13,81	-8,2	8,2	16	3	16	16	0
E	2,05	5	-2,95	2,95	12	7	12	12	0
F	9,6	7,3	2,3	2,3	10	9	10	0	10
G	0,1	0,09	0,01	0,01	1	18	1	0	1
H	0,03	1,18	-1,16	1,16	6	13	6	6	0
I	0	0,66	-0,66	0,66	3	16	3	3	0
J	2,21	3,4	-1,19	1,19	7	12	7	7	0
K	6,95	23,79	-16,84	16,84	18	1	18	18	0
L	0,26	4,67	-4,4	4,4	15	4	15	15	0
M	0,58	2,56	-1,99	1,99	9	10	9	9	0
N	4,9	5,71	-0,81	0,81	4	15	4	4	0
S	1,98	5,05	-3,07	3,07	14	5	14	14	0
X	4,85	1,83	3,02	3,02	13	6	13	0	13

Table 10 Wilcoxon rank sum test statistics for use of cruise control

	Negative rank sum	Positive rank sum
Sum	131	40
Significance level	0,05	One-sided
Number of observations	18	
Critical z	1,64485363	
Critical c	47	
H1:u >0	131	
H1:u<0	40	
H1:u <> 0	40	

We consider increased use of cruise control as beneficial for lower fuel consumption. Since change is measured as use of cruise control before driving course minus use after, a negative change means more use of cruise control. The relevant alternative hypothesis is therefore the second one in Table 10 which states that the expected median difference is less than zero. With this alternative hypothesis, the conclusion from the signed rank test is that we can reject the null hypothesis since the test observator for that alternative hypothesis is less than the critical value. All values less than the critical value are in the rejection region for the null hypothesis. Thus, there is a significant change in use of cruise control as a result of the driving course. The test observator for that outcome is the sum of all positive ranks which is lower than the critical c-value with a one-sided alternative hypothesis. When the test observator is less than the critical value we can reject the null hypothesis.

Table 11 shows the data for the Mann-Whitney test for difference in median change between two independent groups. The group in the rows are drivers who participated in the driving course. The group in the columns consists of the drivers who did not take part in the course. Their respective median change in use of cruise control (use before course minus use after) is shown beside the driver's identification in the rows and below it in the columns. Each time a median change in the row is greater than a median change in the columns, the corresponding cell in the table will have the number 1, if not there will be a zero number. Number of times drivers from group 1 (in the rows) have a greater median change than drivers from group 2 (in the column) is equal to the sum in the table. We call this figure the MW1-number. Number of possible comparisons is number of drivers in group 1 multiplied with number of drivers in group 2. Consequently, the number of times drivers in group 2 has a greater median change than drivers in group 1 will be number of comparisons minus the MW1-number. This figure is referred to as the MW2-number.

Table 11 Calculation of Mann-Whitney test for use of cruise control

		AT	B	D	F	G	H	I	J	N	S	X
		0,95	-0	-8,2	2,3	0,01	-1,2	-0,7	-1,2	-0,8	-3,1	3,02
AK	-1,2	0	0	1	0	0	0	0	0	0	1	0
AY	2,84	1	1	1	1	1	1	1	1	1	1	0
BA	-16	0	0	0	0	0	0	0	0	0	0	0
E	-3	0	0	1	0	0	0	0	0	0	1	0
K	-17	0	0	0	0	0	0	0	0	0	0	0
L	-4,4	0	0	1	0	0	0	0	0	0	0	0
M	-2	0	0	1	0	0	0	0	0	0	1	0

Table 12 Test statistics for the Mann-Whitney test for use of cruise control

Number of drivers group 1	7	
Number of drivers group 2	11	
Number of comparisons	77	
MW1-figure	17	
MW2-figure	60	
Significance level	0,05	1 (one sided)
Critical z	1,959963985	
Critical c	17	
H1:u1<u2	17	
H1:u1>u2	60	
H1:u1 different from u2	17	
Median change	-2,9538	Drivers who participated
Median change	-0,6571	Other drivers

Table 12 shows the test statistics for the Mann-Whitney test for use of cruise control between the two groups of drivers. Our alternative hypothesis is that drivers in the treatment group (group 1) has a lower median change than drivers in the control group (group 2) since change is measured as use of cruise control before the course minus the use after it and a negative change means more use of cruise control. The relevant test observator is therefore the MW1-figure since the most appropriate alternative hypothesis is the first one stated in Table 12. The result from the test is that we cannot reject the null hypothesis since the test statistic is equal to the critical c-value. We must observe a test observator less than the critical c-value since this is the lowest value for the test observator that is outside the rejection region for the null hypothesis. Consequently, there is no significant difference in change in use of cruise control between the two group of drivers as a result of the driving course.

Let us sum up the conclusions on use of cruise control from the different tests. We find that drivers have significantly altered their use of cruise control as a consequence of the driving course measured by the Wilcoxon's test. At the same time, we do not find any significant difference between the drivers who participated in the course and those who did not by use of the Mann-Whitney test.

The binomial tests shows no systematic change. It is important to note that these tests used the significance probabilities (p-values) from the t-tests as a starting point. Consequently, the binomial tests are dependent on results which assume a normal distribution of the test statistics, mean use of cruise control. Difference in conclusions from the different tests may come from difference in assumptions of underlying probability distributions.

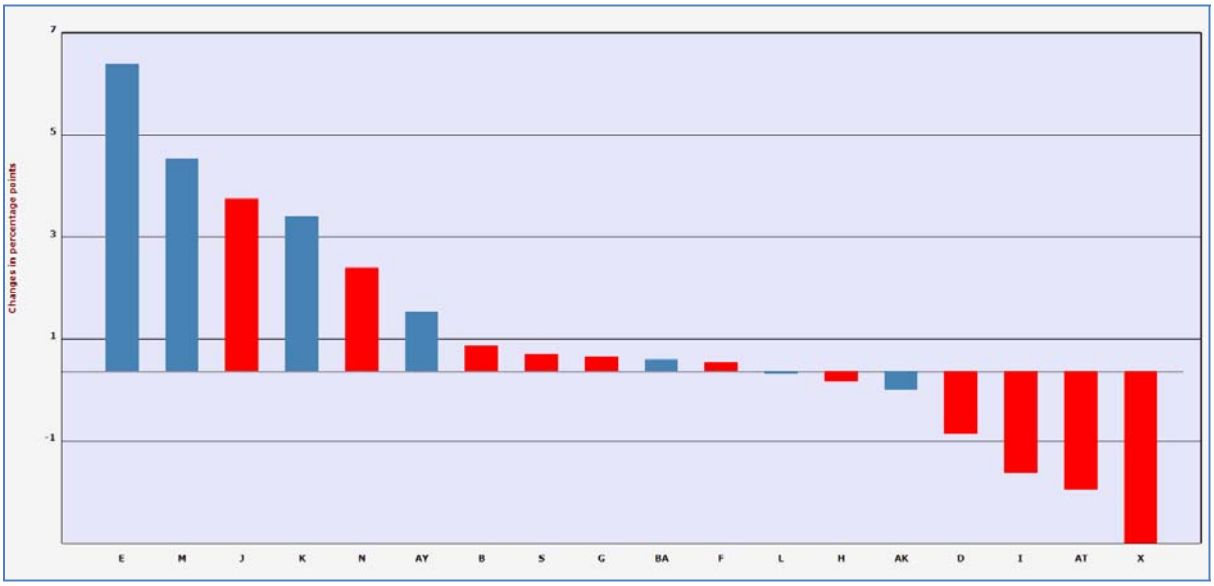
Automatic gear shift

Table 13 Distribution of use of automatic gear shift as percentage of total driving time before and after the driving course

Driver	Mean before	Mean after	t-value	degrees of freedom	p-value (two-sided)	p-value (one-sided)	Partici-pation	Signi-ficant change (one-sided)
AK	98,83	98,45	0,950	88	0,3450	0,1725	*	
AT	96,28	93,86	1,889	31	0,0683	0,0341		*
AY	98,62	99,85	-1,851	29	0,0744	0,0372	*	*
B	99,32	99,85	-3,663	60	0,0005	0,0003		*
BA	99,65	99,91	-2,138	47	0,0377	0,0189	*	*
D	98,71	97,43	2,959	94	0,0039	0,0020		*
E	90,40	96,72	-7,216	136	0,0000	0,0000	*	*
F	98,63	98,82	-0,274	7	0,7923	0,3962		
G	95,12	95,43	-0,253	91	0,8009	0,4004		
H	99,05	98,85	0,253	13	0,8044	0,4022		
I	86,05	83,98	0,666	29	0,5106	0,2553		
J	84,31	87,86	-3,504	95	0,0007	0,0004		*
K	92,15	95,34	-0,671	1	0,6238	0,3119	*	
L	99,88	99,83	0,407	56	0,6855	0,3428	*	
M	88,53	92,91	-3,529	170	0,0005	0,0003	*	*
N	90,78	92,92	-2,618	132	0,0099	0,0049		*
S	96,73	97,09	-0,482	38	0,6324	0,3162		
X	98,95	95,43	3,787	20	0,0012	0,0006		*

Table 13 shows the distribution of use of automatic gear shift for drivers before and after the driving course. Of all the 18 differences, 10 are significant with a one-sided test and of these differences 4 come from drivers who participated in the driving course. But of the 10 drivers with significant one-sided change, only 7 had an *increase* in use of automatic gear shifts, the 4 who participated in the driving course are all among these drivers. Figur 4 shows that of 18 drivers, 11 have an increase in automatic gear shift before and after the driving course. The figure also shows that of the 7 drivers who participated in the course, 5 have an increase in use of automatic gear shift. Of the 5 drivers with highest change in use of automatic gear shifts, 3 participated in the driving course. The differences in the figure is calculated as use of automatic gear shifts after the course minus the same use in the period before so that a positive change means more use of automatic gear shifts.

Figur 4 Changes in use of automatic gear shift before and after driving course per driver



Using our binomial probability measures, there is a 88% chance that 7 or more differences out of 18 can be significant by chance alone. Also, there is a 50% probability that 4 out of 7 significant differences can occur randomly. These probabilities alone suggest that use of automatic gear shift has not changed systematically since the driving course and that the drivers who participated in the course has no larger share of the significant differences that what can be expected from random variations alone.

Table 14 Wilcoxon rank sum test statistics for use of automatic gear shift

	Negative rank sum	Positive rank sum
Sum	111	60
Significance level	0,05	1,00
Number of observations	18	
Critical z	1,64485363	
Critical c	47	
H1:u >0	111	
H1:u<0	60	
H1:u <> 0	60	

Table 14 shows the test statistics from the Wilcoxon's signed rank test for use of automatic gear shifts. We can not detect any significant change with a one-sided alternative hypothesis. The test statistic for the alternative hypothesis H1:u<0 is 60, we apply this hypothesis since negative values imply more use of automatic gear shifts. The critical value for a one sided test is 47 so we cannot reject the null hypothesis.

Table 15 Test statistics for the Mann-Whitney test for use of automatic gear shift

Number of drivers group 1	7	
Number of drivers group 2	11	
Number of comparisons	77	
MW1-figure	21	
MW2-figure	56	
Significance level	0,05	One-sided
Critical z	1,959963985	
Critical c	17	
H1:u1<u2	21	
H1:u1>u2	56	
H1:u1 different from u2	21	
Median change	-1,2288	Drivers who participated
Median change	-0,1952	Other drivers

Table 15 shows the test statistics for the Mann-Whitney test for differences in median change in use of automatic gear shift. The table shows that we cannot reject the null hypothesis of no difference between the treatment and control group. The relevant test observator is the MW1-figure since according to alternative hypothesis one in Table 15 we expect the difference in use of automatic gear shifts in the treatment group to be less than the corresponding difference in the control group since a larger negative difference means that drivers use more automatic gear shifts after the course.

The MW1-figure is 21 while the critical c-value for a one sided test is 18. Since the test observator is larger than the critical c-value we cannot reject the null hypothesis.

The conclusion for use of automatic gear shift is that we cannot find any evidence to suggest that its use has been increased as an effect of the driving course.

Use of more than 90% of maximum torque

Table 16 shows changes in use of more than 90% of maximum torque before and after the driving course. For one of the drivers we lack information for this driving behaviour indicator. Figur 5 shows the change in use of this amount of torque. The figure shows that the three drivers who increased their use of this indicator the most all participated in the driving course. On the other hand the driver who reduced use of more than 90% of maximum torque the most also did participate in the driving course.

Of 18 drivers half of them have decreased their use of more than 90% of maximum torque while the others have increased it. All in all 6 drivers have a significant change in their use of more than 90% of maximum torque, but of these 6 only one has decreased this use, the other have increased it. There is practically 100% chance of getting at least one significant change in 18 trials. Two of the drivers with significant change did participate in the driving course, none of these drivers have decreased use of more than 90% of maximum torque.

Both the table and the figure suggests that other factors than drivers' intention are determining use of high engine load since half the drivers have an increase and half a decrease in the value of this indicator. These factors are most likely driving conditions and road quality with many narrow, winding roads.

Table 16 Distribution of use of 90% of maximum torque as percentage of total driving time before and after the driving course

Driver	Mean before	Mean after	t-value	degrees of freedom	p-value (two-sided)	p-value (one-sided)	Partici-pation	Signi-ficant change (one-sided)
AK	7,46	7,43	0,033	73	0,9735	0,4867	*	
AT	10,57	9,71	0,596	20	0,5576	0,2788		
AY	11,38	14,33	-2,684	60	0,0094	0,0047	*	*
B	4,10	4,93	-2,259	58	0,0277	0,0138		*
BA	17,79	16,90	0,520	67	0,6050	0,3025	*	
D	15,88	10,41	4,962	113	0,0000	0,0000		*
E	14,36	16,85	-3,095	223	0,0022	0,0011	*	*
F	15,59	13,33	0,692	6	0,5145	0,2573		
G	12,66	14,88	-1,591	103	0,1146	0,0573		
H	9,35	9,04	0,131	20	0,8968	0,4484		
I	13,80	14,46	-0,296	28	0,7698	0,3849		
J	13,00	13,12	-0,102	82	0,9187	0,4593		
K	16,95	9,59	0,811	1	0,5661	0,2830	*	
L	0,00	8,88	-19,957	236	0,0000	0,0000	*	*
M	13,41	13,16	0,237	164	0,8127	0,4064	*	
N	12,82	13,99	-2,046	172	0,0423	0,0212		*
S	19,95	19,85	0,068	46	0,9457	0,4728		
X	9,01	9,88	-0,745	29	0,4620	0,2310		

Table 17 shows the test statistics for Wilcoxon's test for use of more than 90% of maximum torque. The alternative hypothesis is that the median difference between use before and after the course is positive, meaning that there was more use of this indicator before the course than after. From the table we an see that the test observator for this alternative hypothesis, the first one, is far above the critical c-value for rejecting the null hypothesis. This then cannot be rejected.

Figur 5 Changes in use of more than 90% of maximum torque before and after driving course per driver

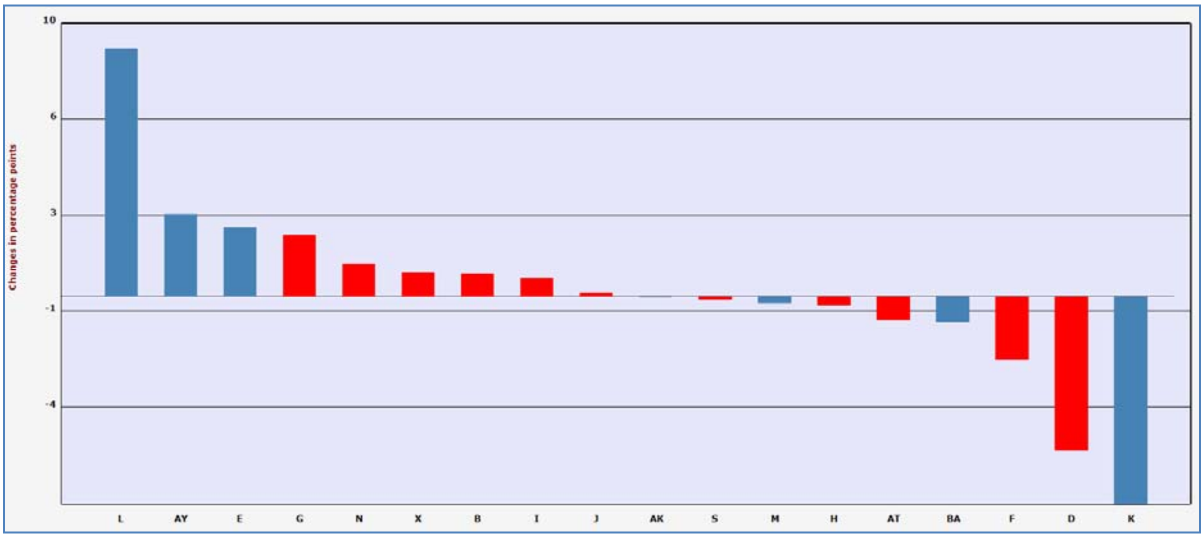


Table 17 Wilcoxon rank sum test statistics for use of more than 90% of maximum torque

	Negative rank sum	Positive rank sum
Sum	95	60
Significance level	0,05	1,00
Number of observations	18	
Critical z	1,64485363	One-sided test
Critical c	47	
H1:u >0	95	
H1:u<0	76	
H1:u <> 0	76	

Table 18 shows the test statistics for the Mann-Whitney test for differences in use of more than 90% of maximum torque between the treatment group and the control group. A positive difference means less use of more then 90% of maximum torque. We therefore expect the drivers in the treatment group in general to have difference values larger than drivers in the control group since we expect them to reduce use of more than 90% of maximum torque more than members of the control group. The appropriate alternative hypothesis is therefore the second one stated in Table 18. The relevant test observator is the MW2-figure. This test observator has a larger value than the critical c-value which is the lowest value for the test observator that does not belong to the rejection region for the null hypothesis. We therefore cannot reject the null hypothesis and conclude that there is no difference in use of more than 90% maximum torque between the two groups.

Table 18 Test statistics for the Mann-Whitney test for use of more than 90% of maximum torque

Number of drivers group 1	7	
Number of drivers group 2	11	
Number of comparisons	77	
MW1-figure	33	
MW2-figure	44	

Significance level	0,05	One-sided
Critical z	1,959963985	
Critical c	17	
H1:u1<u2	33	
H1:u1>u2	44	
H1:u1 different from u2	33	
Median change	0,0273	Drivers who participated
Median change	-0,1213	Other drivers

The conclusion for use of more than 90% of maximum torque is that we can find no effect of the driving course for the application of this indicator, the use of it has rather increased than decreased after the driving course took place.

Number of brake applications

Table 19 Distribution of number of brake applications per 100 km before and after the driving course

Driver	Mean before	Mean after	t-value	degrees of freedom	p-value (two-sided)	p-value (one-sided)	Partici-pation	Signi-ficant change (one-sided)
AK	80,39	87,35	-1,243	86	0,2171	0,1086	*	
AT	45,17	71,77	-2,190	17	0,0427	0,0214		*
AY	53,45	69,06	-2,334	71	0,0224	0,0112	*	*
B	240,43	221,88	1,575	43	0,1225	0,0613		
BA	27,36	22,66	1,285	71	0,2029	0,1014	*	
D	45,18	35,70	3,537	131	0,0006	0,0003		*
E	61,67	65,88	-1,490	221	0,1377	0,0689	*	
F	71,43	89,23	-2,804	8	0,0230	0,0115		*
G	52,27	55,59	-0,750	102	0,4548	0,2274		
H	59,82	69,28	-1,129	27	0,2690	0,1345		
I	35,65	50,07	-2,191	26	0,0376	0,0188		*
J	89,75	81,02	1,863	109	0,0652	0,0326		*
K	50,00	43,61	0,545	1	0,6822	0,3411	*	
L	116,14	107,45	0,818	15	0,4261	0,2130	*	
M	80,78	77,89	0,638	148	0,5246	0,2623	*	
N	71,90	66,58	2,081	159	0,0390	0,0195		*
S	71,21	60,58	1,529	29	0,1370	0,0685		
X	73,90	84,00	-1,925	24	0,0661	0,0331		*

Table 9 and Figur 6 shows the distribution of changes in number of brake applications per 100 km. The figure is constructed as number of brake applications after the course minus the number of applications before the course. A negative change therefore means less us of brake applications which we consider beneficial for lower fuel consumption.

Out of 18 drivers, 8 have significantly changed their use of brake applications per 100 km. But out of these 8 drivers only three have actually reduced their use of this indicator and none of these are from the treatment group. The chance of having at least 3 significant beneficial changes for fuel consumption out of 18 trials is 99%. There is no reason to test the proportion of significant changes in the treatment group relative to all significant changes since there are no significant changes in this group that goes in the right direction.

Figur 6 Changes in number of brake applications per 100 km before and after driving course per driver

Table 20 Wilcoxon rank sum test statistics for number of brake applications per 100 km

	Negative rank sum	Positive rank sum
Sum	97	60
Significance level	0,05	1,00
Number of observations	18	
Critical z	1,64485363	One-sided test
Critical c	47	
H1:u >0	97	
H1:u<0	74	
H1:u <> 0	74	

Table 20 shows the test statistics for the Wilcoxon's signed rank test for differences in use of brake applications per 100 km before and after the driving course. The appropriate alternative hypothesis in the table is the first one which states that the expected use of this behavioural indicator was larger before the driving course. The test observator for this hypothesis (97) is way above the critical c-value for a one-sided test which means we cannot reject the null hypothesis which indicates no change at all.

Table 21 shows the test statistics for the Mann-Whitney test of different median change in the treatment group and the control group for this driving behavioural indicator. The relevant alternative hypothesis is the second alternative hypothesis in the table which states that the median difference is larger in the treatment group. If use of brakes has gone down there will be a positive difference so a larger difference means less use of the indicator after the driving course. And if the application of brakes per 100 km has gone down more in the treatment group than in the control group, the positive difference will be larger in the treatment group.

The test observator for that alternative hypothesis (MW2-figure) is 39 which is outside the rejection region for the null hypothesis which consists of all values less than 15 for that test observator. We consequently cannot reject the null hypothesis, there is no significant difference in change in use of brakes per 100 km between the treatment group and the control group.

Table 21 Test statistics for the Mann-Whitney test for use number of brake applications per 100 km

Number of drivers group 1	7	
Number of drivers group 2	11	
Number of comparisons	77	
MW1-figure	38	
MW2-figure	39	
Significance level	0,05	One-sided
Critical z	1,959963985	
Critical c	17	
H1:u1<u2	38	
H1:u1>u2	39	
H1:u1 different from u2	38	
Median change	2,8822	Drivers who participated
Median change	-3,3207	Other drivers

The conclusion for use of brakes per 100 km is that there is not evidence enough to reject the null hypothesis of no change in its use.

Number of stops

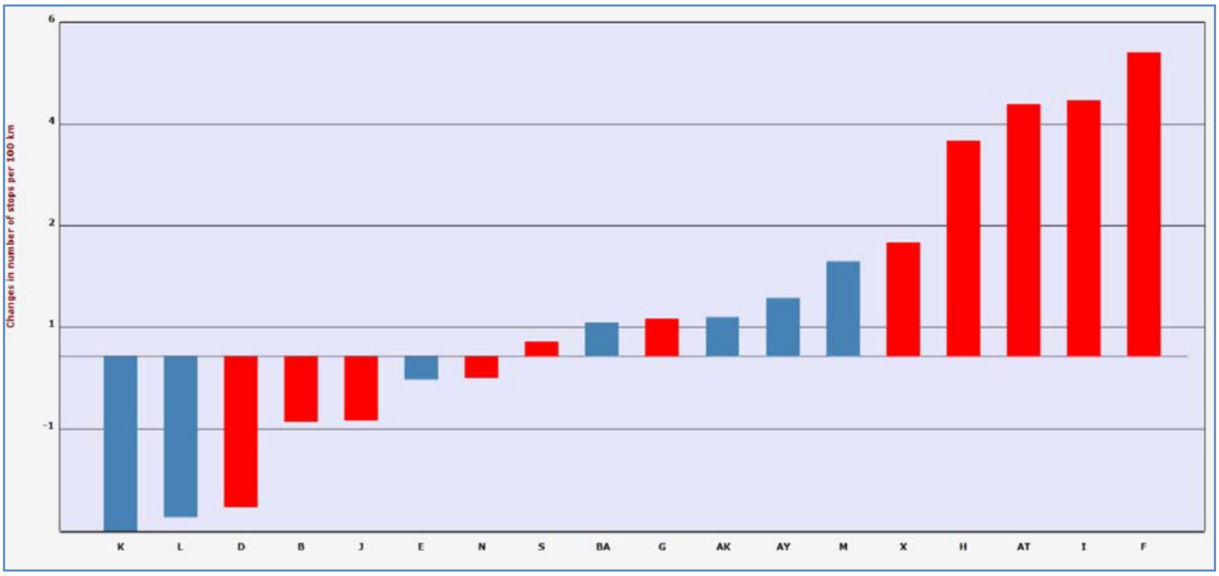
Table 22 shows the change in number of stops per 100 km before and after the driving course. We consider a reduction in number of stops to be beneficial for lower fuel consumption. There is no obvious trend in the table which is confirmed in Figur 7. More drivers actually have an increase in number of stops than have a decrease. There are 7 significant changes in stops per 100 km, only one of them is a reduction and that driver did not take part in the driving course. The change of at least 1 significant change in 18 trials is practically a 100%.

Table 22 Distribution of number stops per 100 km before and after the driving course

Driver	Mean before	Mean after	t-value	degrees of freedom	p-value (two-sided)	p-value (one-sided)	Partici-pation	Signi-ficant change (one-sided)
AK	8,12	8,84	-0,622	87	0,5353	0,2676	*	

AT	4,67	9,30	-3,009	34	0,0049	0,0025		*
AY	8,03	9,10	-0,672	63	0,5038	0,2519	*	
B	34,07	32,87	0,526	55	0,6012	0,3006		
BA	11,23	11,86	-0,363	70	0,7177	0,3589	*	
D	9,49	6,73	3,832	120	0,0002	0,0001		*
E	9,93	9,51	0,612	202	0,5409	0,2705	*	
F	8,00	13,58	-4,697	11	0,0007	0,0003		*
G	8,39	9,08	-0,607	91	0,5456	0,2728		
H	8,82	12,78	-1,713	27	0,0982	0,0491		*
I	6,59	11,29	-2,137	22	0,0439	0,0220		*
J	12,53	11,36	1,060	111	0,2916	0,1458		
K	10,50	7,30	0,701	1	0,6110	0,3055	*	
L	10,00	7,07	1,682	14	0,1148	0,0574	*	
M	9,37	11,12	-2,090	148	0,0383	0,0191	*	*
N	9,59	9,19	0,692	170	0,4901	0,2450		
S	11,21	11,49	-0,166	36	0,8691	0,4346		
X	8,06	10,16	-2,729	34	0,0100	0,0050		*

Figur 7 Changes in number of stops per 100 km before and after driving course per driver



In Figur 7 the difference is constructed as number of stops per 100 km after the course minus number of stops before. A negative value means that number of stops are reduced. The two drivers with the biggest reduction both took part in the driving course, but their change is not significant.

The conclusion is that number of stops are probably influenced more by other factors than drivers' intention.

Table 23 shows the test statistics for the Wilcoxon's test for changes in use of number of stops per 100 km. The relevant alternative hypothesis is the first one in the table since we expect the effect of the driving course to be more number of stops before the driving course. The test observator for that alternative hypothesis (110) is far above the critical value (47) which defines the lower bound for the region where we cannot reject the null hypothesis. We can therefore not detect any significant change in use of number of stops per 100 km.

Table 23 Wilcoxon rank sum test statistics for number of stops per 100 km

	Negative rank sum	Positive rank sum
Sum	110	61,00
Significance level	0,05	
Number of observations	18	
Critical z	1,64485363	One sided test
Critical c	47	
H1:u >0	110	
H1:u<0	61	
H1:u <> 0	61	

Table 24 shows the result of the Mann-Whitney test for differences in median change in number of stops per 100 km between the treatment group and the control group. Since less use of stops per 100 km means that the change is positive, the appropriate alternative hypothesis is that the median change in the treatment group is larger than the corresponding change in the control group. This means that the second alternative hypothesis in the table is the relevant one and that the MW2-figure is the relevant test observator for that alternative hypothesis.

The test observator for that alternative hypothesis is 26 which is larger than the critical value for that test observator (c=18). We cannot reject the null hypothesis that the change is identical in the treatment group and the control group.

Table 24 Test statistics for the Mann-Whitney test for use number of stops per 100 km

Number of drivers group 1	7	
Number of drivers group 2	11	
Number of comparisons	77	
MW1-figure	51	
MW2-figure	26	
Significance level	0,05	One-sided
Critical z	1,959963985	
Critical c	17	
H1:u1<u2	51	
H1:u1>u2	26	
H1:u1 different from u2	26	
Median change	-0,6264	Drivers who participated
Median change	-0,6918	Other drivers

The conclusion for number of stops is that we cannot find any evidence of systematic change for this driving behavioural indicator, neither for all drivers nor for the treatment group.

Running idle

Table 25 shows the distribution of relative amount of driving time spent running idle before and after the driving course. Figur 8 shows the change in this indicator before and after the driving course. The figure is constructed by taking relative amount of driving time spent running idle after the driving course minus the same relative amount before the course. A negative value therefore indicates less amount of driving time spent running idle.

The figure shows a distinct change. This is probably because many of the observations made before the driving course took place during winter months and early spring when cold weather often leads to more use of running idle in order to keep the vehicle warm. Still, there is a clear change in the direction of less amount of driving time spent running idle. All in all, there are 12 significant changes in the amount of driving time spent running idle before and after the driving course, for 11 of them the change means *less* running idle which is beneficial for lower fuel consumption. With a total of 18 observations there is about 40% probability to get at least 11 significant changes in the positive direction. That means we cannot rule out that this change can occur by pure chance.

It is also worth noting that 6 out of 7 participants in the driving course have reduced the relative amount of driving time spent running idle after the course took place. Of these 6 changes, 5 are significant. From a total of 11 drivers who spend significantly less relative amount of time running idle 5 are drivers who participated in the driving course. There is a 73% chance of obtaining at least that many successes on 11 trials by pure chance. Consequently, there seems to be a change in driving behaviour for all drivers regardless of whether they participated in the course.

Table 25 Distribution of relative time spent running idle before and after the driving course

Driver	Mean before	Mean after	t-value	degrees of freedom	p-value (two-sided)	p-value (one-sided)	Partici-pation	Signi-ficant change (one-sided)
AK	17,53	18,03	-0,274	88	0,7847	0,3923	*	
AT	6,40	6,22	0,135	16	0,8944	0,4472		
AY	11,01	7,52	2,994	43	0,0045	0,0023	*	*
B	34,42	22,50	6,311	48	0,0000	0,0000		*
BA	9,85	5,15	5,681	66	0,0000	0,0000	*	*
D	14,50	6,16	8,355	120	0,0000	0,0000		*
E	14,30	7,36	11,317	158	0,0000	0,0000	*	*
F	9,46	12,24	-2,085	8	0,0706	0,0353		*
G	23,46	16,50	3,026	106	0,0031	0,0016		*
H	10,55	10,20	0,156	16	0,8781	0,4391		
I	16,25	18,51	-0,808	26	0,4265	0,2133		
J	9,66	5,82	5,518	124	0,0000	0,0000		*
K	14,10	6,57	7,169	5	0,0008	0,0004	*	*
L	11,04	9,91	1,490	25	0,1487	0,0743	*	
M	17,92	10,83	6,672	169	0,0000	0,0000	*	*
N	17,93	11,63	7,018	122	0,0000	0,0000		*
S	13,88	7,99	5,156	30	0,0000	0,0000		*

X	10,65	10,54	0,085	48	0,9326	0,4663		

Figur 8 Changes in relative amount of driving time spent running idle before and after driving course per driver

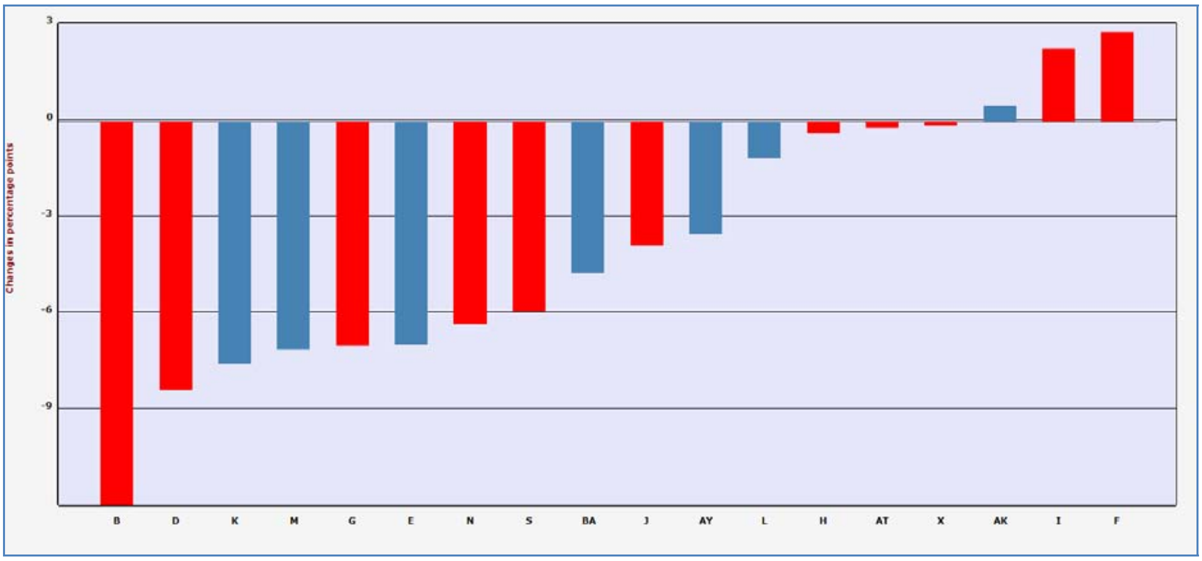


Table 26 shows the Wilcoxon's signed rank test for relative amount of time spent running idle. The relevant alternative hypothesis is the first one in the table, we expect the amount of time spent running idle to be higher before the driving course. The test observator for this alternative hypothesis (17) is less than the critical value for the null hypothesis (40), therefore we *can* reject the null hypothesis. This test therefore suggests that drivers spend less time running idle after the driving course. This is in line with what we already have discussed, what we cannot claim is that drivers who participated in the course have a different development that other drivers. In order to test this explicitly we perform a Mann-Whitney test for different locations of the median difference between amount of time spent running idle before and after the driving course between the two group of drivers. The result of this test is shown in Table 27.

Table 26 Wilcoxon rank sum test statistics for relative amount of time spent running idle

	Negative rank sum	Positive rank sum
Sum	17	154
Significance level	0,05	
Number of observations	18	
Critical z	1,95996398	One sided test
Critical c	40	
H1:u >0	17	
H1:u<0	154	
H1:u <> 0	17	

Table 27 Test statistics for the Mann-Whitney test for relative amount of time spent running idle

Number of drivers group 1	7	

Number of drivers group 2	11	
Number of comparisons	77	
MW1-figure	44	
MW2-figure	33	
Significance level	0,05	One-sided
Critical z	1,959963985	
Critical c	20	
H1:u1<u2	44	
H1:u1>u2	33	
H1:u1 different from u2	33	
Median change	4,7030	Drivers who participated
Median change	3,8414	Other drivers

If drivers spend less relative amount of time spent running idle after the driving course, the difference between that amount of time before and after the driving course will be positive. The less amount of time spent running idle after the course compared to the amount of time before the course, the larger the difference. If drivers who did participate in the driving course use less amount of time spent running idle after the driving course than drivers who did not, their differences should then be larger than differences for drivers in the control group. The second alternative hypothesis in Table 27 should then be the appropriate and the MW2-number is the test observator for this alternative hypothesis. This test observator has a value (33) that is higher than the critical c-value (20). We are therefore outside the rejection region for the null hypothesis and we cannot reject it. Drivers in the treatment group do not have a different development than drivers in the control group, all drivers spend less amount of time spent running idle after the driving course regardless of whether they participated or not.

The conclusion for the behavioural indicator running idle is that we can find evidence of systematic change for all drivers before and after the driving course, but there is no evidence to suggest that the change is different in the treatment group compared to the control group.

Driving in highest gear

Table 28 shows distribution of relative amount of driving time spent driving in highest gear. There is a trend towards more time spent driving in highest gear. This is confirmed by Figur 9. In the figure, change is calculated as the amount of time spent driving in highest gear after the driving course minus that amount of time before the course, so that a positive difference means more time spent in highest gear.

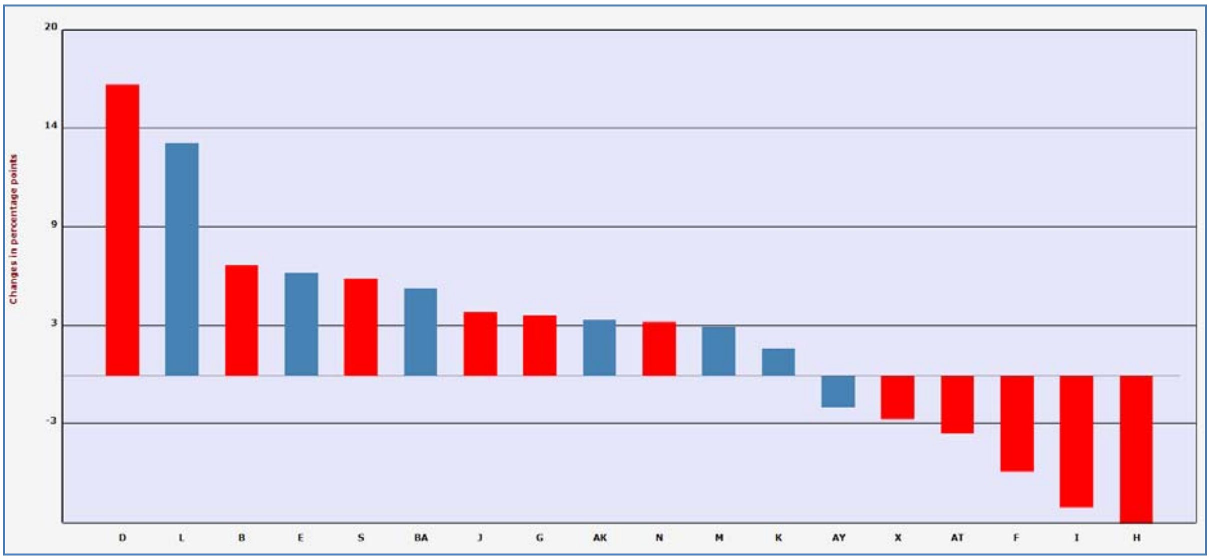
In Table 28, 11 out of 18 drivers have a significant change in the amount of time spent driving in highest gear. But 2 of these 11 drivers spent less time in highest gear. There is a 59% change of getting 9 successes on 18 trials by pure chance, we therefore cannot reject a null hypothesis of no change in time spent using the highest gear.

Table 28 Distribution of relative time spent driving in highest gear before and after the driving course

Driver	Mean before	Mean after	t-value	degrees of freedom	p-value (two-sided)	p-value (one-sided)	Partici-pation	Signi-ficant change

								(one-sided)
AK	37,60	40,82	-1,300	82	0,1972	0,0986	*	
AT	61,04	57,69	0,494	13	0,6294	0,3147		
AY	50,52	48,71	0,455	61	0,6505	0,3252	*	
B	30,85	37,24	-3,988	62	0,0002	0,0001		*
BA	58,13	63,18	-2,471	70	0,0159	0,0080	*	*
D	56,07	72,91	-9,632	129	0,0000	0,0000		*
E	50,28	56,22	-5,573	215	0,0000	0,0000	*	*
F	57,10	51,54	1,474	7	0,1840	0,0920		
G	46,80	50,28	-1,382	92	0,1703	0,0851		
H	61,13	52,66	1,913	21	0,0695	0,0348		
I	52,99	45,37	1,855	26	0,0750	0,0375		
J	50,33	53,99	-1,827	94	0,0708	0,0354		*
K	45,85	47,42	-0,147	1	0,9070	0,4535	*	
L	44,09	57,54	-3,198	15	0,0060	0,0030	*	*
M	48,86	51,71	-1,836	168	0,0682	0,0341	*	*
N	48,11	51,21	-2,317	158	0,0218	0,0109		*
S	47,10	52,73	-1,967	35	0,0572	0,0286		*
X	70,91	68,38	1,269	27	0,2153	0,1076		

Figur 9 Changes in relative amount of driving time spent driving in highest gear before and after driving course per driver



It is also worth noting that 6 out of 7 drivers who participated in the driving course increased their amount of time spent driving in highest gear, 4 of these changes are significant. This means that 4 out of 9 significant changes that lead to more time in higest gear come from drivers in the treatment group. There is a 75% chance of obtaining at least 4 successes in 9 trials, so there is no evidence in the data that suggest that drivers who participated in the driving course spend more time in highest gear after the driving course than other drivers.

Table 29   Wilcoxon rank sum test statistics for relative amount of time spent driving in highest gear

	Negative rank sum	Positive rank sum
Sum	117	54
Significance level	0,05	
Number of observations	18	
Critical z	1,95996398	One sided test
Critical c	40	
H1:u >0	117	
H1:u<0	54	
H1:u <> 0	54	

Table 29 shows test statistics for the Wilcoxon's signed rank tests for differences in use of time spent driving in highest gear before and after the driving course. If drivers spend more time in highest gear after the course, there will be negative difference since the amount of time spent driving in highest gear after the course is larger than the corresponding amount of time before the course. The relevant alternative hypothesis is the second one in Table 29, the test observator for that hypothesis is the positive rank sum which is 54, this sum is higher than the critical c-value. This means that we cannot reject the null hypothesis. We find no significant change in the amount of time spent driving in highest gear among all drivers.

Table 28 shows the test statistics for the Mann-Whitney test for difference in median change between the treatment group and the control group. Again, since a negative change means more time spent in highest gear we expect that if the driving course has an effect, the median change in the treatment group should be less than the same change in the control group. The relevant test observator then is the MW1-figure (29) which is higher than the critical c-value (20). We therefore cannot reject the null hypothesis, there is no difference in the change of time spent driving in the highest gear between the treatment group and the control group.

Table 30 Test statistics for the Mann-Whitney test for relative amount of time spent driving in highest gear

Number of drivers group 1	7	
Number of drivers group 2	11	
Number of comparisons	77	
MW1-figure	29	
MW2-figure	48	
Significance level	0,05	One-sided
Critical z	1,644853627	
Critical c	20	
H1:u1<u2	29	
H1:u1>u2	48	
H1:u1 different from u2	29	
Median change	-3,2206	Drivers who participated
Median change	-3,1051	Other drivers

The conclusion for the driving behavioural indicator driving in highest gear is that we cannot reject the null hypothesis of no change in this indicator, neither for all drivers nor for the treatment group compared to the control group.

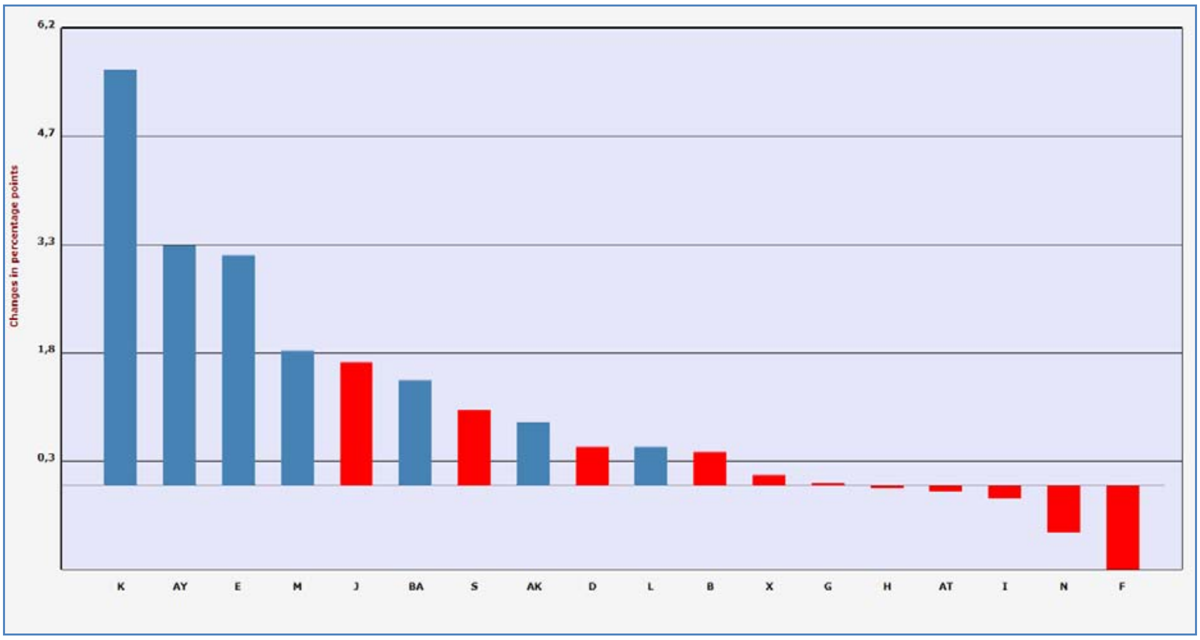
Rolling without engine load

Table 31 shows the distribution of the driving behavioural indicator time spent rolling without engine load. The indicator is measured as a percentage of total driving time. Figur 10 shows the changes in this indicator per driver before and after the driving course took place. The figure is constructed using amount of time spent rolling without engine load after the driving course minus the corresponding amount before the course. A positive difference means more use of rolling without engine load.

Table 31 Distribution of relative time spent rolling without engine load before and after the driving course

Driver	Mean before	Mean after	t-value	degrees of freedom	p-value (two-sided)	p-value (one-sided)	Partici-pation	Signi-ficant change (one-sided)
AK	7,35	8,20	-2,003	87	0,0483	0,0241	*	*
AT	14,74	14,66	0,070	18	0,9447	0,4724		
AY	11,10	14,37	-3,761	69	0,0004	0,0002	*	*
B	5,41	5,86	-1,545	47	0,1291	0,0645		
BA	11,69	13,11	-1,990	70	0,0505	0,0252	*	*
D	12,88	13,41	-1,152	105	0,2518	0,1259		
E	6,43	9,55	-6,917	248	0,0000	0,0000	*	*
F	4,39	3,24	1,390	7	0,2070	0,1035		
G	0,53	0,56	-1,129	104	0,2617	0,1309		
H	6,95	6,91	0,063	18	0,9501	0,4750		
I	1,25	1,07	0,773	29	0,4456	0,2228		
J	5,07	6,74	-6,122	103	0,0000	0,0000		*
K	10,15	15,80	-3,539	5	0,0166	0,0083	*	*
L	6,76	7,29	-1,039	15	0,3153	0,1576	*	
M	7,11	8,94	-7,689	133	0,0000	0,0000	*	*
N	8,54	7,89	2,197	134	0,0297	0,0149		*
S	12,81	13,83	-2,180	54	0,0336	0,0168		*
X	9,62	9,76	-0,237	34	0,8139	0,4070		

Figur 10 Changes in relative amount of driving time spent driving without engine load before and after driving course per driver



The figure shows a clear trend, drivers spend more time rolling without engine load after the course and the drivers who participated in the course have the largest changes. Among these drivers, all of them spend more time rolling without engine load. Of the seven drivers in the treatment group, six had significant changes with more rolling without engine load after the course. Among the five drivers with the largest positive change, four took part in the driving course.

All in all, there are 8 significant changes in the positive direction when all drivers are taken into consideration. The chance of getting 8 successes in 18 trials is 76%, so we cannot reject the null hypothesis of no significant change with this test. Looking only at significant changes in the positive direction, 6 out of 8 changes come from the treatment group. There is a 14,5% chance that this may happen by pure chance, according to the binomial distribution. This is not enough evidence to claim that drivers in the treatment group are doing better than drivers in the control group.

Table 32 Wilcoxon rank sum test statistics for relative amount of time spent rolling without engine load

	Negative rank sum	Positive rank sum
Sum	140	31
Significance level	0,05	
Number of observations	18	
Critical z	1,64485363	One sided test
Critical c	47	
H1:u >0	140	
H1:u<0	31	
H1:u <> 0	31	

If we turn to Wilcoxon's test for changes in the behavioural indicator, the picture is a bit different. Table 32 shows the test statistics from this test. The appropriate alternative hypothesis is the second one in the table since a negative value means more use of rolling without engine load. This is obviously beneficial for lower fuel consumption. The test observator for this alternative hypothesis is lower than the critical, so we are in the rejection region for the null hypothesis with a one sided test. According to this test there is a significant change in the direction of more rolling without any engine load after the driving course.

We can claim that there is a change in the positive direction among all drivers, but is the change significantly different among drivers in the treatment group compared to the control group? In order to test this we perform a Mann-Whitney test for difference in median change between the two groups. Table 33 shows the result of this test. A negative change means more use of rolling without engine load after the driving course since the difference is calculated as use before minus use after. So if drivers in the treatment group use more rolling without engine load than drivers in the control group, their changes should be more negative than the ones in the control group. The relevant alternative hypothesis is therefore the first one. The test observator for this hypothesis is 6 while the critical value for a one-sided test is 20. This means we can safely reject the null hypothesis of no differences in change between the two groups. There is a significantly larger change among drivers in the treatment group according to this test.

Table 33 Test statistics for the Mann-Whitney test for relative amount of time spent rolling without any engine load

Number of drivers group 1	7	
Number of drivers group 2	11	
Number of comparisons	77	
MW1-figure	6	
MW2-figure	71	
Significance level	0,05	One-sided
Critical z	1,644853627	
Critical c	20	
H1:u1<u2	6	
H1:u1>u2	71	
H1:u1 different from u2	6	
Median change	-1,8264	Drivers who participated
Median change	-0,0280	Other drivers

The conclusion for the driving behavioural indicator rolling without engine load is that we find evidence of more use of this indicator for all drivers after the driving course. We also find that drivers in the treatment group use this indicator more after the course than drivers from the control group. So there is positive change among all drivers and the positive change is largest among drivers in the treatment group.

Fuel consumption

Finally, we will look at fuel consumption for the drivers before and after the driving course took place. Table 34 shows the distribution of fuel consumption. There are 6 significant changes in fuel consumption, one of them is actually an increase which leaves us with 5 significant reductions in fuel consumption. The chance of getting at least 5 significant changes on 18 trials by random is 98%, so we cannot reject a null hypothesis of no change in fuel consumption.

The picture shown in Figur 11 display a clear trend, fuel consumption is lower after the driving course and drivers who participated in the course are among the drivers with the largest savings in fuel consumption. Of the 5 drivers with the largest savings, 3 participated in the driving course. Of the 5 significant reductions in fuel consumption, 3 come from the treatment group. The chance of obtaining at least this result by random is 50%, so again we cannot reject the null hypothesis of no change.

Table 34 Distribution of mean fuel consumption before and after the driving course

Driver	Mean before	Mean after	t-value	degrees of freedom	p-value (two-sided)	p-value (one-sided)	Partici-pation	Signi-ficant change (one-sided)
AK	4,97	4,85	0,914	87	0,3635	0,1817	*	
AT	4,46	4,24	0,855	14	0,4068	0,2034		
AY	4,75	5,09	-1,936	58	0,0577	0,0289	*	*
B	3,75	3,65	1,659	67	0,1018	0,0509		
BA	4,88	4,50	2,228	70	0,0291	0,0146	*	*
D	4,39	3,66	6,732	124	0,0000	0,0000		*
E	4,85	4,57	3,350	192	0,0010	0,0005	*	*
F	4,45	4,60	-0,352	6	0,7371	0,3686		
G	4,75	4,61	0,790	96	0,4315	0,2157		
H	4,34	4,32	0,086	21	0,9326	0,4663		
I	4,90	5,00	-0,396	29	0,6951	0,3475		
J	4,55	4,30	1,830	85	0,0707	0,0354		*
K	4,72	4,72	0,004	1	0,9973	0,4986	*	
L	4,24	4,08	0,679	14	0,5082	0,2541	*	
M	4,77	4,33	3,491	162	0,0006	0,0003	*	*
N	4,62	4,52	1,293	171	0,1977	0,0989		
S	4,69	4,54	0,889	41	0,3790	0,1895		
X	3,60	3,66	-0,443	28	0,6609	0,3304		

Figur 11 Changes in fuel consumption before and after driving course per driver

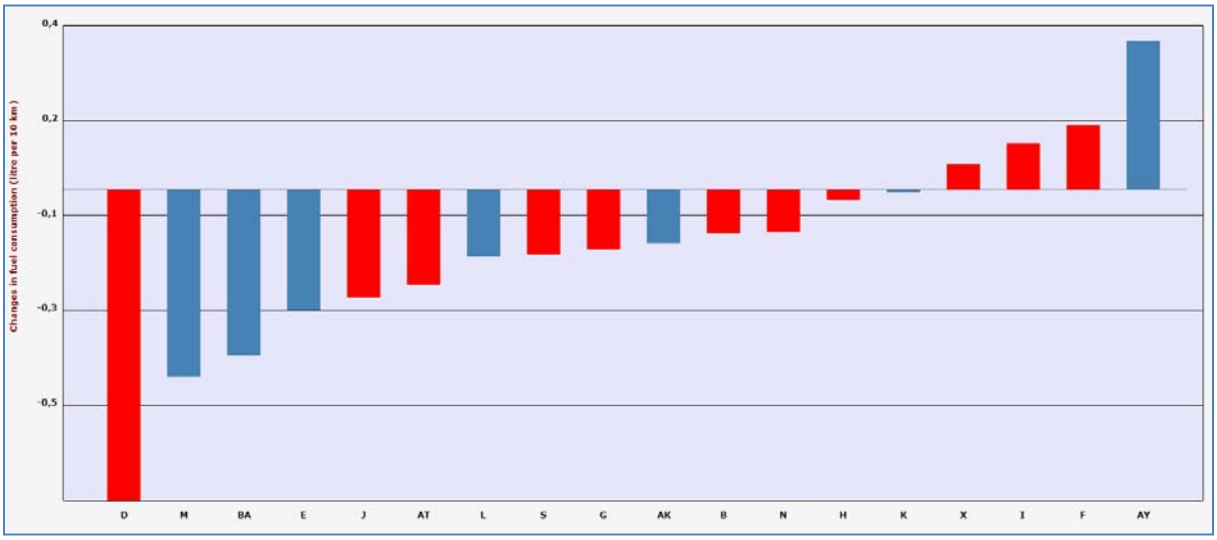


Table 35 shows the test statistics for Wilcoxon's test for changes in fuel consumption before and after the driving course for all drivers. Since a reduction in fuel consumption means that there was a larger consumption before the course than after, the relevant alternative hypothesis is the first one in the table. The test observator for this hypothesis (34) is less than the critical value (47) , so we are in the rejection region for the null hypothesis. We therefore reject the null hypothesis and conclude that there is a significant reduction in fuel consumption after the driving course.

Table 35 Wilcoxon rank sum test statistics for fuel consumption

	Negative rank sum	Positive rank sum
Sum	34	137
Significance level	0,05	
Number of observations	18	
Critical z	1,64485363	One sided test
Critical c	47	
H1:u >0	34	
H1:u<0	137	
H1:u <> 0	34	

Do drivers from the treatment group perform better than drivers in the control group?

Table 36 Test statistics for the Mann-Whitney test for fuel consumption

Number of drivers group 1	7	
Number of drivers group 2	11	
Number of comparisons	77	
MW1-figure	47	
MW2-figure	30	
Significance level	0,05	One-sided
Critical z	1,644853627	
Critical c	20	

H1:u1<u2	47	
H1:u1>u2	30	
H1:u1 different from u2	30	
Median change	0,1558	Drivers who participated
Median change	0,1014	Other drivers

Table 36 shows the result of a Mann-Whitney test for differences in changes between the treatment group and the control group. Again, a positive change means less fuel consumption so the relevant alternative hypothesis is the second one in the table. The null hypothesis is that the change is identical in the treatment group and the control group. The test observator for this hypothesis is larger than the critical value, so we cannot reject it.

The conclusion therefore must be that there is a significant reduction in fuel consumption after the driving course, but the course itself seems to have no effect since all drivers reduce their consumption regardless of whether they participated or not.

The explanation for this conclusion may be rather trivial: The drivers who participated in the course spread information about measures to reduce fuel consumption (more cruise control, more rolling without engine load, less running idle) to the drivers that did not attend the course. All drivers therefore share information about measures to reduce fuel consumption.

Overall test

We will perform an overall test for each driver which can tell us whether there has been a significant change in driving behaviour or not. We will proceed as follows:

- For each driver and for each indicator, find the mean indicator value before and after the driving course,
- if there is a significant difference between the means and the change is in the right direction, mark the difference as success,
- count the number of successes for each driver over all indicators,
- use the binomial test to decide whether the driver has a change in behavioural values that is more than what can be expected from pure chance,
- analyze whether drivers in the treatment group has a larger share of successes than drivers in the control group.

The key point in the list above is what is meant by "right direction". For cruise control, an increase in use of it after the driving course is a change in the right direction. The same is true for use of automatic gear shift, use of the highest gear and rolling without engine load. More is better. On the other hand, less use of more than 90% of maximum torque is a change in the right direction. Also, less use of brakes, less stops, less amount of driving time running idle and less fuel consumption is a change for the better. So less is better. Let's use driver N as an example:

Table 37 Overall test for driver N

	Before	After	p-value	Right direction?	Significant Change
Cruise control	4,90	5,71	0,0987	Yes	

Automatic gear shift	90,78	92,92	0,0049	Yes	Yes
Use of more than 90% of maximum torque	12,82	13,99	0,0212		
Number of brake application per 100 km	71,90	66,58	0,0195	Yes	Yes
Number of stops per 100 km	9,59	9,19	0,2450	Yes	
Running idle	17,93	11,63	0,0000	Yes	Yes
Use of highest gear	48,11	51,21	0,0109	Yes	Yes
Use of rolling without engine load	8,54	7,89	0,0149		
Fuel consumption	4,62	4,52	0,0989	Yes	

The first column is the driving behavioural indicator. The second column is the mean value of that indicator before the driving course. The third column is the mean value after the course. The fourth column is the p-value from the one-sided t-test of difference between two unrelated samples with assumed unequal variance. The fifth column indicates whether the change is in the correct direction as discussed above. For i.e. use of cruise control, driver N used more of it after the course than before. So it is a change in the right direction, but it is not significant as shown by the p-value in the fourth column. If we look at use of more than 90% of maximum torque, driver N use more of that after the course than before. So it is a change in the wrong direction. It does not matter whether that change is significant. Driver N uses less amount of driving time running idle after the course, and this change is significant. Therefore, that is marked as a success in the sixth column.

All in all, driver N has 4 successes in 9 trials. According to the binomial probability distribution, there is a 75% chance of getting 4 or more successes in 9 trials. We can do similar analysis of the other drivers which give us the overview in Table 38. In the table, number of successes as defined above is registered for each driver in column two. Column three has the proportion of successes relative to trials for each driver, number of trials are the 9 different indicators for different behavioural indicators. Probability values from the binomial probability distribution are calculated in the fourth column while the fifth column indicates whether the driver is in the treatment group or in the control group.

Table 38 Overall statistical test for driving behavioural change for each driver

Driver	No of significant changes	Share successes of all trials	p-value from binomial probability distribution	Participation in driving course
AK	1	0,11	0,9980	*
AT	0	0,00	1,0000	
AY	3	0,33	0,9102	*
B	3	0,33	0,9102	
BA	6	0,67	0,2539	*
D	7	0,78	0,0898	
E	6	0,67	0,2539	*
F	0	0,00	1,0000	
G	1	0,11	0,9980	
H	1	0,11	0,9980	

I	0	0,00	1,0000	
J	6	0,67	0,2539	
K	2	0,22	0,9805	*
L	2	0,22	0,9805	*
M	6	0,67	0,2539	*
N	4	0,44	0,7461	
S	4	0,44	0,7461	
X	0	0,00	1,0000	

Table 38 shows that no driver has more than 7 significant changes in the correct direction. If we state a null hypothesis of no change and require a 5% significance level for the hypothesis to be rejected, there is no driver that has the required number of changes. A total of 7 successes on 9 trials can happen by chance with a probability of 9%, given that success and failure is equally likely to happen for each indicator. Given our significance level, this is not enough to reject the null hypothesis of no change.

This means that we cannot establish a systematic change for any of the drivers. If we use a 10% significance level, driver D will have a systematic change. This driver did not participate in the driving course. Four drivers have 6 improvements on the 9 indicators, three of them (drivers BA, E and M) did participate in the driving course. This is some indication for the effect of the driving course but it is no evidence since the numbers do not pass the statistical test.

In the analysis above we calculate the proportion of successes relative to trials for each driver. If we take the mean of that proportion in the different groups we find that drivers in the treatment group on average has 42% successes while the corresponding number in the control group is 29%. Again, this is another indication but no evidence. A z-test for two proportions shows no significant difference between the two groups when we take number of drivers in each group into consideration.

The conclusion therefore is that we do not find evidence to support a hypothesis of significant change in driving behaviour for any driver. This proposition is true when we measure driving behaviour by all 9 indicators listed in Table 38.

But we have found evidence of change for some behavioural indicators with Wilcoxon's test, these are use of cruise control, running idle, rolling without engine load and fuel consumption itself. Only for one of these indicators, rolling without engine load, we also find a significant difference between drivers in the treatment group and the control group as tested by the Mann-Whitney test.

It may be that all 9 indicators are not equally valid as indicators of driving behaviour. Several of them are more determined by external factors than by drivers' intention. Use of maximum torque, driving in highest gear, number of brake applications and number of stops may be more dependent on attributes like road quality, the vehicles drivers use and variations in driving conditions and cargo. These indicators may not describe driver's behaviour at all. On the other hand, indicators like use of running idle, rolling without engine load and cruise control may be more valid indicators of drivers behaviour since the values on these indicators are more determined by driver's choice and intention. Since we find evidence of systematic change for these indicators among all drivers, it may be that the driving course and its attention on potential for changing driving behaviour did have an effect. We find this effect also among drivers who did not participate, probably because discussions among drivers helped to spread information about how to change driving behaviour in order to achieve lower fuel consumption.

ANOVA tests for the post-course period

We will perform an ANOVA-test on selected driving behavioural indicators in order to further test whether there are any significant differences between drivers who participated in the driving course and those who did not. We will also test whether there is any significant difference in fuel consumption between the groups.

The ANOVA post hoc-test is the Scheffe test for multiple comparisons. We perform an ANOVA-test for differences between drivers' mean indicator values after the driving course took place. Behavioural indicators are registered per day, not per trip. We use only data where we can identify what vehicle the drivers used on a specific day. We use regression analysis to perform this ANOVA-analysis since we want to include vehicles' horsepower as a control variable. This is the same as using vehicle power as a covariate in a ANOVA-analysis. We only include trips larger than 100 km in the analysis.

Each driver is included in the regression analysis as a binary variable. One of the drivers is used as constant term. By using the regression coefficients from the regression analysis, we calculate the different means for different drivers by taking their regression coefficient and their vehicle horsepower into the calculation. This means that we calculate means corrected for differences in use of vehicles with different horsepower. Since drivers may drive several vehicles, we must select one of them in order to calculate that driver's mean value for a behavioural indicator. We will use the vehicle that has the most horsepower.

Out of 17 drivers, 7 drivers used more than one vehicle. If we select the vehicle that is most used, we may end up with negative predicted values for a specific indicator for these drivers. This is because the vehicle with the most horsepower has the greatest impact on that driver's predicted value from the regression analysis. This means that drivers B, H, I and K has a value for vehicle horsepower that is not the same as the vehicle these drivers used the most. Driver B used two vehicles, one with 500 horsepower for 4 days and one with 540 horsepower for 1 day. Driver H used two vehicles, one with 500 horsepower for 8 days and one with 700 horsepower for 4 days. Driver I used two vehicles, one with 500 horsepower for 7 days and one with 540 horsepower for 2 days. Driver K used three vehicles, one with 500 horsepower for 8 days, one with 480 horsepower for 5 days and one with 560 horsepower for 1 day. For all these drivers, the vehicle with the most horsepower is selected even if other vehicles are used more. Since these drivers have few days registered after the driving course, the selection of horsepower value will affect the predicted value for each indicator more than for other drivers.

Table 39 shows the drivers included in the analysis and what horsepower value we use for each driver. As mentioned, the calculated means are corrected for the effect of vehicle power on the driving behavioural indicators we are testing. This is an important control since vehicle horsepower may have an impact on each driver's potential use of that specific behavioural indicator.

Table 39 Drivers and vehicles used in the ANOVA post hoc analysis

Driver	Vehicle horsepower	Total number of days per driver
AK	700	28
AT	700	25
AY	700	47
B	540	5
BA	540	32
D	540	8
E	500	162
F	500	156
G	500	47
H	700	12
I	540	9
J	500	46
K	560	14
L	520	5
M	500	64
N	500	317
S	500	49

As a post-hoc analysis we will use the Scheffe test for multiple comparisons. When multiple comparisons are made, we must correct the significance level for number of comparisons made. This is because the significance level we use for a comparison between two drivers will not be the same if more drivers are compared with these two. The chance of making a Type I error (rejecting a true null hypothesis) will then be affected by the number of comparisons. Scheffe's test correct for this so that the expected chance of making the Type I error will be equal to the significance level corrected for number of comparisons that are made [6].

Equation 2 shows the formula for calculation of the Scheffe test statistic for any pairwise comparison between to drivers. The result of the calculation is the critical value for the difference between the two groups when we take results from the ANOVA analysis for all drivers into consideration. In the equation, k is number of groups minus 1, f_{crit} is the critical f-value with degrees of freedom from the ANOVA-analysis. There are two degrees of freedom, one for within group variance and one for between group variance. The alpha level used in the calculation of the critical f-value is the preset significance level for any individual comparison. MSE is the mean squared error from the ANOVA analysis and n_i and n_j are the two numbers of observations for the groups being tested.

Equation 2 Scheffe test statistic

[6] See Simonsen, M.: *Fuel consumption in heavy duty vehicles*, section *Analysis of Variance* for a more detailed discussion of different ANOVA post-hoc tests. The report is available at http://vfp1.vestforsk.no/sip/Lerum/Model.pdf

$$\sqrt{k * f_{crit}} * \sqrt{MSE\left(\frac{1}{n_i}+\frac{1}{n_j}\right)}$$

We then compare the critical Scheffe value for differences in means with the actual, empirical difference for a specific comparison. If the empirical difference is greater than the Scheffe critical value, we have a statistical significant difference between two groups that satisfy the preset significance level for individual tests. We repeat this procedure for all comparisons.

After all calculations are done, we have a number of significant differences between different groups. We then calculate how many times drivers who took the driving course have a significant different mean than drivers who did not participate. We also calculate how many comparisons we make between the two types of drivers. Finally, we calculate a binomial test for these two numbers where number of trials are number of comparisons made between the treatment group and the control group and number of successes is number of times these comparisons are significant. We use the set up in Table 6 to determine whether the number of significant comparisons between the two group of drivers is larger than what can be expected from random variation. If it is, we have a significant difference between the two groups of drivers for that specific driving behavioural indicator.

Note that we do not check whether the differences between drivers from he treatment group (the ones that participated in the driving course) and the drivers from the control group have any specific direction. We only check whether their means are different, not if some means are larger than or smaller than others. We therefore perform a two-sided test.

Table 40 shows the significant comparisons for use of cruise control between the different drivers according to the Scheffe test. The letters for the row labelled course are F for false and T for true. The drivers who participated in the driving course have the value T for true. The numbers corresponding to the drivers id in rows and columns are the drivers' mean for using cruise control. The means in the third row are arranged in ascending order, the means in the second column are arranged in descending order. The means with the largest differences are therefore located in the upper-left corner of the table. The significant comparisons between drivers are marked with an asterisk. All in all, there are 37 significant differences in the table.

Table 40 Comparisons between means of cruise control for different types of drivers

	Course	F	F	F	F	T	T	T	T	F	F	F	T	F	F	F	T	T
	Drivers	B	G	I	H	L	E	M	AK	J	S	AT	AY	N	F	D	BA	K
		0,0	0,7	1,0	1,3	2,6	2,7	3,4	4,8	5,2	5,7	5,9	6,1	6,4	6,7	16,6	25,8	26,1
K	26,1	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
BA	25,8	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
D	16,6	*																
F	6,7																	
N	6,4																	
AY	6,1																	
AT	5,9																	
S	5,7																	
J	5,2																	
AK	4,8																	

M	3,4																	
E	2,7																	
L	2,6																	
H	1,3																	
I	1,0																	
G	0,7																	
B	0,0																	

Table 41 Binomial test for significant differences between mean use of cruise control between types of drivers

	Value
n=Number of comparison between drivers who took the driving course and those who did not	77
a=Number of significant comparisons	18
P_0	0,5
p=Binomial probability for at least a successes	1

Table 41 shows the binomial test for differences in mean use of cruise control between drivers who took the driving course and those who did not. The conclusion from the table is that there are no significant difference between the two groups.

We will test two other driving behavioural indicators. These are amount of driving time spent running idle and amount of driving time spent rolling without engine load. We have shown above that there are significant differences in use of these indicators when all drivers are taken into considerations. The question is then whether there are any differences between drivers in the treatment group and drivers in the control group. In the section above we tested this by using the non-parametric Mann-Whitney test. In this section we will use Scheffe's test to answer this question.

In the addition to the indicators mentioned above, we will also perform the Scheffe test for fuel consumption.

Table 42 shows the comparisons between drivers for mean use of running idle. The significant differences between drivers according to the Scheffe test are marked with an asterisk as above.

Table 42 Comparisons between means of running idle for different types of drivers

	Course	T	T	F	F	T	F	T	F	T	F	T	F	F	F	T	F	F
	Drivers	K	BA	J	AT	AY	S	E	D	M	N	L	H	F	G	AK	I	B
		5,3	5,8	6,1	6,4	7,3	7,5	8,0	9,9	10,1	11,0	11,5	11,6	11,8	16,4	18,6	18,6	19,5
B	19,5	*	*	*	*	*	*	*										
I	18,6																	
AK	18,6	*	*	*	*	*	*	*	*			*		*				
G	16,4	*	*	*	*	*	*	*	*			*						
F	11,8	*	*			*												
H	11,6																	
L	11,5	*	*			*												
N	11,0																	

M	10,1																	
D	9,9																	
E	8,0																	
S	7,5																	
AY	7,3																	
AT	6,4																	
J	6,1																	
BA	5,8																	
K	5,3																	

Table 43 shows that there are 18 significant differences between drivers who took the course and those who did not. This is not enough to reject the null hypothesis of random variation as the cause of the observed differences in running idle.

Table 43 Binomial test for significant differences between mean use of running idle between types of drivers

	Value
n=Number of comparison between drivers who took the driving course and those who did not	77
a=Number of significant comparisons	18
P_0	0,5
p =Binomial probability for at least a successes	1

Table 44 shows differences between means of running without engine load for different types of drivers. All in all there are 80 significant differences in the table, 39 of them are between drivers from the treatment group and drivers from the control group.

Table 44 Comparisons between means of running without engine load for different types of drivers

	Course	F	F	F	F	F	F	T	T	T	F	T	T	T	F	F	T	F
	Drivers	G	I	F	B	H	J	L	AK	M	N	K	E	BA	D	S	AY	AT
		0,6	1,2	3,0	6,4	6,8	7,3	7,8	7,9	8,6	8,9	9,6	12,8	13,5	13,9	14,5	15,0	16,4
AT	16,4	*	*	*	*	*	*	*	*	*	*	*						
AY	15,0	*	*	*	*	*	*	*	*	*	*	*						
S	14,5	*	*	*	*	*	*	*	*	*	*	*						
D	13,9	*	*	*	*	*	*		*	*	*	*						
BA	13,5	*	*	*		*	*		*									
E	12,8	*	*	*		*	*		*	*	*	*						
K	9,6	*	*	*		*			*									
N	8,9	*	*	*														
M	8,6	*	*	*														
AK	7,9	*	*	*														
L	7,8	*																
J	7,3	*	*	*														
H	6,8	*	*	*														
B	6,4																	

F	3,0	*																
I	1,2																	
G	0,6																	

Table 45 Binomial test for significant differences between mean use of running without engine load between types of drivers

	Value
n=Number of comparison between drivers who took the driving course and those who did not	77
a=Number of significant comparisons	39
P_0	0,5
p =Binomial probability for at least a successes	0,5

Table 45 shows that there are 39 significant comparisons between drivers who took the driving course and those who did not. The binomial probability of obtaining this number of significant differences out of the total number of comparisons shows that we do not have enough significant differences to reject the null hypothesis of random variation. We therefore find no systematic difference between the two groups of drivers when we look at rolling without engine load. However, there are more differences between drivers in the two groups for this indicator. This is also in line with the conclusions from the Mann-Whitney tests above.

Table 46 Comparisons between mean fuel consumption for different types of drivers

	Course	F	T	F	F	F	F	T	F	T	T	T	F	F	F	F	T	T
	Drivers	D	K	B	J	AT	N	L	H	M	BA	E	S	G	F	I	AK	AY
		3,9	4,1	4,3	4,3	4,4	4,5	4,5	4,5	4,5	4,5	4,5	4,5	4,6	4,9	5,1	5,1	5,1
AY	5,1																	
AK	5,1			*					*									
I	5,1																	
F	4,9																	
G	4,6																	
S	4,5																	
E	4,5																	
BA	4,5																	
M	4,5																	
H	4,5																	
L	4,5																	
N	4,5																	
AT	4,4																	
J	4,3																	
B	4,3																	
K	4,1																	
D	3,9																	

Table 46 shows number of significant differences in mean fuel consumption between drivers in the treatment group and drivers in the control group. As the table shows, there are only 2 significant difference between drivers from the two groups. All of them are between one driver who took the course and two drivers who did not. The driver that took the course has the second largest fuel consumption and the two others therefore have significant lower mean fuel consumption.

Binomial test for significant differences between mean fuel consumption between types of drivers

	Value
n=Number of comparison between drivers who took the driving course and those who did not	77
a=Number of significant comparisons	2
P_0	0,5
p =Binomial probability for least a successes	1

Table 46 shows the result of the binomial test for fuel consumption. As expected, with so few significant differences, we cannot reject the null hypothesis.

Is the effect of the driving course weakening over time?

This section will analyse three questions: Is there a trend in use of selected behavioural indicators and is this trend slowing over time? And: Is there a shift in the trend after the driving course in summer 2011? We will look at three driving behavioural indicators: Use of cruise control, use of running idle and use of rolling without engine load. In addition, we will also look at the trend for fuel consumption.

We will analyse the trend for all drivers during the time Dynafleet fleet management system has been installed in vehicles used by Lerum Freight BA. Dynafleet registers use of the these driving behavioural indicators per day. All drivers are included in analysis, but only daily trips longer than 100 km are included.

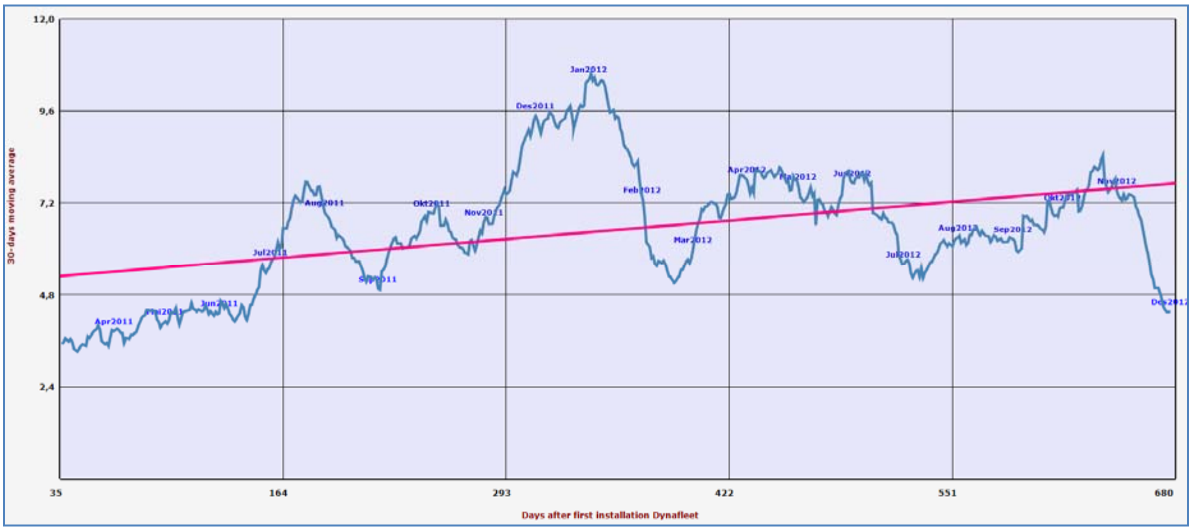
We will look at the following driving behavioural indicators: Use of cruise control, use of running idle and use of rolling without engine load. All indicators are measured as the percentage of total driving time per day that the indicator is in use. In order to detect a trend we will use a moving average over the last 30 days. By using a moving average we will even out variations from day to day that are caused by different driving conditions and difference in cargos. This will ensure that it is easier to detect a trend in the material.

We will proceed as follows: We calculate the mean use of the behavioural indicator in question for all drivers who have registrations on a particular day. After that we calculate a moving 30-day average up to the last registration day. This means that the first 30 registrations are discarded. In order to detect any trend we will use a bivariate linear regression model. The independent variable is number of days since Dynafleeet first was installed in vehicles in Lerum Frakt. The dependent variable is the 30-day moving average for the behavioural indicator in question or for fuel consumption. If there is a trend, the linear bivariate regression coefficient will be statistically significant larger than zero.

Cruise control

Figur 12 shows the 30-days moving average for use of cruise control for all drivers. There is an upward trend in use of cruise control. The coefficient from the bivariate regression model shows that the trend is statistically significant with a t-value of 11,65 and 567 degrees of freedom [7]. The regression coefficient is significantly larger than zero which means the use of cruise control will increase over time. According to the model, during the next 100 days use of cruise control will be 0,38 percentage points higher relative to total driving time per day. The trend explains about 19% of variation in cruise control measured by R^2.

Figur 12 Moving average for use of cruise control

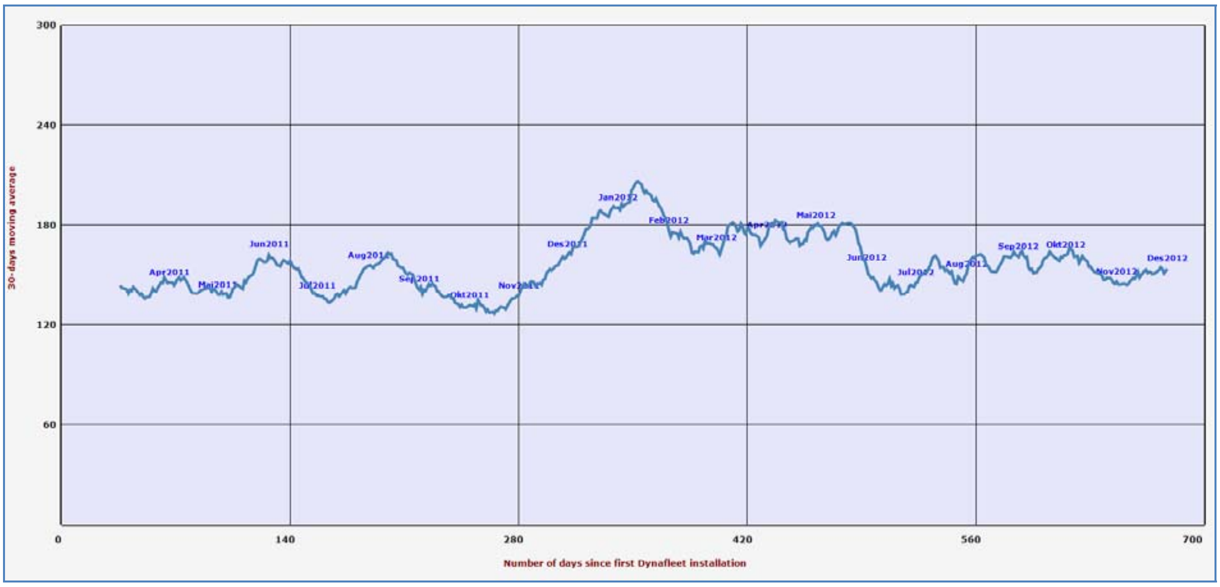


The figure shows that there is a clear increase in use of cruise control after the driving course in mid June 2011. Except for a dip in september 2011, there is an upward trend all up to January 2012. After that use of cruise control has gone gradually down. One interpretation of this trend is that the driving course created an awareness about use of cruise control as a measure for reducing fuel consumption but that this awareness has weakened over time.

Is the observed trend the same for all drivers or is there a tendency of greater variation in use of cruise control as its use increases? We will answer this question by calculating the Coefficient-of-variation (CV)-value which is the standard deviation as a percentage of the mean. In order to even out short-term variation and get a smooth trend we have calculated a 30-days moving average also for this value.

Figur 13 Moving average for variation in use of cruise control

[7] The maximum number of days since Dynafleet was installed is 677 days, but the drivers do not drive each day in between. Week ends and holidays will explain much of the difference between maximum number of days and days in use.

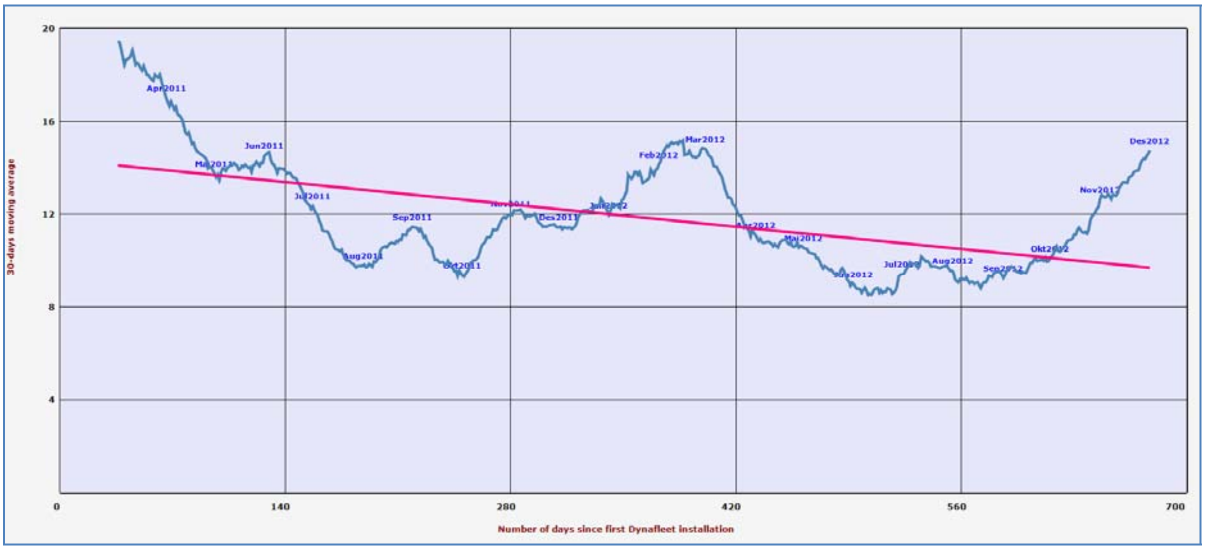


Figur 13 shows the moving average for variation in use of cruise control. The figure shows that the variation indeed increases when use of cruise control increases, therefore the trend towards more use is not common among all drivers. When use of cruise control decreases the variation again stabilises around a CV-value of 150. This is a high variation in itself which indicates that use of cruise control varies quite a lot between drivers. In this context we must take into consideration that since mean and variation are calculated on a daily basis, fewer drivers are included in the calculations at the start of the project. This is a consequence of the fact that Dynafleet was not installed in all vehicles at the same time.

Running idle

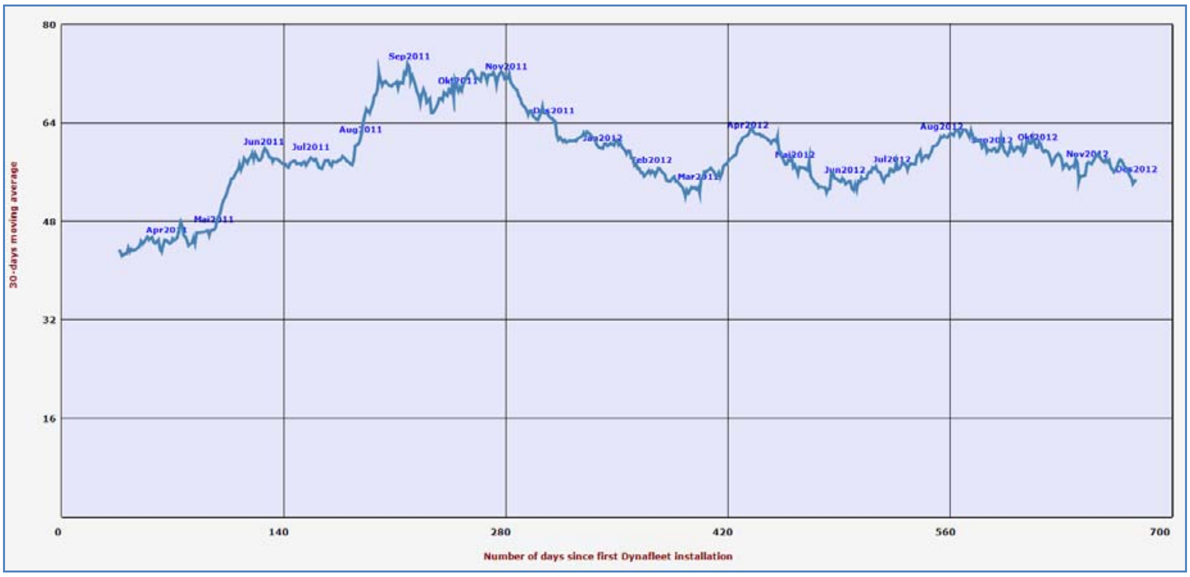
Figur 14 shows a 30-days moving average for use of running idle. The figure shows a clear downward trend, but there is also an obvious seasonal trend. Use of running idle is lowest in the summer months and increases in the winter months December, January, February and March. So the trend is rather well-shaped than linear. Anyway, the linear bivariate regression model shows that in the next 100 days, the expected decrease in use of running idle is 0,7 percentage points of total driving time per day. This effect is statistically significant with a t-value of -14,98 and 567 degrees of freedom. The model explains 28% of total variation in use of running idle.

Figur 14 Moving average for use of running idle



The figure shows that the level of use of running idle is higher in November 2012 than in November 2011. The figure therefore suggests that the trend towards decreasing use of running idle is weakening over time.

Figur 15 Moving average for variation in use of running idle

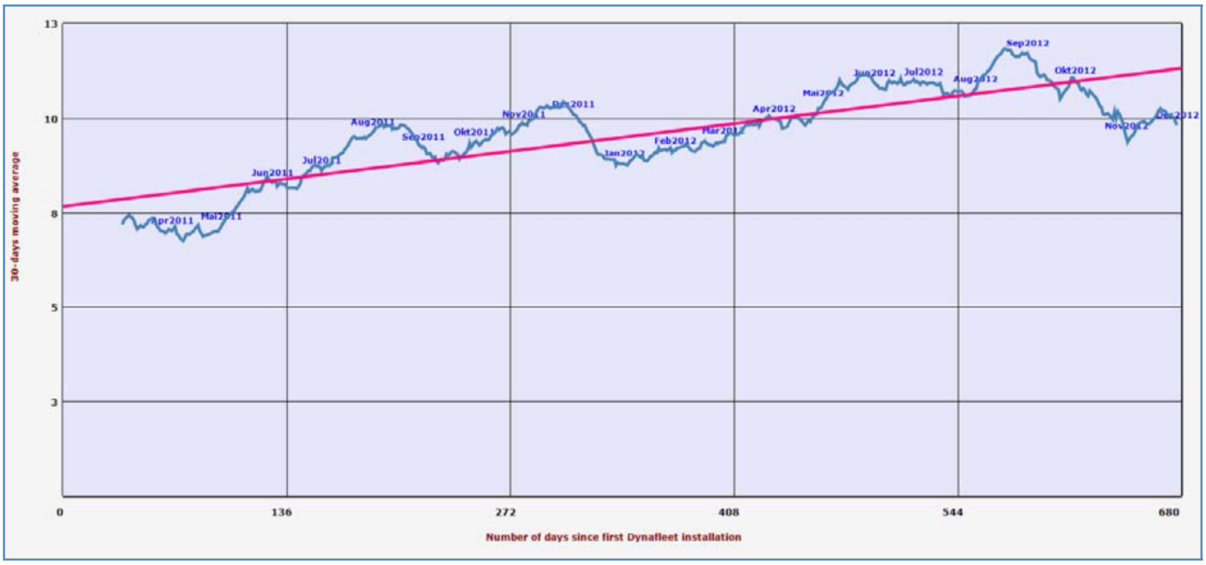


Figur 15 shows the trend in variation in use of running idle. The variation in use of running idle is less than the variation in use of cruise control. There is a statistically significant upward linear trend in the figure which suggests that as use of running idle decreases over time, this trend is less common among drivers. In other word, some drivers decrease their use of running idle more than other drivers.

Running without engine load

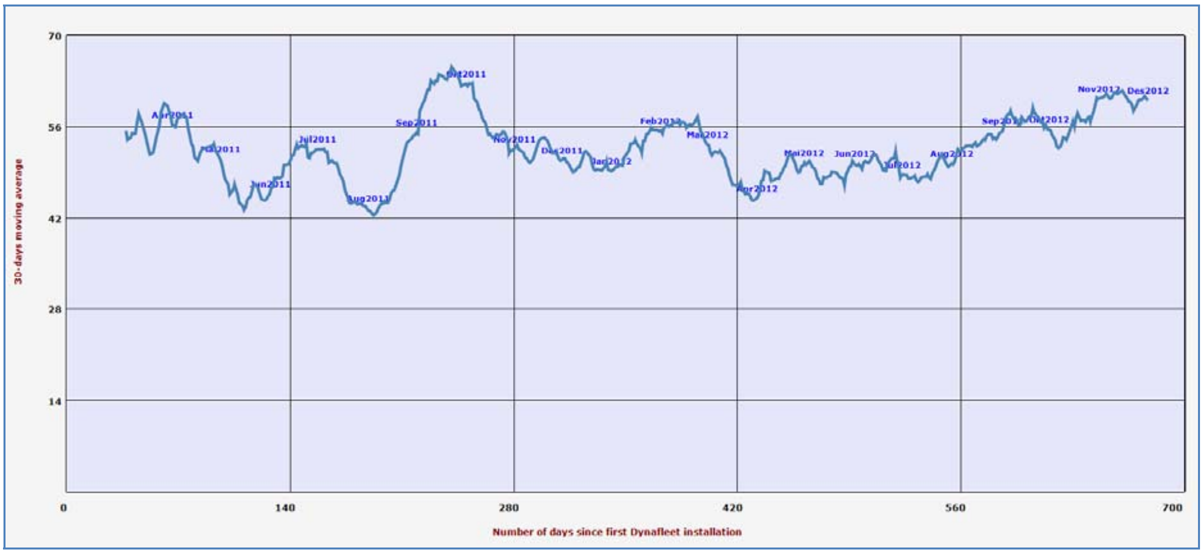
Figur 16 shows the trend for using rolling without engine load. There is a clear upward trend in the figure. The linear trend estimate is statistically significant with a t-value of 35,3 and degrees of freedom of 567. The effect suggests that for the next 100 days, the use of rolling without engine load will be 0,56 percentage points higher than the average trend in the figure. The linear bivariate model explains 69% of total variation in rolling without engine load, measured by R^2.

Figur 16 Moving average for use of rolling without engine load



Again, there is a trend towards weakening effect over time. The figure shows that the level of using rolling without engine load is higher in September and October 2012 as compared to the same months one year earlier. For November 2012 though, the trend is the opposite, the level of use of rolling without engine load is lower in 2012 compared to the same month one year earlier [8].

Figur 17 Moving average for variation in use of rolling without engine load

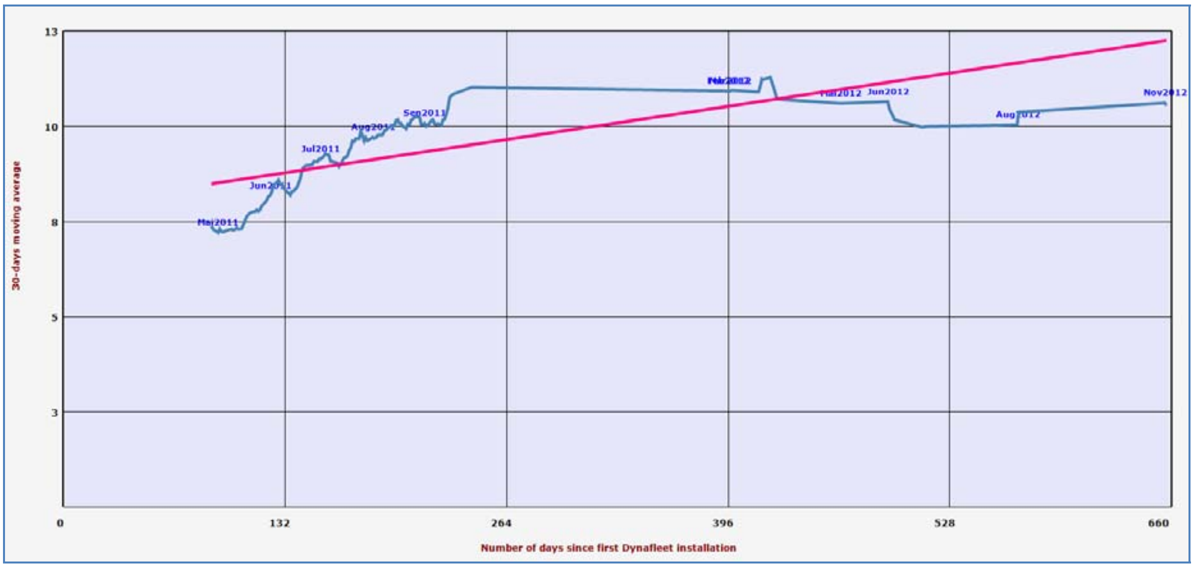


Figur 17 shows the trend in variation in use of rolling without engine load. The variation measured by CV-values (Coefficient Of Variation) is less than both variation in use of cruise control and running idle. We also note that there are two upward trends right after the driving course in July 2011 and August 2011. The dip between may be caused by summer holiday and more use of temporary substitute drivers during that holiday. The variation in use of rolling without engine load was at its highest in August 2011. This may be an effect of the driving course which led to greater attention to rolling without engine load among some drivers but not all. There is also a weak significant linear

[8] There are very few days of December 2013 included in the analysis, we therefore do not not comment the difference for this month compared to December 2011.

trend in the figure which may suggests that more use of rolling without engine load corresponds with more variation in use of it.

Figur 18 Moving average for use of rolling without engine load for drivers who participated in the driving course



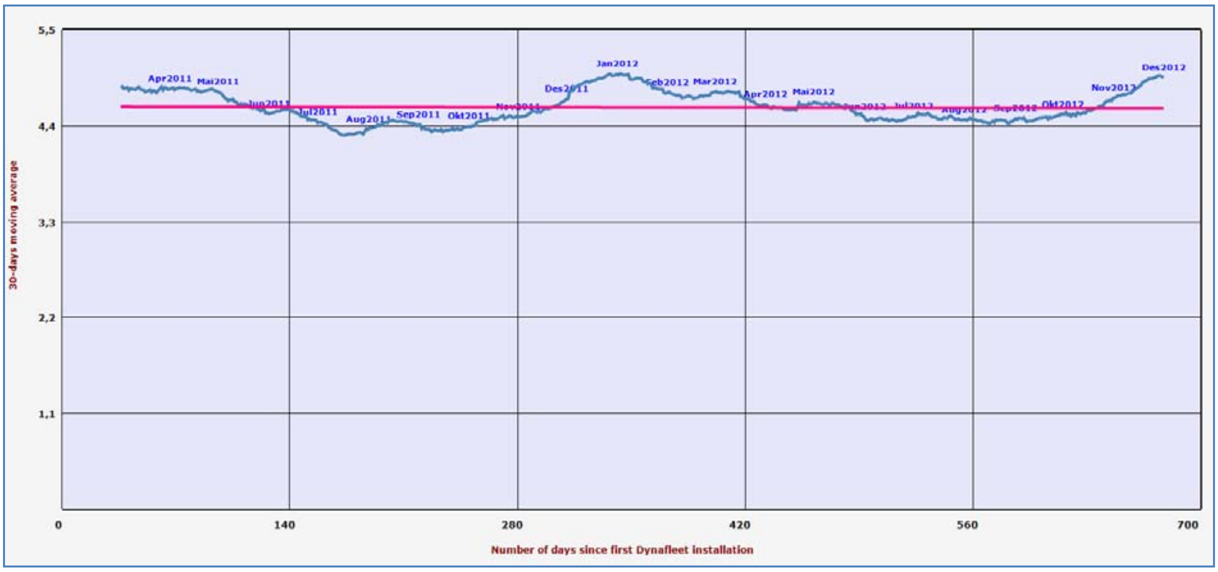
We have confirmed in the analysis above that there is a significant difference in changes in use of rolling without engine load among drivers who participated in the driving course and the ones who didn't. Therefore it may be reasonable to show a figure for the trend in use of rolling without engine load only for drivers who participated in the course. Figur 18 shows that trend. The upward linear effect is significant with a t-value of 12,38 and 143 degrees of freedom. The models explains about 52% of total variation in use of rolling without engine load among drivers who participated in the driving course. According to the model, during the next 100 days the increase in use of rolling without engine load will increase with 0,7 percentage points compared to the average trend. This effect is higher than the effect for all drivers.

The increase in use of rolling without engine load is a bit stronger among drivers who participated in the driving course in the first few months after the course in June 2011 until October 2011. After this period it is hard to detect any significant difference in the trend among different group of drivers.

Fuel consumption

Finally, is there a different trend in fuel consumption? Figur 19 shows the development in fuel consumption among all drivers since the first Dynafleet installations. There is no linear upwards trend in the figure. The bivariat model has no statistically significant coefficient with a t-value of -0,57 and 567 degrees of freedom. There is however a clear seasonal trend. The fuel consumption is lowest in summer months and higher in winter months. The highest value for the moving average is 4,97 litre per 10 km in January 2012. The lowest consumption is 4,27 litre per 10 km in July 2011, the first month after the driving course. The well-shaped seasonal trend does not seem to change much over time or after the driving course.

Figur 19 Moving average for fuel consumption



Conclusions

In summer 2011 seven drivers employed by Lerum Frakt AB, a transport company in Western Norway, took part in a driving course. The aim of the course was to teach driving behaviour beneficial for lower fuel consumption. Eighteen of the vehicles used by the company had the fleet management system Dynafleet[9] installed before the driving course.

The overall research question is: Are there any significant differences in driving behaviour after the driving course for each individual driver and for different groups of drivers? The drivers are divided into two groups, one consist of the drivers who took the course and the other of the drivers who did not. The first is referred to as the treatment group and the second as the control group.

Nine different driving behavioural indicators are included in the analysis. These are use of cruise control, use of running idle, use of rolling without any engine load, use of highest gear, of automatic gear shift and of use of more than 90% of maximum torque. All these indicators are measured as use in percentage of total driving time per day. In addition number of brake applications and number of stops, both per 100 km, are included in the analysis as well as fuel consumption per 10 km.

We have made three different tests for each driver in order to determine whether there are any differences before and after the driving course. We perform a t-test for independent samples with assumed unequal variance for each driver where the two samples tested are the days before the driving course and the days after. We then use binomial tests to determine whether there are more significant differences between drivers from the treatment group and the control group than what would be expected from pure chance alone. In addition we use Wilcoxon's signed rank test in order to determine whether there is any change among all drivers before and after the course and Mann-Whitney test to determine whether the median difference is different in the treatment group and in the control group. Both the Wilcoxon tests and the Mann-Whitney tests use the means from the t-tests as measurement of behaviour before and after the driving course.

[9] Dynafleet is a fleet management system developed by Volvo.

Both the last two tests are non-parametric which means they do not assume any underlying normal distribution for the behavioural indicators. The t-tests are based on he normal distribution, but according to the central limit theorem a sum of independent non-normal variables can itself be normal. Since a mean is a sum of independent variables, this means the assumption of normality is made about the means we are testing, not about any individual indicator distribution.

For each indicator, we state a null hypothesis along with an alternative hypothesis. If the null hypothesis can be rejected, we interpret this as evidence to support the alternative hypothesis. The null hypothesis is always that there is no change in use of an indicator among all drivers (Wilcoxon's test) or no difference between the treatment group and the control group (Mann-Whitney). The binomial tests have the same null-hypothesis.

Table 47 shows the different alternative hypothesis for the different driving behavioural indicators.

Table 47 Alternative hypothesis for different driving behaviour indicators

	Wilcoxon	Mann-Whitney (treatment group first)	Test observator Mann-Whitney test	Beneficial use for fuel consumption
Use of cruise control	u<0	u1<u2	MW1	Increasing
Use of automatic gear shift	u<0	u1<u2	MW1	Increasing
Use of more than 90% of maximum torque	u>0	u1>u2	MW2	Decreasing
Application of brakes per 100 km	u>0	u1>u2	MW2	Decreasing
Number of stops per 100 km	u>0	u1>u2	MW2	Decreasing
Use of high gear	u<0	u1<u2	MW1	Increasing
Use of running idle	u>0	u1>u2	MW2	Decreasing
Use of rolling without engine load	u<0	u1<u2	MW1	Increasing
Fuel consumption	u>0	u1>u2	MW2	

For cruise control, we find that drivers have significantly altered their use of cruise control as a consequence of the driving course, measured by the Wilcoxon's test. At the same time, we do not find any significant difference between the drivers who participated in the course and those who did not by use of the Mann-Whitney test. The t-tests reveal no significant difference between the treatment group and the control group.

The conclusion for use of automatic gear shift is that we cannot find any evidence to suggest that its use has changed as an effect of the driving course. For use of more than 90% of maximum torque we also cannot find any effect of the driving course. A decreasing use of this indicator is beneficial for fuel consumption, but its use has rather increased after the driving course though this change is not significant as measured by the Wilcoxon's signed rank test.

The conclusion for application of brakes per 100 km is that there is not enough evidence to reject the null hypothesis. The same is true for indicator number of stops per 100 km.

For running idle we find a significant change in use of it among all drivers. We do not find significant differences between the treatment group and the control group. Looking at driving in highest gear, we find that we cannot reject the null hypothesis, neither for all drivers nor for the treatment group compared to the control group.

The conclusion for rolling without engine load is that we find evidence of more use of this indicator for all drivers after the driving course. We also find evidence to support the claim that drivers from the treatment group use this indicator more than drivers from the control group. So there is positive change among all drivers and the positive change is largest among drivers in the treatment group.

We find a significant reduction in fuel consumption after the driving course, but the course itself seems to have had no effect since all drivers reduce their consumption regardless of whether they participated or not.

We do we find significant change among all drivers for use of cruise control, running idle and fuel consumption, but not between the treatment group and the control group. How can that be? The drivers who participated in the course may have spread information about measures to reduce fuel consumption (more cruise control, more rolling without engine load, less running idle) to the drivers that did not attend it. The ones that did take the course acted as information agents for the ones who did not. Therefore, useful information and experiences from the driving course may also have an influence on drivers who did not participate. The two groups do not act independent of each other, they have daily contact and the control group is not "blind" about the positive experiences and knowledge acquired by drivers who participated in the driving course.

All the 9 behavioural indicators may also not be equally valid as indicators of driving behaviour. Several of them are more determined by external factors than by drivers' intention. Use of maximum torque, driving in highest gear, number of brake applications and number of stops may be more dependent on attributes like road quality, the vehicles drivers use and variations in driving conditions and cargo. These indicators may not describe driver's behaviour at all. On the other hand, indicators like use of running idle, rolling without engine load and cruise control may be more valid indicators since the values on these indicators are more determined by driver's choice and intention.

Since we find evidence of systematic change for these last indicators among all drivers, it may be that the driving course did have an effect on the behavioural indicators that drivers have the largest potential of changing.

The ANOVA analysis with Scheffe's post hoc test did not reveal any significant differences between drivers who participated in the driving course and those who did not.

Table 48 Test conclusion for each driving behavioural indicator

	Alternative hypothesis Wilcoxon	Conclusion H0 reject/ accept	Alternative hypothesis Mann-Whitney (treatment group first)	Conclusion H0 reject/ accept
Use of cruise control	u<0	Reject	u1<u2	Accept
Use of automatic gear shift	u<0	Accept	u1<u2	Accept
Use of more than 90% of maximum torque	u>0	Accept	u1>u2	Accept
Application of brakes per 100 km	u>0	Accept	u1>u2	Accept

Number of stops per 100 km	u>0	Accept	u1>u2	Accept
Use of high gear	u<0	Accept	u1<u2	Accept
Use of running idle	u>0	Reject	u1>u2	Accept
Use of rolling without engine load	u<0	Reject	u1<u2	Reject
Fuel consumption	u>0	Reject	u1>u2	Accept

Table 48 shows the test conclusions from Wilcoxon's signed rank test and Mann-Whitney test for each driving behavioural indicator. For Wilcoxon's test the null hypothesis (H0) is that there is no change among all drivers. For the Mann-Whitney test the null hypothesis is that there is no difference in change among drivers in the treatment group (the ones that participated in the driving course) and the control group (the ones that didn't).

Looking at trends in use of selected behavioural indicators, we find that for use of cruise control there is a clear increase in use of it after the driving course in mid June 2011. Except for a dip in September 2011, there is an upward trend all up to January 2012. After that use of cruise control has gone gradually down. One interpretation of this trend is that the driving course created an awareness about use of cruise control that has decreased over time.

The variation in use of cruise control increases as the use of it also increases. Therefore, the trend towards more use of cruise control is not a common trend among all drivers.

For use of running idle, we find a clear downward trend. For this behavioural indicator, there is also an obvious seasonal trend. Use of running idle is lowest in the summer months and increases in the winter months December, January, February and March. So the trend is rather well-shaped than linear. The analysis suggests that the trend towards decreasing use of running idle is weakening over time.

We also find that the variation in use of running idle increases as the use of it decreases. Not all drivers are therefore reducing their use of running idle to the same degree.

For rolling without engine load, we find a clear upward trend. But also for this indicator we find a weakening effect over time. The level of using rolling without engine load is higher in September and October 2012 as compared to the same months one year earlier measured by the moving average. For November 2012 the trend is the opposite, the level of use of rolling without engine load is lower in 2012 compared to the same month one year earlier.

The variation in use of rolling without engine load increased the most just after the driving course in June 2011. The awareness of the potential for more use of rolling without engine load was therefore strong just after the course but it has levelled off since.

For fuel consumption we find a clear seasonal trend but not a linear one, We therefore find no indications that suggest lower fuel consumption over time for all drivers.

Multimodal transport med utgangspunkt Lerum Frakt

I løpet av månedene fra januar til og med september 2012 har de lastebilene i Lerum Frakt som er registrert i flåtestyringssystemet Dynafleet fraktet 22 006 tonn med syltetøy og saft for Lerum

Fabrikker. Det er tilbakelagt 308 769 km for å frakte disse varene. Det ble brukt 159 378 liter diesel for å frakte varene, dette gir et gjennomsnittlig drivstofforbruk på 5,2 liter pr mil med tilnærmet full last.

Det ble produsert til sammen 7 503 681 tonn-km i perioden. Dette er vel og merke transport med varer fra Lerum Fabrikker. I tillegg kommer transport av varer pluss tomkjøring. I beregninger i dette notatet tar vi bare hensyn til transport med kjent last fra Lerum Fabrikker.

Samlede miljøvirkninger av transport ved Lerum Frakt

Hva er miljøvirkningene av denne transporten? Hvilke miljøvirkninger ville en fått med alternative transportformer? For å svare på disse spørsmålene skal vi se på energibruk og utslippsfaktorer for transport av gods. Vi skal ta hensyn til tre typer utslipp:

- Globale utslipp av klimagasser måles med utslippsfaktorer for CO_2-ekvivalenter pr tonn-km for ulike transportmidler.
- Lokale og regionale utslipp av gasser måles med to typer utslippsfaktorer: TOPP-faktorene gir utslippsfaktorer for dannelse av bakkenært ozon og SO_2-ekvivalenter gir utslippsfaktorer for gasser som påvirker surhetsgraden. Faktorene er hentet fra den tyske online LCA-databasen ProBas[10].

SO_2-ekvivalenter måler et sett med komponenters potensial for forsuring. Utslippene fra hver komponent er regnet om til SO_2-verdier ut fra dere bidrag til forsuring relativt til SO2. Komponentene er SO_2, NOx, HCl (saltsyre), HF (hydrogenfluorid), NH3 (amoniakk) og H_2S (hydrogensulfid). Jo større ekvivalentverdi, jo større bidrag til forsuring. TOPP-ekvivalent er et mål for gassers bidrag til dannelse av bakkenært ozon. Ekvivalentverdien består av et sett med gasser som er veid i forhold til hverandre etter deres bidrag til ozondannelse. Komponentene er CO, NMVOC, NOx og CH4. Jo større ekvivalentverdi, jo større er bidraget til bakkenær ozondannelse.

Det tas hensyn til energibruk og utslipp i flere energikjeder. En energikjede er en kjede med energibruk som starter med en energikilde, inkluderer dennes omdanning til nyttbar energi og ender med bruken av den nyttbare energi til et formål. Det skilles mellom to hovedkjeder, den direkte energikjede og den indirekte energikjede. Den direkte energikjede omfatter energi til framdrift av et transportmiddel inklusive energibruk til utvinning, omdanning og distribusjon av energien som benyttes. Diesel er et drivstoff for framdrift, i tillegg kreves det energi for å utvinne olje, raffinere diesel og transportere den til distribusjonsledd for sluttbruker.

Den indirekte energikjeden omfatter energibruk for konstruksjon, drifting og vedlikehold av transportmidlenes infrastruktur i tillegg til produksjon og vedlikehold av transportmiddelet selv. For hver av disse prosessene kreves innsats av energi som medfører visse utslipp. Den samlede energibruk for en tonn-km produsert av et transportmiddel omfatter både den direkte og indirekte energibruk. For å sammenlikne energibruk og utslipp for produksjon av en tonn-km for ulike transportmiddel tas det hensyn til både direkte og indirekte energibruk. Dette gir den mest fullstendige sammenlikning mellom transportmidlene og det beste grunnlaget for å vurdere miljøeffekten av å bruke dem.

---
10 http://www.probas.umweltbundesamt.de/php/glossar.php?&PHPSESSID=8ebfcf27e1a9f0cc32886e49f85363fd#S

De ulike energikjeder representerer ulike faser i transportmiddelets livsløp. Analysen som presenteres her er derfor en livsløpanalyse med energibruk som kriterium for å kvantifisere miljøeffekten av produksjon av 1 tonn-km med transportmiddelet.

Tabell 1 Energibruk og utslipp for produksjon av 1 tonn-km med tyngre lastebil

Energiformål	MJ pr tonn-km	CO2-ekvivalent gram pr tonn-km
Framdrift	1,02	76
Utvinning, produksjon og distribusjon av drivstoff	0,15	7,38
Konstruksjon, drift og vedlikehold av Infrastruktur	0,11	2,69
Fabrikasjon og vedlikehold av transportmiddel	0,05	11,81
Sum	1,33	97,87

For TOPP-ekvivalenter og SO2-ekvivalenter beregnes utslipp bare for framdrift av transportmiddelet inklusive utslipp knyttet til utvinning, produksjon og distribusjon av drivstoffet. Tabell 2 viser utskipsfaktorene som benyttes for produksjon av 1 tonn-km med tyngre lastebil.

Tabell 2 Utslippsfaktorer i gram pr tonn-km for framdrift og utvinning, produksjon og distribusjon av drivstoff for tyngre lastebiler

	TOPP gram per tonn-km	SO2 gram per tonn-km
Framdrift	0,771	0,481
Drivstoff	0,052	0,055
Sum	0,823	0,536

Med utgangspunkt i produksjon av tonn-km kan den samlede miljøvirkningen av Lerum's transport for månedene januar til og med september 2012 bestemmes.

Tabell 3 Samlede miljøvirkninger av godstransport Lerum januar til og med september 2012

	TJ	GWh	Tonn CO2-ekv	Tonn TOPP-ekv	Tonn So2-ekv
Framdrift	7,7	2,1	570,3	5,8	3,6
Drivstoff	0,8	0,2	55,4		
Infrastruktur	0,4	0,1	20,2		
Transportmiddel	1,1	0,3	88,6	0,4	0,4
Sum	10,0	2,8	734,5	6,2	4,0

Alternativ transport

Hva ville miljøvirkningene vært om den samme mengde gods ville blitt fraktet med andre transportmidler? Vi skal se på disse alternativene:

- Sjøtransport til Oslo, Bergen eller Trondheim.
- Transport med lastebil til Gol og transport videre med jernbane til Østlandet.
- Transport med lastebil til Voss og transport med jernbane videre til Bergen.
- Transport med lastebil til Otta og jernbane videre til Trondheim.

For å gjøre realistiske sammenlikninger tar vi utgangspunkt i noen ruter og beregner miljøeffekten av å frakte en viss mengde gods langs disse rutene med ulike transportmidler. For sjøtransport antas et frakteskip med 1000 tonn dødvekt, det vil si en lastekapasitet på 1 000 tonn. Vi bruker utslippsfaktorer for en gruppe med frakteskip med middelverdi 3000 tonn dødvekt [11]. Vi gjør en forenkling og tar bare hensyn til frakt til leveringssted. Dermed tar vi ikke hensyn til eventuell tomkjøring tilbake fra leveringsstedet. Vi antar videre at transportmidlene utnytter full lastekapasitet.

Det finnes mange ulike vektbegrep i forbindelse med skip. De fleste av vektene måler hvor mye last skipet kan frakte. Dette har sin historiske bakgrunn i at skip betaler havne-avgifter og avgifter til Suez-kanalen og Panama-kanalen etter hvor mye last de kan frakte. Jo mer last, jo mer profitabel er frakten og jo høyere er avgiftene. Skipets lastekapasitet måles med dødvekten på skipet. Dødvekten er den totale vekt et skip kan frakte medregnet motor-rom, oppholdsrom for mannskap, drivstoff, utrustning og ballast-tanker. Dødvekten er differensen mellom vekten på vannet som skipet fortrenger med full last og utrustning og vekten som vannet fortrenger bare med sin egen vekt. Den siste vekten kalles lettvekt(”lightweight”) og er altså skipets egenvekt fullstendig uten last, utrustning og drivstoff. Summen av dødvekt og lettvekt kalles fortrengnings-vekten (”displacement weight”).

Vi antar at skipet er 100% fullastet ved sjøtransport. For å frakte 1000 tonn trengs det 34 lastebiler siden hver lastebil kan ta maksimalt 30 tonn. Lerum Fabrikker ligger rett ved sjøkanten i Sogndal. I tillegg til sjøtransport må det beregnes frakt fra terminal på mottaksstedet til endelig levering kunde. Vi må derfor på hvert leveringssted regne med frakt til en konkret kunde. Derom kunden er ASKO Øst i Vestby vil transport med skip omfatte sjøtransport fra Sogndal til Oslo og transport med tyngre lastebil fra kai Oslo til Vestby Om vi regner med frakt til Tollbukaia i Oslo er det 42,6 km videre til Dehlitoppen på Vestby hvor ASKO Øst er lokalisert.

På tilsvarende måte må vi regne med frakt fra jernbaneterminal i Oslo til Vestby. Distansen som fraktes med jernbane regnes som lik distansen med lastebil fra Voss til Bergen og fra Otta til Trondheim. Når det gjelder distanse til sjøs har vi brukt en online kalkulator[12] for å beregne distansen i fra Bergen til Oslo, Larvik eller Trondheim. Tabell 4 viser resultatet. Avstanden Sogndal-Bergen er 121,21 nautiske mil [13] som tilsvarer 224,5 km. Avstand for jernbane er hentet fra Wikipedia og avstand for semitrailer er hentet fra Google Maps. Det er regnet med at det trengs bare ett godstog for å frakte 1000 tonn.

Tabell 4 Distanse sjøveien

Fra	Til	Nautiske mil	km

[11] Simonsen, M. : *Transport, energi og miljø*. VF-Rapport 2/2010, ISBN 978-82-428-0297-2 http://vfp1.vestforsk.no/sip/pdf/Felles/Sluttrapport.pdf og Simonsen, M.: *Godstransport med skip*, http://vfp1.vestforsk.no/sip/pdf/Skip/SkipGodstransport.pdf

[12] http://www.searates.com/reference/portdistance/?

[13] http://www.dataloy.com/ og http://dataloy.com/ddt-server/showRoute.jsp?distance_ids=418959611&date=27.0.2011.12.0&ports=SOGNDAL-BERGEN&speed=13

Bergen	Larvik	305,0	564,9
Bergen	Oslo	371,0	687,1
Bergen	Trondheim	296,0	548,2
Sogndal	Bergen	121,2	224,5
Sogndal	Oslo	492,2	911,6
Sogndal	Larvik	426,2	789,3
Sogndal	Trondheim	417,2	772,7

For å beregne miljøeffekten av transport sjøveien bruker vi utslippsfaktorer for godstransport til sjøs utarbeidet av Vestlandsforsking[14,15] .

Tabell 5 Energibruksfaktorer og utslippsfaktorer for godstransport med skip pr tonn-km

	MJ pr tonn-km	gram CO2-ekvivalenter pr tonn-km	gram SO2-ekvivalenter pr tonn-km	gram TOPP ekvivalenter pr tonn-km
Framdrift	0,1869	13,9	0,38	0,3
Infrastruktur	0,000011	0,0013		
Bygging og vedlikehold skip	0,0103	0,86		
Drivstoff	0,0357	0,41	0,04	0,02

Fra samme sted henter vi energibruksfaktorer og utslippsfaktorer for godstransport med jernbane. Vi antar at godstoget har elektrisk drift og vi regner videre med at elektrisiteten kommer fra norsk vannkraft. Jernbaneverket har leveringssertifikater som garanterer at elektrisiteten som leveres til jernbanens nett kommer fra norsk vannkraft [16].

Tabell 6 Energibruksfaktorer og utslippsfaktorer for godstransport med jernbane pr tonn-km

Jernbane	MJ	gram CO2-ekvivalenter	gram SO2-ekvivalenter	gram TOPP ekvivalenter
Framdrift	0,252	0	0	0
Infrastruktur	0,298	21,7		
Bygging og vedlikehold skip	0,003	0,3		
Drivstoff	0,057	0,7	0,001	0,002
Sum	0,61	22,7	0,001	0,002

Rute 1: Sjøtransport Sogndal-ASKO Øst, Vestby

Vi skal først se på transport av 1000 tonn saft og syltetøy sjøveien fra Sogndal til Vestby. Lasten fraktes med frakteskip til Tollbukaia i Oslo og deretter med tung lastebil fra Tollbukaia til Dehlitoppen

[14] http://transport.vestforsk.no/
[15] http://vfp1.vestforsk.no/sip/pdf/Felles/Sluttrapport.pdf
[16] Høyer, K.G.: Høyhastighetstog, Høgskolen i Oslo, TDM-Rapport 1/09, s 39

i Vestby hvor ASKO Øst holder til. For transport med tungt kjøretøy til Vestby brukes samme utslippsfaktorer som i beregningen av miljøeffekt av godstransport ved Lerum Frakt ovenfor.

Tabell 7 Beregnede tonn-km for transport med sjø og landevei fra Sogndal til Vestby

Fra	Til	km	Tonn-km	Transportmiddel
Sogndal	Oslo	911,6	911 572,9	Skip
Oslo	Vestby	42,6	42 600,0	Semitrailer
Sum			954 172,9	

Tabell 8 viser samlet miljøeffekt av transport av 1000 tonn med skip fra Sogndal til Oslo. Den samlede produksjon er på nesten 954 000 tonn-km. Tabell 9 viser effekten av transport med semitrailer med inntil 30 tonn nyttelast fra Oslo til Vestby. Tabell 10 viser de samlede miljøeffektene for hele transporten Sogndal-Vestby med skip og semitrailer. Det samlede energiforbruket for transport av 1000 tonn gods er på 269 GJ eller 74 722 kWh. De samlede utslipp av CO2-ekvivalenter er på 18 tonn mens det slippes ut 0,4 tonn SO2-ekvivalenter og 0,3 tonn TOPP-ekvivalenter..

Tabell 8 Miljøeffekt Sogndal-Oslo med skip

	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	170,4	12,7	0,3	0,3
Infrastruktur	0	0		
Bygging og vedlikehold skip	9,4	0,8		
Drivstoff	32,5	0,4	0	0
Sum	212,3	13,8	0,4	0,3

Tabell 9 Miljøeffekt Oslo-Vestby semitrailer

Lastebil	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	43,5	3,24	0	0
Infrastruktur	4,7	0,31		
Bygging og vedlikehold lastebil	2,1	0,11		
Drivstoff	6,4	0,5	0	0
Sum	56,7	4,2	0	0

Tabell 10 Samlet miljøeffekt Sogndal-Vestby med skip og semitrailer

Sum	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	213,8	15,9	0,4	0,3

Infrastruktur	4,7	0,3	0	0
Bygging og vedlikehold transportmiddel	11,5	0,9	0	0
Drivstoff	38,9	0,9	0	0
Sum	269	18	0,4	0,3

Hva ville miljøeffekten vært om den samme mengde gods blir transportert landeveien med semitrailer slik tilfellet er i dag? Avstanden fra Lerum Frakt på Kaupanger til Vestby er på 384 km. Det skal fraktes 1000 tonn med gods og den totale produksjon blir dermed på 384 000 tonn-km. Vi bruker de samme energibruks- og utslippsfaktorene som i analysen av samlede miljøvirkninger av Lerum's transport ovenfor.

Tabell 11 viser miljøeffekten av å bruke bare semitrailer på frakt av 1000 tonn gods fra Sogndal til Vestby. Det brukes 1,9 ganger mer energi med bare semitrailer enn med kombinasjonen skip-semitrailer. Utslippene av CO2-ekvivalenter er over dobbelt så store dersom bare semitrailer benyttes. Ser vi på utslipp av SO2-ekvivalenter er utslippene halvparten så store med bare semitrailer mens utslippene av TOPP-ekvivalenter er omlag de samme selv om antall tonn-km er nesten 2,5 ganger større med sjøtransport. Pr tonn-km er dermed utslippene av TOPP-ekvivalenter mindre med sjøtransport.

Tabell 11 Miljøeffekt Sogndal-Vestby bare med semitrailer.

Bare lastebil	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalanter	Tonn TOPP ekvivalenter
Framdrift	391,7	29,2	0,2	0,3
Infrastruktur	42,2	2,8		
Bygging og vedlikehold transportmiddel	19,2	1		
Drivstoff	57,6	4,5	0	0
Sum	510,7	37,6	0,2	0,3

Rute 2: Semitrailer Kaupanger-Gol, togtransport Gol-ASKO Øst, Vestby

I denne beregningen antar vi transport av varer med semitrailer til Gol, omlasting til godstog på Gol, transport med godstog til terminal i Oslo og videre transport med semitrailer fra terminal til Vestby. For å kunne gjøre sammenlikninger med sjøtransport antar vi at 1000 tonn fraktes til ASKO Øst på denne måten.

Det er 136 km fra Lerum Frakt på Kaupanger til jernbanestasjon på Gol. Det er 237 km fra Gol jernbanestasjon til Oslo S [17]. Vi bruker samme distanse til Alnabru. Fra Alnabru til ASKO Øst på Delitoppen i Vestby er det 46,9 km.

Tabell 12 Distanser og tonn-km for transport av gods med semitrailer og jernbane til ASKO Øst, Vestby

Fra	Til	km	Tonn-km	Merknad

[17] http://no.wikipedia.org/wiki/Bergensbanen

Kaupanger	Gol	136	136 000	Fra Lerum Frakt til jernbanestasjon Gol
Gol	Alnabru	237	237 000	Fra jernbanestasjon Gol til godsterminal Alnabru
Alnabru	ASKO Øst	46,9	46 900	Fra godsterminal Alnabru til ASKO Øst Vestby
Sum		419,9	419 900	

Tabell 13 Miljøeffekt av transport Kaupanger-Gol med semitrailer.

	Kaupanger-Gol			
Semitrailer	Energibruk GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP-ekvivalenter
Framdrift	138,7	10,3	0,1	0,1
Infrastruktur	15	1		
Bygging og vedlikehold lastebil	6,8	0,4		
Drivstoff	20,4	1,6	0	0
Sum	180,9	13,3	0,1	0,1

Tabell 13 viser den samlede miljøeffekt av å transportere 136 000 tonn-km fra Kaupanger til jernbanestasjon på Gol. Tabell 14 viser de samme effekter av transport av 237 000 tonn-km fra Gol jernbanestasjon til godsterminal Alnabru. Vi ser at energibruken med tog er mye mindre mens utslippene av CO2-ekvivalenter utgjør bare 40% av utslippene med semitrailer selv om produksjon i tonn-km er større.

Tabell 14 Miljøeffekt av transport Gol-Alnabru med jernbane

Godstog	Energibruk GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP-ekvivalenter
Framdrift	59,7	0	0	0
Infrastruktur	70,6	5,1		
Bygging og vedlikehold transportmiddel	0,7	0,1		
Drivstoff	13,5	0,2	0	0
Sum	144,6	5,4	0	0

Tabell 15 viser miljøeffekt av transport av 46 900 tonn-km fra Alnabru til Vestby. Utslippene av CO2-ekvivalenter er nesten like store for denne transporten som transporten med godstog fra Gol til Alnabru selv om den siste transporten er over 4 ganger så stor målt i tonn-km.

Tabell 15 Miljøeffekt av transport Alnabru-Vestby med semitrailer

Semitrailer	Energibruk GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP-ekvivalenter
Framdrift	47,8	3,6	0	0

Infrastruktur	5,2	0,3		
Bygging og vedlikehold lastebil	2,3	0,1		
Drivstoff	7	0,6	0	0
Sum	62,4	4,6	0	0

Tabell 16 viser den samlede miljøeffekten av transport av 419 900 tonn-km med semitrailer og godstog fra Kaupanger til Vestby.

Tabell 16 Samlet miljøeffekt av godstransport Kaupanger-Vestby med semitrailer og godstog

Sum	Energibruk GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP-ekvivalenter
Framdrift	246,3	13,9	0,1	0,1
Infrastruktur	90,7	6,5		
Bygging og vedlikehold lastebil	9,9	0,6		
Drivstoff	40,9	2,3	0	0
Sum	387,8	23,3	0,1	0,2

Sammenlikner vi med den samme mengde gods transportert sjøveien til Oslo og deretter med semitrailer til Vestby er samlet energibruk over 1,4 ganger så stor med semitrailer og godstog som med skip og semitrailer. De samlede utslipp av CO2-ekvivalenter er nesten 1,3 ganger så store. Målt med energibruk og utslipp av CO2-ekvivalenter er derfor transport med skip det mest miljøvennlige alternativet. Ser vi på samlede utslipp av SO2-ekvivalenter har derimot alternativet med godstog 28% av utslippene med skip og utslipp av TOPP-ekvivalenter er 46% av tilsvarende utslipp med skip. En konklusjon er derfor at transport med skip er best for energibruk og globale utslipp mens bruk av godstog er best for lokale og regionale utslipp.

Sammenlikner vi kombinasjonen semitrailer-godstog med dagens ordning har transport med godstog 76% av energibruken og 62% av utslipp av CO2-ekvivalenter i forhold til transport med semitrailer. Utslipp av CO2-ekvivalenter utgjør med sjøtransport under 48% av utslippene med semitrailer alene. Sjøtransport er derfor det viktigste tiltaket for å redusere utslipp av CO2-ekvivalenter.

Rute 3: Sjøtransport Sogndal- ICA Distribusjon Bergen,Blomsterdalen

Vi skal i denne delen se på transport av 1000 tonn gods fra Sogndal til Bergen med skip og deretter transport med semitrailer fra kai i Bergen til ICA Distribusjon Bergen som ligger i Lønningsflaten 22, Blomsterdalen ikke langt fra Flesland Flyplass. Vi bruker de samme energibruksfaktorer for skip og semitrailer som vi har diskutert ovenfor. Vi antar at Hurtigrutekaia (Nøstegaten 30) brukes som kai i Bergen. Vi bruker samme sjøavstand Sogndal-Bergen som ovenfor, 121,21 nautiske mil eller 224,5 km. Avstanden fra Hurtigrutekaia til ICA Distribusjon er 17,5 km. Tabell 18 viser beregnede tonn-km for transport med skip til Bergen og semitrailer til Blomsterdalen.

La oss først se på referansetransporten som er dagens transport med semitrailer fra Kaupanger til Blomsterdalen. Avstanden er 242 km som med 1000 tonn last gir 242 000 tonn-km. Tabell 17 viser miljøeffekten av denne transporten.

Tabell 17 Miljøeffekt Kaupanger-Blomsterdalen med semitrailer

Lastebil	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	246,8	18,39	0,1	0,2
Infrastruktur	26,6	1,79		
Bygging og vedlikehold lastebil	12,1	0,65		
Drivstoff	36,3	2,86	0	0
Sum	321,9	23,7	0,1	0,2

Tabell 18 Beregnede tonn-km for transport med sjø og landevei fra Sogndal til Blomsterdalen

Fra	Til	km	Tonn-km	Transport-middel
Sogndal	Hurtigrutekai, Bergen	224,5	224 481	Skip
Hurtigrutekai, Bergen	ICA Distribusjon, Blomsterdalen	17,5	17 500	Semitrailer
Sum		241 981		

Tabell 19 viser miljøeffekten av sjøtransport av 224 481 tonn-km fra Sogndal-Bergen. Tabell 20 viser miljøeffekten av transport av 17 500 tonn-km med semitrailer fra Hurtigrutekaia til ICA Distribusjon Blomsterdalen og Tabell 21 viser samlet miljøeffekt av hele transporten Sogndal-Blomsterdalen med skip og semitrailer

Tabell 19 Miljøeffekt sjøtransport Sogndal-Bergen

Skip	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	42	3,1	0,1	0,1
Infrastruktur	0	0		

Bygging og vedlikehold skip	2,3	0,2		
Drivstoff	8	0,1	0	0
Sum	52,3	3,4	0,1	0,1

Tabell 20 Miljøeffekt transport Hurtigrutekaia-Blomsterdalen med semitrailer

Lastebil	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	17,9	1,33	0	0
Infrastruktur	1,9	0,13		
Bygging og vedlikehold lastebil	0,9	0,05		
Drivstoff	2,6	0,21	0	0
Sum	23,3	1,7	0	0

Tabell 21 Samlet miljøeffekt av sjøtransport Sogndal-Bergen og transport semitrailer Hurtigrutekaia-Blomsterdalen

Sum	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	59,8	4,5	0,1	0,1
Infrastruktur	1,9	0,1	0	0
Bygging og vedlikehold lastebil	3,2	0,2	0	0
Drivstoff	10,6	0,3	0	0
Sum	75,6	5,1	0,1	0,1

Tabell 21 viser at energibruken med skip og semitrailer er 23% av energibruk med semitrailer alene mens utslippene av CO2-ekvivalenter med sjøtransport er 22% av tilsvarende utslipp med semitrailer. Utslippene av SO2-ekvivalenter og TOPP-ekvivalenter er omlag de samme med noenlunde samme produksjon av tonn-km.

Rute 4: Semitrailer Kaupanger-Voss, togtransport Voss-Bergen, semitrailer Bergen-Blomsterdalen

Tabell 22 viser avstander og beregnede tonn-km for strekningen Kaupanger-Blomsterdalen med semitrailer og godstog. Til sammen blir det produsert nesten 250 000 tonn-km for hele transporten. Vi har antatt at jernbanestasjonen i Bergen også fungerer som godsterminal.

Tabell 23 viser miljøeffekten av transport av 1000 tonn fra Kaupanger til Voss jernbanestasjon. Tabell 24 viser miljøeffekt av transport av samme last fra Voss til Bergen med godstog. Vi ser at produksjonen av tonn-km på strekningen Voss-Bergen med godstog er 85% av produksjonen av tonn-km fra Kaupanger til Voss med semitrailer. Likevel er energibruken med godstog bare 39% av energibruken med semitrailer og utslippene av CO2-ekvivalenter er under 20%. Tabell 25 viser miljøeffekt av transport Bergen jernbanestasjon til ICA Distribusjon i Blomsterdalen med semitrailer mens Tabell 26 viser samlet miljøeffekt for hele transporten Kaupanger-Blomsterdalen.

Tabell 22 Avstander og beregnet tonn-km for transport lastebil og godstog Kaupanger-Blomsterdalen

Avstander		km	Tonn-km	
Kaupanger	Voss jernbanestasjon	126	126000	Semitrailer
Voss jernbanestasjon	Bergen jernbanestasjon	106,68	106680	Godstog[18]
Bergen jernbanestasjon	Blomsterdalen	16,8	16800	Semitrailer
Sum		249,48	249 480	

Tabell 23 Miljøeffekt av transport Kaupanger-Voss jernbanestasjon med semitrailer

Lastebil	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	128,5	9,58	0,1	0,1
Infrastruktur	13,9		0,93	
Bygging og vedlikehold lastebil	6,3	0,34		
Drivstoff	18,9	1,49	0	0
Sum	167,6	12,3	0,1	0,1

Tabell 24 Miljøeffekt av transport Voss-Bergen med godstog

Godstog	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	26,9	0	0	0
Infrastruktur	31,8	2,31		
Bygging og vedlikehold transportmiddel	0,3	0,03		
Drivstoff	6,1	0,07	0	0
Sum	65,1	2,4	0	0

Tabell 25 Miljøeffekt av transport Bergen-Blomsterdalen med semitrailer

Lastebil	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	17,1	1,28	0	0

[18] http://no.wikipedia.org/wiki/Bergensbanen

Infrastruktur	1,8	0,12		
Bygging og vedlikehold lastebil	0,8	0,05		
Drivstoff	2,5	0,2	0	0
Sum	22,3	1,6	0	0

Tabell 26 Samlet miljøeffekt av transport Bergen-Blomsterdalen med semitrailer og godstog

Sum	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	172,5	10,9	0,1	0,1
Infrastruktur	47,5	3,4		
Bygging og vedlikehold lastebil	7,5	0,4		
Drivstoff	27,5	1,8	0	0
Sum	255	16,4	0,1	0,1

Om vi sammenlikner med sjøtransport til Bergen og videre til Blomsterdalen er energibruken med godstog 3,3 ganger høyere og utslipp av CO2-ekvivalenter 3,2 ganger høyere. Om vi sammenlikner med transport av samme last bare med semitrailer er energibruken for alternativet med godstog 79% av energibruken for alternativet med bare semitrailer og de tilsvarende utslipp av CO2-ekvivalenter er 69%. Konklusjonen blir derfor at sjøtransport til Bergen er det klart mest miljøvennlige alternativ. Strekningen med godstog er for liten til at dette transportmiddelet kan ha noen avgjørende effekt på miljøeffekten av den samlede transporten.

Rute 5: Sjøtransport Sogndal- REMA Distribusjon, Heimdal

I dette alternativet forutsettes veitransport over Sognefjellet til Otta. Alternativet er derfor bare aktuelt så lenge Sognefjellet er åpent for trafikk med tyngre kjøretøy. Referansetransporten er transport fra Lerum Frakt, Kaupanger til REMA Distribusjon avdeling Trondheim på Heimdal utenfor Trondheim. Distansen fra Lerum Frakt til RENA Distribusjon Heimdal er 418 km. Med frakt av 1000 tonn blir det 418 000 tonn-km.

Tabell 27 Miljøeffekt av transport Kaupanger-Heimdal med semitrailer

Lastebil	GJ	TonnCO2-ekv	Tonn SO2-ekv	Tonn TOPP ekv
Framdrift	426,4	31,77	0,2	0,3
Infrastruktur	46	3,08		
Bygging og vedlikehold lastebil	20,9	1,12		
Drivstoff	62,7	4,94	0	0
Sum	555,9	40,9	0,2	0,3

Tabell 27 viser miljøeffekten av transport fra Lerum Frakt Kaupanger til REMA Distribusjon Heimdal med semitrailer. Dette er referansetransporten for sammenlikning med andre transportalternativ. Tabell 28 viser avstander med skip fra Sogndal til Trondheim og beregnet produksjon av tonn-km for transporten. Samlet produksjon er på litt under 632 000 tonn-km. Det er antatt lossing av skip og lasting av semitrailere ved Hurtigrutekaia i Trondheim. Avstanden fra Sogndal til Trondheim sjøveien er 333 nautiske mil.

Tabell 28 Distanser og beregnet transportarbeid sjøtransport Sogndal-Trondheim

Fra	Til	km	Tonn-km	Transportmiddel
Sogndal	Trondheim	616,7	616716	Skip [19]
Trondheim	Heimdal	15,1	15100	Semitrailer
Sum		631,8	631816	

Tabell 29 Miljøeffekt av sjøtransport Sogndal-Trondheim Hurtigrutekai

	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	115,3	8,6	0,2	0,2
Infrastruktur	0	0		
Bygging og vedlikehold skip	6,4	0,5		
Drivstoff	22	0,3	0	0
Sum	143,6	9,4	0,3	0,2

Tabell 30 Miljøeffekt av transport Hurtigrutekai Trondheim - Heimdal med semitrailer

Lastebil	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	15,4	1,15	0	0
Infrastruktur	1,7	0,11		
Bygging og vedlikehold lastebil	0,8	0,04		
Drivstoff	2,3	0,18	0	0
Sum	20,1	1,5	0	0

Tabell 29 viser miljøeffekten av sjøtransport Sogndal-Trondheim. Tabell 30 viser miljøeffekten av transport med semitrailer fra Hurtigrutekaia i Trondheim til REMA Distribusjon Heimdal. Energibruken med skip og semitrailer utgjør 29% av energibruken til referansetransporten. De samlede utslipp av CO2-ekvivalenter utgjør 26% av referansetransporten. Utslipp av SO2-ekvivalenter er nesten 1,2 ganger større mens utslipp av TOPP-ekvivalenter er 60% av referansetransporten. Sjøtransport framstår derfor som et miljøvennlig alternativ til transport over landevei til Trondheim fra Sogndal.

[19] Distansen er hentet fra http://www.dataloy.com/

Tabell 31 Samlet miljøeffekt av transport Sogndal-Trondheim med skip og semitrailer

Sum	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	130,7	9,7	0,2	0,2
Infrastruktur	1,7	0,1		
Bygging og vedlikehold transportmiddel	7,1	0,6		
Drivstoff	24,3	0,4	0	0
Sum	163,7	10,8	0,3	0,2

Rute 6: Kaupanger- REMA Distribusjon, Heimdal med semitrailer og godstog

I dette alternativet skal vi se på transport av 1000 tonn med semitrailer til Otta, omlasting til godstog videre til Trondheim og transport med semitrailer fra sentralbanestasjon i Trondheim til REMA Distribusjon på Heimdal. Det forutsettes at godsterminal for jernbane i Trondheim er sentralbanestasjonen.

Tabell 32 Avstander og beregnet transportarbeid Kaupanger-Trondheim-Heimdal med semitrailer og godstog

Avstander		km	Tonn-km	Transportmiddel
Kaupanger	Otta jernbanestasjon	205	205000	Semitrailer
Otta jernbanestasjon	Trondheim jernbanestasjon	255,63	255630	Godstog
Trondheim jernbanestasjon	Heimdal	13,8	13800	Semitrailer
Sum		474,43	474430	

Tabell 33 Miljøeffekt transport Kaupanger-Otta jernbanestasjon med semitrailer

Lastebil	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	209,1	15,58	0,1	0,2
Infrastruktur	22,6	1,51		
Bygging og vedlikehold lastebil	10,3	0,55		
Drivstoff	30,8	2,42	0	0
Sum	272,7	20,1	0,1	0,2

Tabell 34 viser miljøeffekt av transport med semitrailer fra Kaupanger over Sognefjellet til jernbanestasjon i Otta. Tabell 35 viser miljøeffekt av transport med godstog fra Otta til Trondheim og Tabell 36 viser miljøeffekt av transport med semitrailer fra Trondheim sentralbanestasjon til REMA Distribusjon Heimdal.

Tabell 34 Miljøeffekt transport godstog Otta-Trondheim

Godstog	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	64,4	0	0	0
Infrastruktur	76,2	5,55		
Bygging og vedlikehold transportmiddel	0,8	0,08		
Drivstoff	14,6	0,18	0	0
Sum	155,9	5,8	0	0

Tabell 35 Miljøeffekt av transport Trondheim sentralbanestasjon-Heimdal med semitrailer

Lastebil	GJ	Tonn CO2-ekvivalenter	Tonn SO2-ekvivalenter	Tonn TOPP ekvivalenter
Framdrift	14,1	1,05	0	0
Infrastruktur	1,5	0,1		
Bygging og vedlikehold lastebil	0,7	0,04		
Drivstoff	2,1	0,16	0	0
Sum	18,4	1,4	0	0

Tabell 36 Samlet miljøeffekt av transport Kaupanger-Heimdal med semitrailer og godstog

Sum	GJ	TonnCO2-ekv	Tonn SO2-ekv	Tonn TOPP ekv
Framdrift	287,6	16,6	0,1	0,2
Infrastruktur	100,2	7,2		
Bygging og vedlikehold lastebil	11,7	0,7		
Drivstoff	47,4	2,8	0	0
Sum	446,9	27,2	0,1	0,2

Tabell 36 viser at transportalternativet med semitrailer og godstog til Heimdal har en energibruk som utgjør 80% av referansetransporten med semitrailer. Utslippene av CO2-ekvivalenter utgjør 67% av referansealternativet mens utslippene av SO2-ekvivalenter og TOPP-ekvivalenter utgjør respektive 44% og 85% av referansealternativet.

Sammenlikner vi alternativet med godstog til Trondheim med alternativet med sjøtransport viser det seg at alternativet med godstog har en energibruk som er 2,7 ganger større mens utslippene av CO2-ekvivalenter er 2,5 ganger større. Utslippene av SO2-ekvivalenter og TOPP-ekvivalenter er derimot lavere. Alternativet med godstog framstår derfor som mindre gunstig med tanke på klimagassutslipp men mer gunstig når det gjelder lokale og regionale utslipp. Transport med semitrailer utgjør 46% av samlet produksjon av tonn-km i godstog-alternativet. Dette er noe av grunnen til at de gunstige miljøeffekter med godstog ikke får sterkere gjennomslag.

Konklusjoner

Vi beregner energibruk og utslipp i den direkte energikjede og den indirekte energikjede. Den direkte energikjede omfatter energi til framdrift av et transportmiddel inklusive energibruk til utvinning, omdanning og distribusjon av energien som benyttes. Den indirekte energikjeden omfatter energibruk for konstruksjon, drifting og vedlikehold av transportmidlenes infrastruktur i tillegg til produksjon og vedlikehold av transportmiddelet selv. For å sammenlikne energibruk og utslipp for produksjon av en tonn-km for ulike transportmiddel tas det hensyn til både direkte og indirekte energibruk. Dette gir den mest fullstendige og konsistente sammenlikning mellom transportmidlene og det beste grunnlaget for å vurdere miljøeffekten av å bruke dem.

Vi har analysert miljøeffekten av å bruke semitrailer på frakt av 1000 tonn gods fra Sogndal til Vestby. Det brukes 1,9 ganger mer energi med bare semitrailer enn kombinasjonen skip-semitrailer. Utslippene av CO2-ekvivalenter er over dobbelt så store dersom bare semitrailer benyttes. Ser vi på utslipp av SO2-ekvivalenter er utslippene halvparten så store med bare semitrailer mens utslippene av TOPP-ekvivalenter er omlag de samme selv om antall tonn-km er nesten 2,5 ganger større med sjøtransport. Pr tonn-km er dermed utslippene av TOPP-ekvivalenter mindre med sjøtransport. SO_2-ekvivalenter måler et sett med komponenters potensial for forsuring. TOPP-ekvivalenter er mål for gassers bidrag til dannelse av bakkenært ozon.

Vi har også analysert effekt av å bruke jernbane og semitrailer på den samme ruten med samme last. Sammenlikner vi med den samme mengde gods transportert sjøveien til Oslo og deretter med semitrailer til Vestby er samlet energibruk over 1,4 ganger så stor med semitrailer og godstog som med skip og semitrailer. De samlede utslipp av CO2-ekvivalenter er nesten 1,3 ganger så store. Målt med energibruk og utslipp av CO2-ekvivalenter er derfor transport med skip det mest miljøvennlige alternativet. Ser vi på samlede utslipp av SO2-ekvivalenter har derimot alternativet med godstog 28% av utslippene med skip og utslipp av TOPP-ekvivalenter er 46% av tilsvarende utslipp med skip. En konklusjon er derfor at transport med skip er best for energibruk og globale utslipp mens bruk av godstog er best for lokale og regionale utslipp.

Videre har vi analysert miljøeffekten av å bruke skip og semitrailer på frakt av 1000 tonn gods fra Sogndal til Blomsterdalen utenfor Bergen. Vi har sammenliknet dette med dagens ordning hvor bare semitrailer benyttes. Analysen viser at energibruken med skip og semitrailer utgjør 23% av energibruk med semitrailer alene mens utslippene av CO2-ekvivalenter med sjøtransport utgjør 22% av tilsvarende utslipp med semitrailer. Utslippene av SO2-ekvivalenter og TOPP-ekvivalenter er omlag de samme med noenlunde samme produksjon av tonn-km.

Vi har også sett på alternativet jernbane-semitrailer på samme strekning Sogndal-Blomsterdalen. Om vi sammenlikner med sjøtransport til Bergen og videre til Blomsterdalen er energibruken med godstog 3,3 ganger høyere og utslipp av CO2-ekvivalenter 3,2 ganger høyere. Om vi sammenlikner med transport av samme last bare med semitrailer er energibruken for alternativet med godstog 79% av energibruken for alternativet med bare semitrailer og de tilsvarende utslipp av CO2-ekvivalenter er 69%. Konklusjonen blir derfor at sjøtransport til Bergen er det klart mest miljøvennlige alternativ. Strekningen med godstog er for liten til at dette transportmiddelet kan ha noen avgjørende effekt på miljøeffekten av den samlede transporten.

Den siste strekningen vi har analysert er Sogndal-Heimdal. Vi har sammenliknet dagens ordning med bare semitrailer med to alternativ: Kombinasjon skip-semitrailer og kombinasjonen jernbane-semitrailer. Energibruken med skip og semitrailer 29% av energibruken med bare semitrailer. De samlede utslipp av CO2-ekvivalenter utgjør 26% av transport med bare semitrailer. Utslipp av SO2-ekvivalenter er nesten 1,2 ganger større mens utslipp av TOPP-ekvivalenter er 60% av transport med bare semitrailer. Sjøtransport framstår derfor som et miljøvennlig alternativ til transport over landevei til Trondheim fra Sogndal.

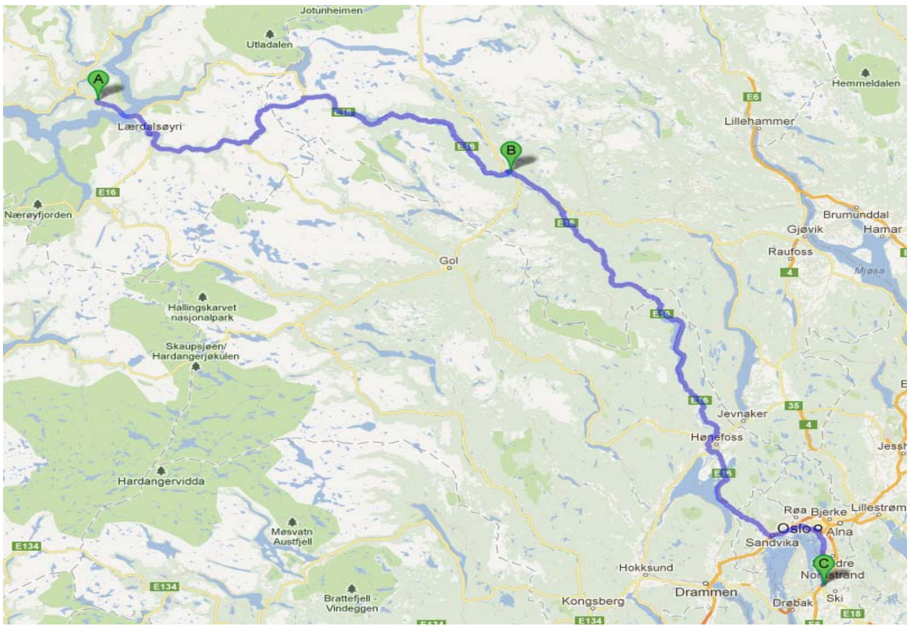
Kombinasjonen godstog og semitrailer til Heimdal har en energibruk som utgjør 80% av transporten med semitrailer. Utslippene av CO2-ekvivalenter utgjør 67% av transport med semitrailer mens utslippene av SO2-ekvivalenter og TOPP-ekvivalenter utgjør respektive 44% og 85% av transport med bare semitrailer.

Sammenlikner vi alternativet med godstog til Trondheim med alternativet med sjøtransport viser det seg at alternativet med godstog har en energibruk som er 2,7 ganger større mens utslippene av CO2-ekvivalenter er 2,5 ganger større. Utslippene av SO2-ekvivalenter og TOPP-ekvivalenter er derimot lavere. Alternativet med godstog framstår derfor som mindre gunstig med tanke på klimagassutslipp men mer gunstig når det gjelder lokale og regionale utslipp. Transport med semitrailer utgjør 46% av samlet produksjon av tonn-km i godstog-alternativet. Dette er noe av grunnen til at de gunstige miljøeffekter med godstog ikke får sterkere gjennomslag.

Ruteanalyse

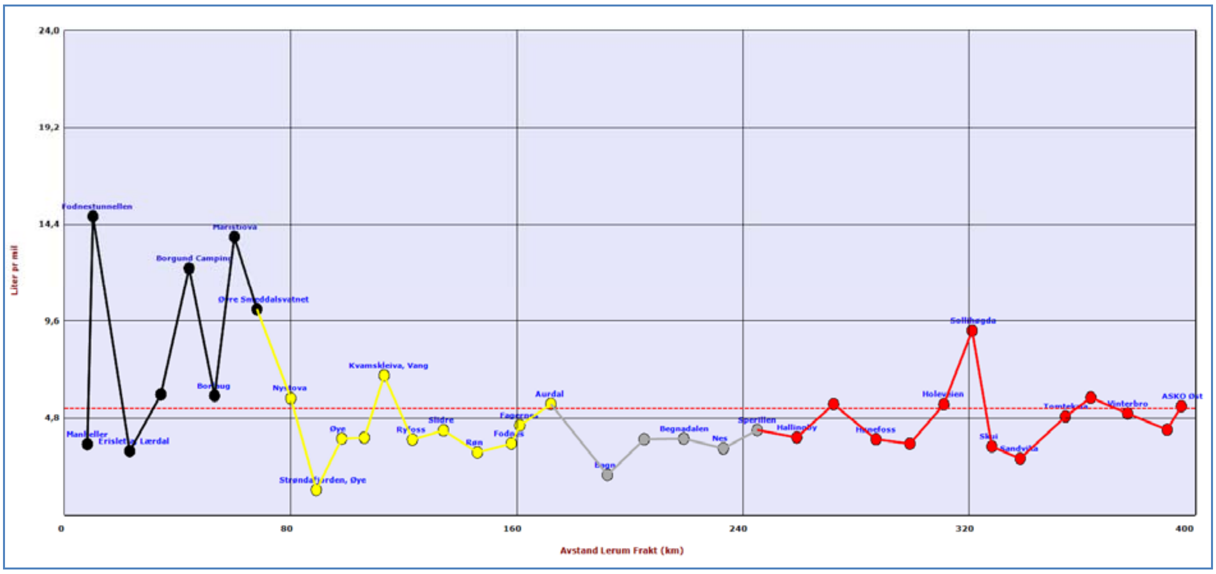
Rute til ASKO Øst Vestby over Filefjell

Figur 20 Rute Kaupanger-ASKO Øst over Filefjell



Lastebil B, 500 hk, semitrailer, 12.6.2012, last 28,3 tonn til UNIL Asko Øst, Vestby. Gjennomsnittlig forbruk: 4,9 liter pr mil.

Figur 21 Drivstofforbruk rute Kaupanger-ASKO Øst over Filefjell

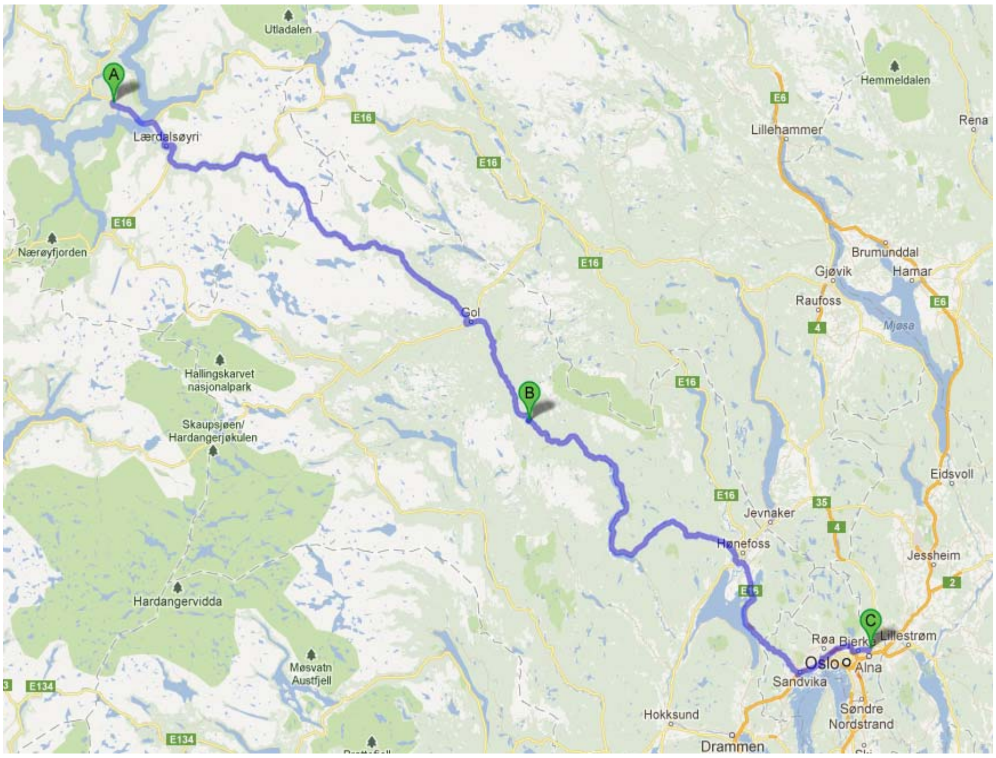


Svart: Sogn og Fjordane (9,4) , Gul: Valdres nord for Bagn (4,2), Grå: Valdres sør for Bagn (3,4), Rød: Sentrale Østlandet (4,8). Liter pr mil i parentes. Hovedinntrykk: Høyest forbruk i stigning opp til Filefjell. Gjennom Valdres stort sett forbruk under gjennomsnittet, lavest forbruk ned Begnadalen fra Bagn til Nes i Ådal. Denne strekningen har også lavest variasjon.

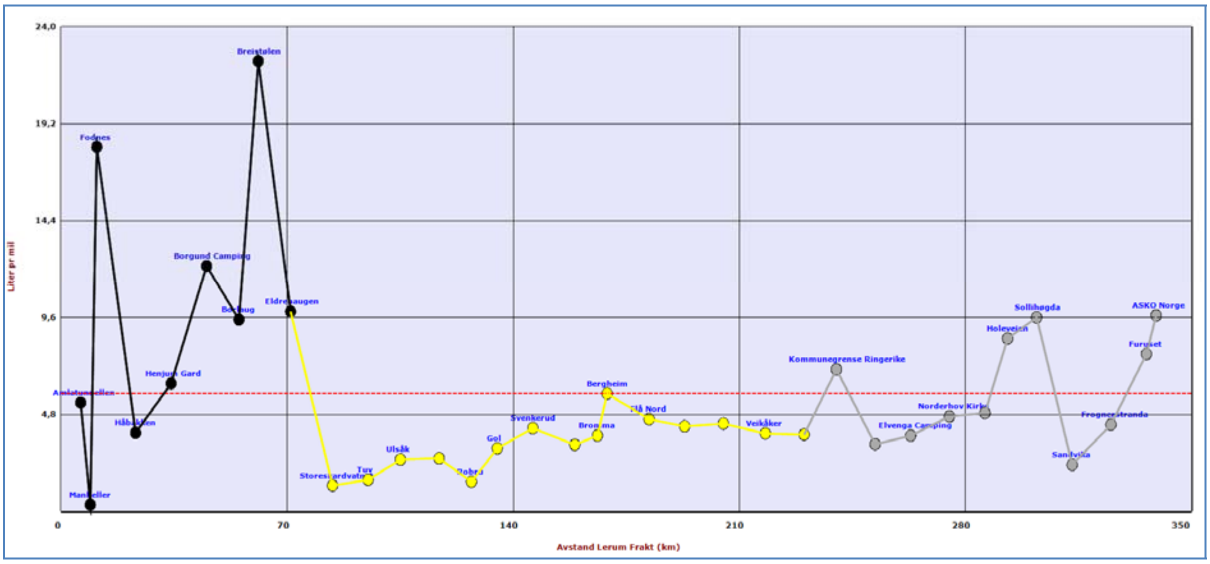
Rute til ASKO Norge Grorud over Hemsedalsfjellet

Lastebil E, 500 hk, semitrailer, 3 juni 2012, last 30 tonn til ASKO Norge, Kalbakkenveien, Oslo. Gjennomsnittlig forbruk: 5,2 liter pr mil. Over Hemsedalsfjellet.

Figur 22 Rute Kaupanger-ASKO Norge over Hemsedalsfjellet



Figur 23 Drivstofforbruk rute Kaupanger-ASKO Norge over Hemsedalsfjellet



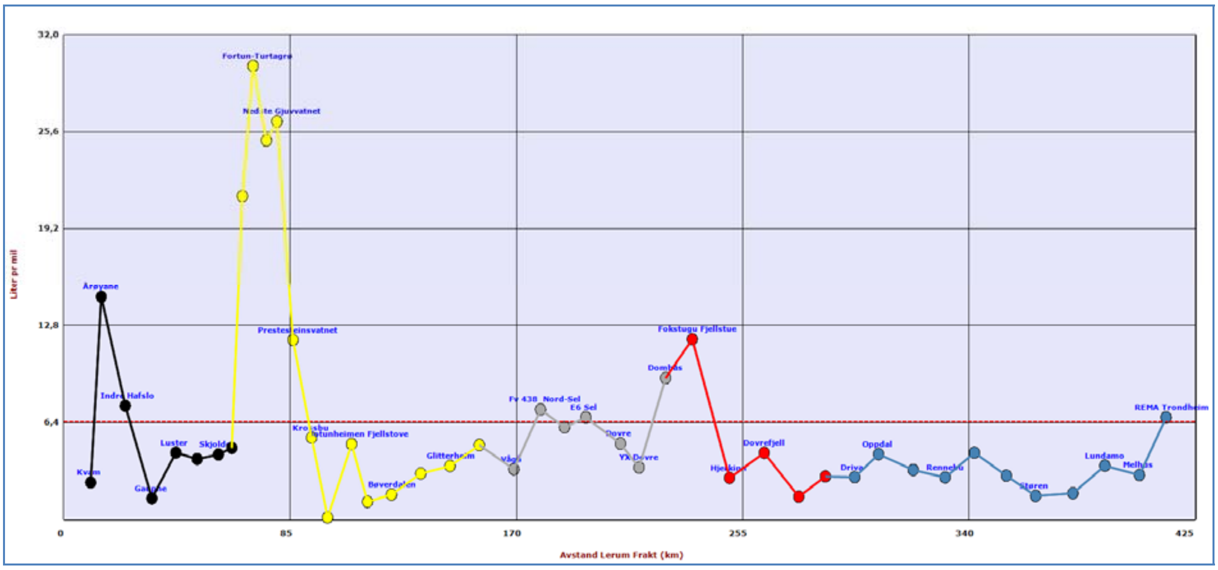
Svart: Sogn og Fjordane (9,8), Gul: Hemsedal-Hallingdal-Krøderen (3,4), Grå: Sentrale Østlandet (6,0). Liter pr mil i parentes. Hovedinntrykk: Større forbruk opp stigning til Hemsedalsfjellet enn til Filefjell. Lavest forbruk nederst i Hemsedal og øverst i Hallingdal. Litt høyere forbruk nederst i Hallingdal sammenliknet med nederst i Valdres. Minst variasjon strekningen Bergheim (Nes) til Veikåker (Krødsherad).

Rute til REMA Distribusjon Heimdal over Sognefjellet

Lastebil F, 500 hk, semitrailer, 1 juli 2012, last 25,9 tonn til REMA Distribusjon, Heimdal. Gjennomsnittlig forbruk: 5,1 liter pr mil. Over Sognefjellet.

Figur 24 Rute Kaupanger-Rema Distribusjon Heimdal over Sognefjellet

Figur 25 Drivstofforbruk rute Kaupanger-Rema Distribusjon Heimdal over Sognefjellet

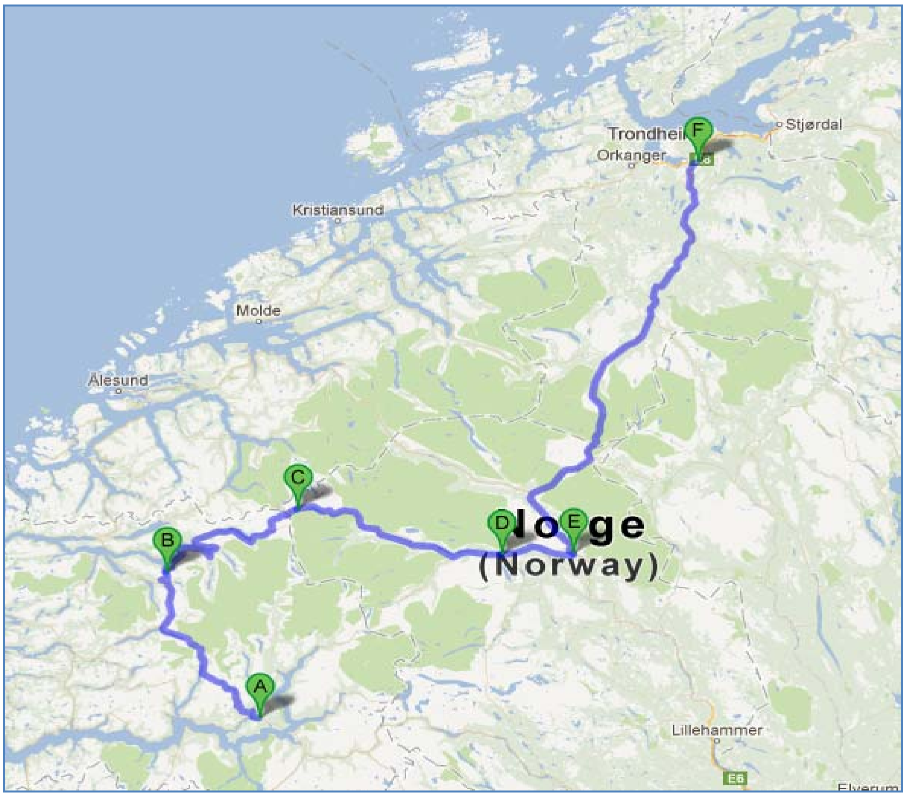


Svart: Indre Sogn (5,4), Gul: Sognefjellet (10.7), Grå: Gudbrandsdal (5,9), Rød: Dovrefjell (4,7), Blå: Trøndelag (3,4). Liter pr mil i parentes). Hovedinntrykk: Høyt forbruk i stigning opp til Sognefjellet. Lavest forbruk med minst variasjon over Dovrefjell og på E6 inn til Trondheim.

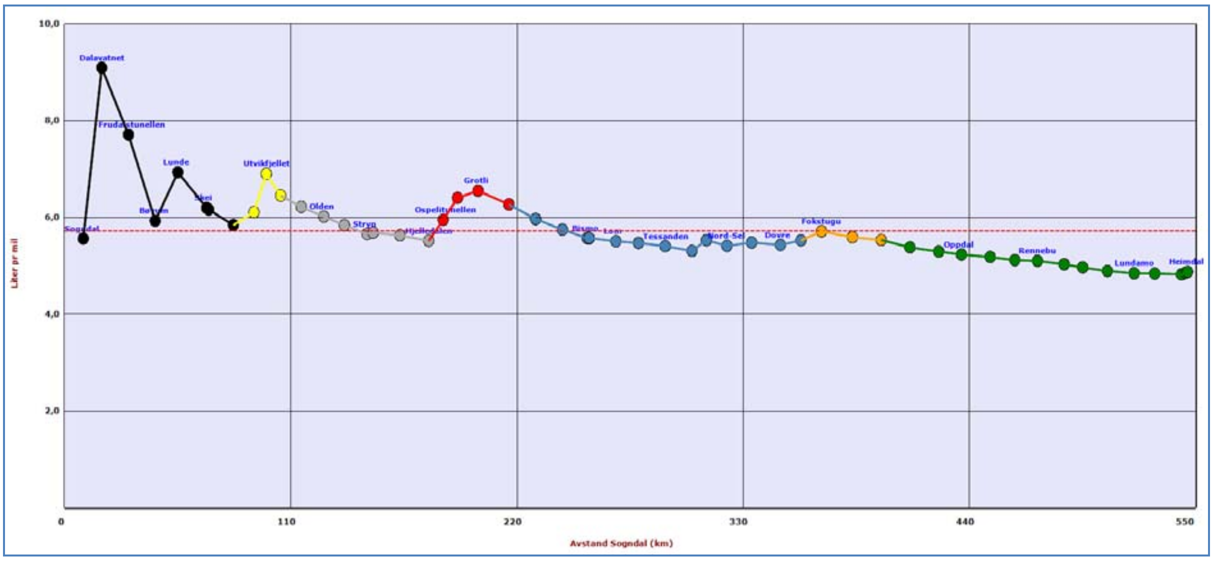
Rute til REMA Distribusjon Heimdal over Strynefjell

Lastebil T, Semitrailer, 500 hk, 25 mars 2012, last 26,9 tonn til Rema Distribusjon, Heimdal. Over Utvikfjellet, Strynefjellet, Dovrefjellet. Forbruk 4,9 liter pr mil.

Figur 26 Rute Kaupanger-Rema Distribusjon Heimdal over Strynefjell



Figur 27 Drivstofforbruk rute Kaupanger-Rema Distribusjon Heimdal over Strynefjell

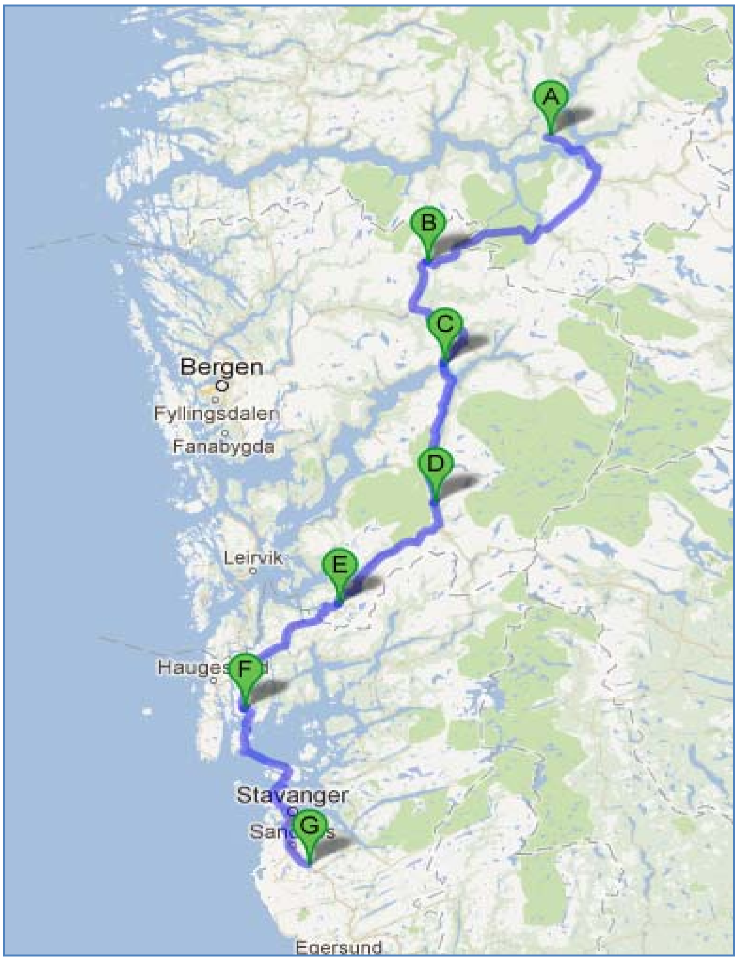


Svart: Sogndal-Byrkjelo (6,7), Gul: Utvikfjellet (6,5), Grå: Stryn (5,8), Rød: Strynefjellet (6,3), Blå: Gudbrandsdalen (5,5), Oransje: Dovrefjell (5,6), Grønn: Sør-Trøndelag (5,0). Gjennomsnitt av disse er 5,7 liter pr mil, det veide gjennomsnittet på 4,9 liter pr mil skyldes at den lengste strekningen er i Sør-Trøndelag. Gjennomsnittet er veid med antall km som vekt. Hovedinntrykk: Variasjon størst Sogndal-Byrkjelo, 4,8 ganger høyere enn Sør-Trøndelag, 6 ganger høyere enn Gudbrandsdalen, nesten 11 ganger høyere enn Dovrefjell. Lavest forbruk med minst variasjon ned Ottadalen, over Dovrefjell og på E6 inn til Trondheim.

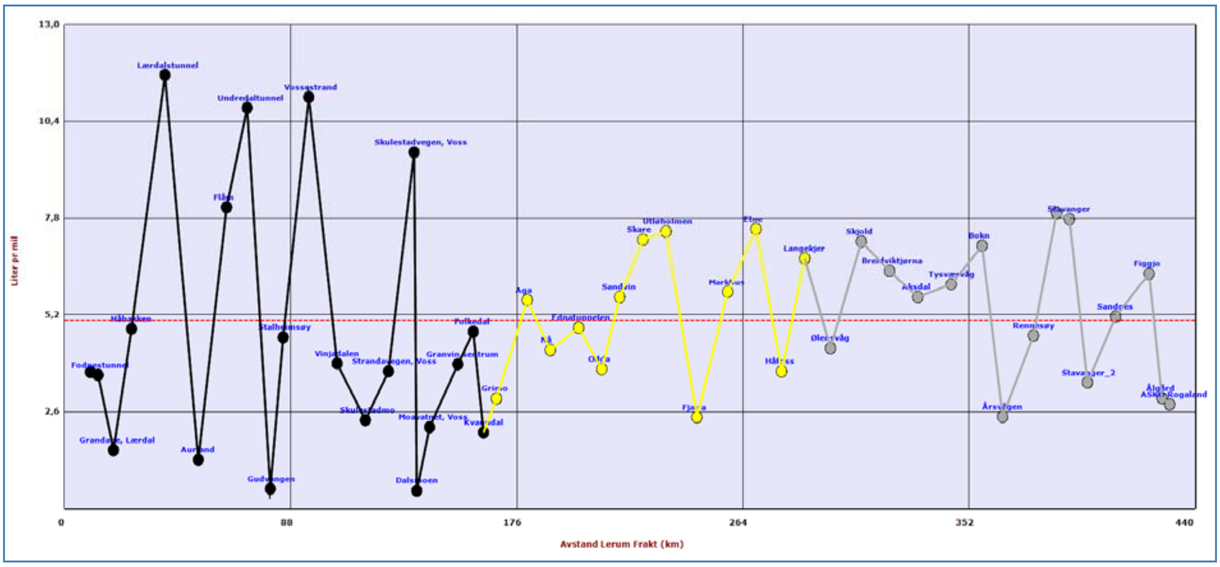
Rute til ASKO Rogaland over Odda

Lastebil E, 500 hk, semitrailer, 21 mars 2012, last 24,4 tonn ASKO Rogaland, Ålgård. Gjennomsnittlig forbruk: 5,7 liter pr mil. Over Hardanger, Odda.

Figur 28 Rute Kaupanger-ASKO Rogaland over Odda



Figur 29 Drivstofforbruk rute Kaupanger-ASKO Rogaland over Odda

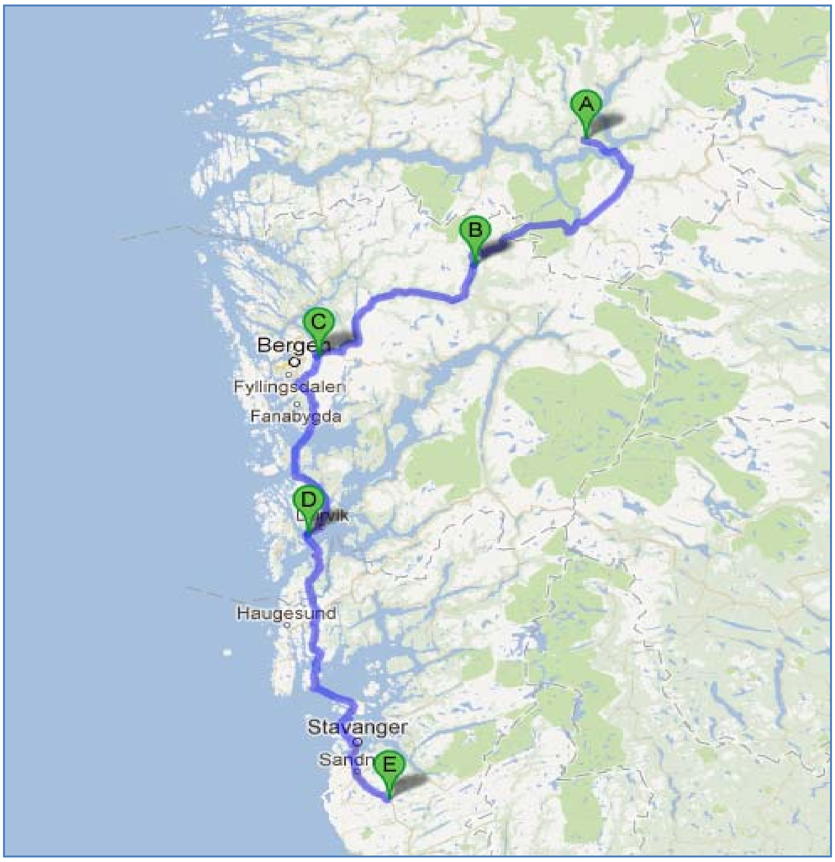


Svart: Sogn/Voss (4,7) , Gul: Hardanger/Åkrafjorden (5,2), Grå: Rogaland (5,3). Liter pr mil i parentes. Variasjon over dobbelt så stor i Sogn/Voss området som resten. Gjennomsnitt for hele turen høyere enn alle gjennomsnitt for delstrekningene, dette skyldes at det er kjørt lengst i de to områdene med høyest forbruk, strekningen utenfor Sogn/Voss veier derfor mest. Hovedinntrykk: Mye mer variasjon enn de andre rutene vi har sett på. Dette gjenspeiler infrastrukturen, trangere og mer svingete veier med mindre mulighet for jamnere fart og forbruk. Størst variasjon i Sogn.

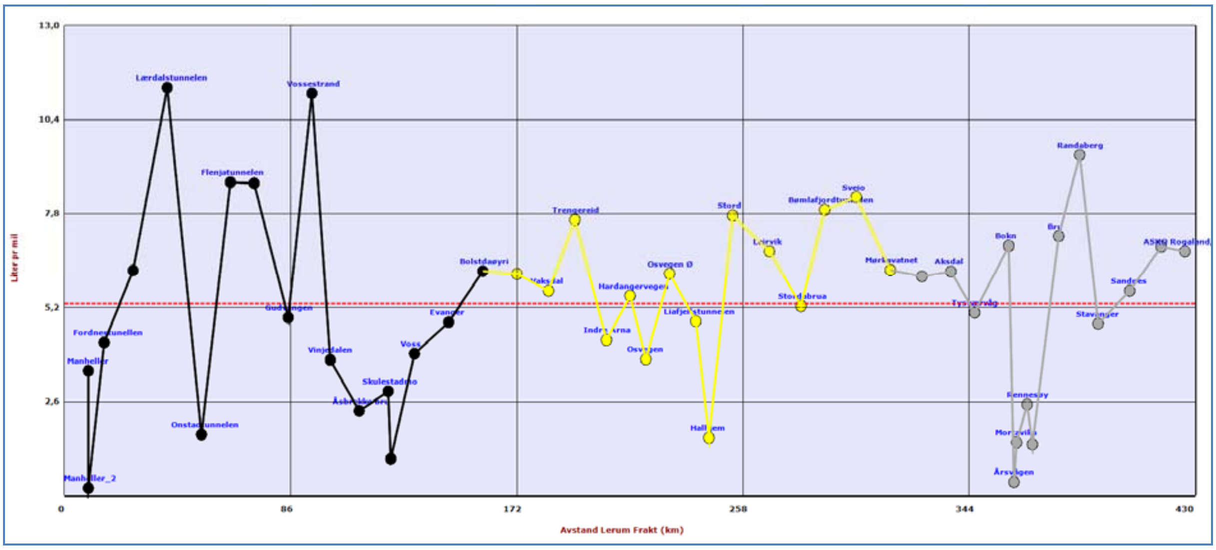
Rute til ASKO Rogaland over Stord

Lastbil J, 500 hk, semitrailer, 19 mars 2012, last 26,3 tonn ASKO Rogaland, Ålgård. Gjennomsnittlig forbruk: 5,7 liter pr mil. Over Indre Arna-Stord.

Figur 30 Rute Kaupanger-ASKO Rogaland over Stord



Figur 31 Drivstofforbruk rute Kaupanger-ASKO Rogaland over Stord

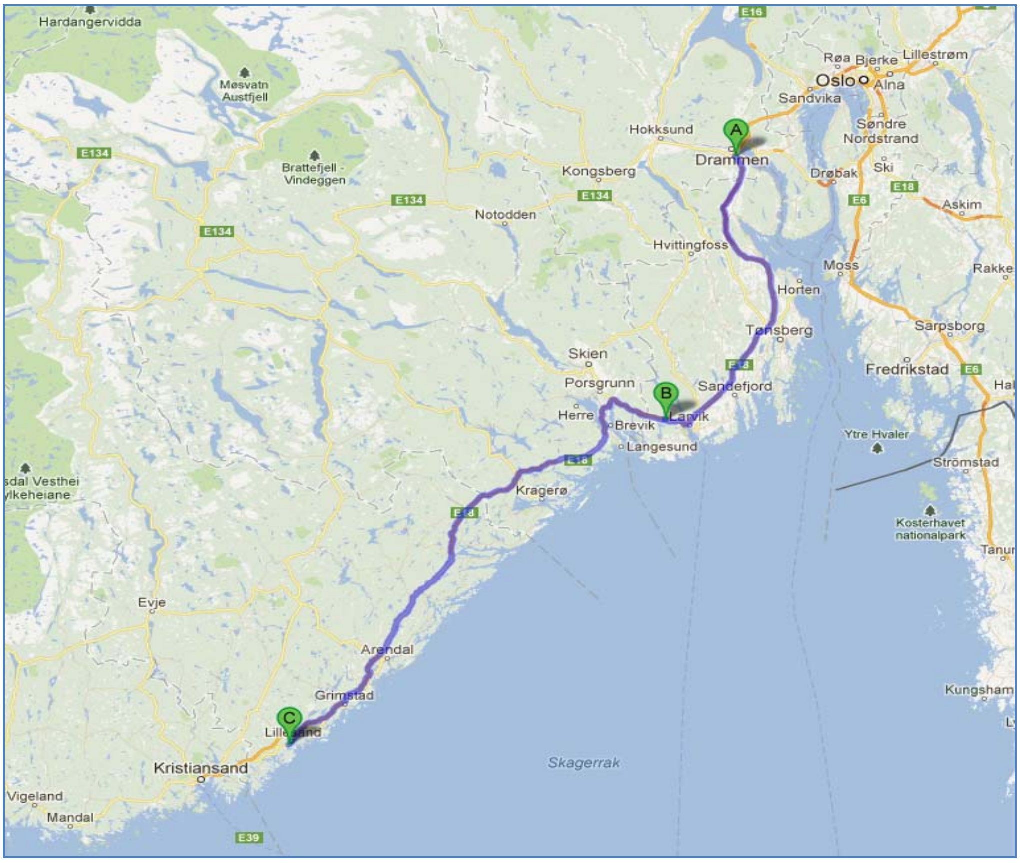


Svart: Sogn/Voss (5,0), Gul: Bergen/Sunnhordaland (5,8), Grå: Rogaland (5,0). Liter pr mil i parentes. Variasjon i Sogn/Voss dobbelt så stor som Bergen/Sunnhordaland. Hovedinntrykk: Samme som forrige rute, mer variasjon og mindre potensiale for jamnere fart og bruk av indikatorer som cruise control og utrullling enn ruter til Østlandet og Trondheim.

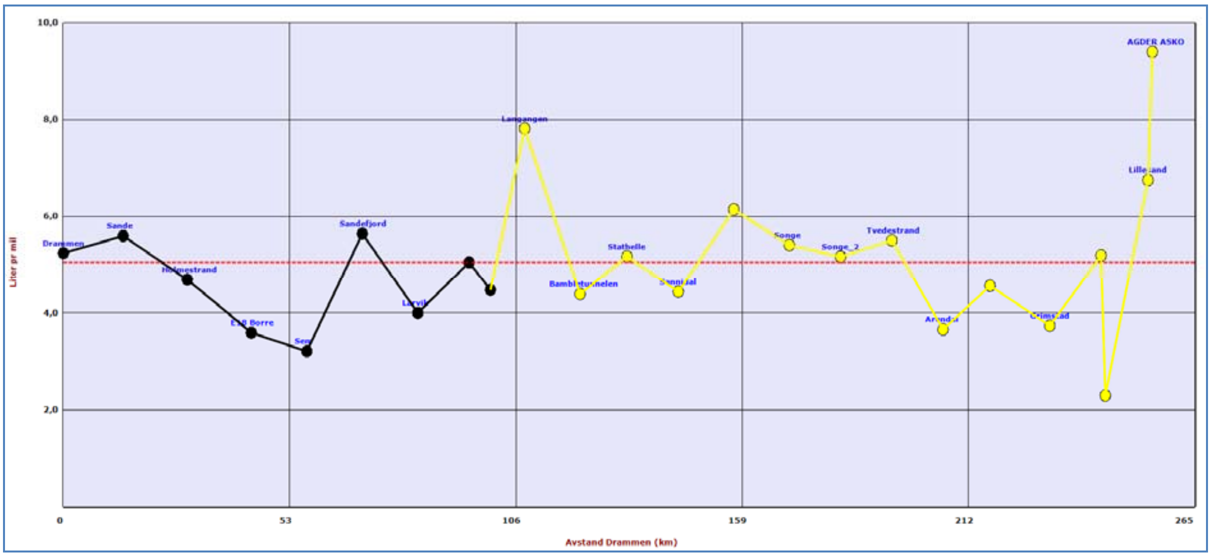
Rute til Drammen-ASKO Agder Lillesand, effekt av motorvei

Drammen Lillesand 25 mars 2012, Lastebil F, 500 hk, semitrailer, last 29,5 tonn til ASKO Agder Lillesand. Effekt av motorvei.

Figur 32 Rute Drammen-ASKO Agder, Lillesand med motorvei Drammen-Larvik



Figur 33 Drivstofforbruk rute Drammen-ASKO Agder, Lillesand med motorvei Drammen-Larvik



Svart: Fire-felts motorvei Drammen-Larvik (4,6), Gul: To-felts vei Larvik-Lillesand (5,3). Liter pr mil i parentes. Hovedinntrykk: Variasjon to-felts vei 1,7 ganger høyere enn fire-felts motorvei. Forbruket på fire-felts motorvei ikke lavere enn forbruk på to-felts vei ned Hallingdal eller Valdres (se rutene ovenfor).

Oppsummering ruteanalyse

Tabell 37 Oppsummering ruteanalyse

Strekning	Dato	Liter pr mil	Laste-vekt tonn	Heste-krefter	Rute
Manheller-Øvre Smedalsvatnet	12.06.2012	9,4	28,3	500	Sogndal-Vestby over Filefjell
Øvre Smedalsvatnet-Aurdal	12.06.2012	4,2	28,3	500	Sogndal-Vestby over Filefjell
Aurdal-Sperillen	12.06.2012	3,4	28,3	500	Sogndal-Vestby over Filefjell
Sperillen - Vestby	12.06.2012	4,8	28,3	500	Sogndal-Vestby over Filefjell
Almatunnelen-Eldrehaugen	03.06.2012	9,8	30	500	Sogndal-Grorud over Hemsedalsfjellet
Eldrehaugen-Hamremoen	03.06.2012	3,4	30	500	Sogndal-Grorud over Hemsedalsfjellet
Hamremoen-Grorud	03.06.2012	6	30	500	Sogndal-Grorud over Hemsedalsfjellet
Kvam-Skjolden	01.07.2012	5,4	25,9	500	Sogndal-Heimdal over Sognefjellet
Skjolden-Lom	01.07.2012	10,7	25,9	500	Sogndal-Heimdal over Sognefjellet
Lom-Dombås	01.07.2012	5,9	25,9	500	Sogndal-Heimdal over Sognefjellet
Dombås-Driva	01.07.2012	4,7	25,9	500	Sogndal-Heimdal over Sognefjellet
Driva-Heimdal	01.07.2012	3,4	25,9	500	Sogndal-Heimdal over Sognefjellet
Sogndal-Byrkjelo	25.03.2012	6,7	26,9	500	Sogndal-Heimdal over Strynefjellet
Byrkjelo-Olden	25.03.2012	6,5	26,9	500	Sogndal-Heimdal over Strynefjellet
Olden-Hjelledalen	25.03.2012	5,8	26,9	500	Sogndal-Heimdal over Strynefjellet
Hjelledalen-Grotli	25.03.2012	6,3	26,9	500	Sogndal-Heimdal over Strynefjellet
Grotli-Fokstugu	25.03.2012	5,5	26,9	500	Sogndal-Heimdal over Strynefjellet
Fokstugu-Oppdal	25.03.2012	5,6	26,9	500	Sogndal-Heimdal over Strynefjellet

Oppdal-Heimdal	25.03.2012	5	26,9	500	Sogndal-Heimdal over Strynefjellet
Fodnes-Kvandal	21.03.2012	4,7	24,4	500	Sogndal-Ålgård over Odda
Kvandal-Langekjer	21.03.2012	5,2	24,4	500	Sogndal-Ålgård over Odda
Langekjer-Ålgård	21.03.2012	5,3	24,4	500	Sogndal-Ålgård over Odda
Manheller-Bolsadøyri	19.03.2012	5	26,3	500	Sogndal-Ålgård over Stord
Bolstadøyri-Mørkavatnet	19.03.2012	5,8	26,3	500	Sogndal-Ålgård over Stord
Mørkavatnet-Ålgård	19.03.2012	5	26,3	500	Sogndal-Ålgård over Stord
Drammen-Langangen	25.03.2012	4,6	29,5	500	Drammen-Lillesand
Langangen-Lillesand	25.03.2012	5,3	29,5	500	Drammen-Lillesand

Lastebilrapporter

Det er utarbeidet lastebilrapporter for hver lastebil som har installert Dynafleet. Figur 34 viser en månedrapport for lastebil N. De røde feltene markerer at lastebilen ikke oppfyller målsettinger satt av Lerum Frakt BA for den aktuelle kjøreindikator. De blå feltene markerer at lastebilen oppfyller målsettingen for den aktuelle indikator. Det er laget en slik rapport for hver lastebil for hver måned lastebilen har vært i bruk for 2012.

Rapportene er laget ved hjelp av makroer i Excel. For hver lastebil gjøres det oppslag i en database som returnerer de aktuelle data for lastebilen som blir brukt i rapporten. Excel-arket inneholder grafiske objekt (seleksjonslister) som gjør det mulig å velge lastebil og år. Deretter blir rapporten automatisk generert og vist i et standard format.

Figur 34 Lastebilrapport pr måned for lastebil N

			Måned	Sep		År	2012			
Periode	Sep2012								Lastebiler	?
Lastebil	N		Prosentdel av køyretid						Årsoversikt	Årsoversikt alle
		Målsetnad	Minimum	Dato	Maksimum	Dato	Gjennomsnitt	Lastebil i høve målsetnad	Alle lastebilar i høve til målsetnad	Alle lastebilar gjennom snitt
Cruise kontroll	Meir enn	20 %	0 %	6. september 2012	6 %	29. september 2012	1 %	-19 %	-14 %	6 %
Utrulling	Meir enn	20 %	10 %	4. september 2012	25 %	2. september 2012	14 %	-6 %	-9 %	12 %
Automatisk gearskift	Meir enn	95 %	0 %		0 %		0 %	-95 %	1 %	96 %
Mer enn 90 % maks kraftuttak	Maksimalt	8 %	0 %	2. september 2012	0 %	2. september 2012	0 %	-8 %	3 %	11 %
Tomgang	Maksimalt	5 %	3 %	29. september 2012	18 %	4. september 2012	10 %	5 %	6 %	11 %
			Alle ?							
Antall dager	24									
Totalt antall km	11 236		140 431							
Totalt antall liter	5 365		63 719							
Gjennomsnitt liter pr mil	4,8		4,5							
Total last tonn	190		2 028							
Totalt km med last fra Lerum	3 325		34 564							
Totalt liter med last fra Lerum	1 848		18 168							
Gj. snitt liter pr mil med last	5,6		5,3							

I tillegg til månedsrapporter lages det også årsrapporter for hver lastebil. Figur 35 viser en årsrapport for lastebil N.

Figur 35 Årsrapport lastebil N

2012	Lastebil	N				Tilbake							
2012	Cruise kontroll	Utrulling	Automatisk gearskift	Mer enn 90 % maks kraftuttak	Tomgang	Antall dager	Totalt antall km	Totalt antall liter	Gj.snitt liter pr mil	Tonn	Total km med last fra Lerum	Total liter med last fra Lerum	Gj.snitt liter pr mil med last fra Lerum
Januar	2 %	11 %		0 %	17 %	25	10 894	5 658	5,2	141	1 927	1 158	6,0
Februar	2 %	12 %		0 %	15 %	25	9 814	4 951	5,0	91	1 390	828	6,0
Mars	9 %	11 %		0 %	10 %	22	11 605	5 427	4,7	105	1 097	637	5,8
April	4 %	14 %		0 %	9 %	20	8 998	4 491	5,0	164	2 299	1 314	5,7
Mai	3 %	13 %		0 %	12 %	23	9 570	4 511	4,7	219	2 059	1 156	5,6
Juni	4 %	13 %		0 %	11 %	23	10 519	4 850	4,6	224	3 040	1 590	5,2
Juli	2 %	13 %		0 %	10 %	22	10 168	4 939	4,9	214	3 041	1 717	5,6
August	2 %	15 %		0 %	10 %	25	11 676	5 401	4,6	307	3 936	2 163	5,5
September	1 %	14 %		0 %	10 %	24	11 236	5 365	4,8	190	3 325	1 848	5,6
Oktober	10 %	12 %		0 %	9 %	24	12 225	5 481	4,5				
November	1 %	13 %		0 %	13 %	26	12 485	6 441	5,2				
Desember	0 %	8 %		0 %	43 %	1	288	150	5,2				
Total	3 %	12 %		0 %	14 %	260	119 477	57 663	4,8	1 655	22 114	12 409	5,6

Det lages også en årsoversikt over alle lastebiler. Antall lastebiler vil ikke være det samme hver måned siden flere av lastebilene har fått Dynafleet installert i løpet av året 2012. Figur 36 viser årsrapporten for alle lastebiler som har hatt Dynafleet installert i løpet av 2012.

Figur 36 Årsrapport alle lastebiler

2012	Lastebil	Alle					Tilbake						
2012	Cruise kontroll	Utrulling	Automatisk gearskift	Mer enn 90 % maks kraftuttak	Tomgang	Antall dager	Totalt antall km	Totalt antall liter	Gj.snitt liter pr mil	Tonn	Total km med last fra Lerum	Total liter med last fra Lerum	Gj.snitt liter pr mil med last fra Lerum
Januar	6 %	10 %	95 %	10 %	14 %	293	129 941	60 651	4,7	1 039	12 853	6 871	5,3
Februar	6 %	10 %	96 %	10 %	15 %	297	132 198	62 258	4,7	2 558	33 847	18 200	5,4
Mars	7 %	10 %	97 %	11 %	11 %	317	148 016	67 473	4,6	2 877	37 201	19 475	5,2
April	6 %	11 %	96 %	11 %	11 %	280	123 286	56 442	4,6	2 440	31 763	16 262	5,1
Mai	7 %	11 %	97 %	11 %	9 %	324	146 860	65 208	4,4	2 793	37 387	18 966	5,1
Juni	5 %	11 %	96 %	11 %	10 %	314	137 424	62 005	4,5	2 843	37 423	18 957	5,1
Juli	6 %	11 %	96 %	11 %	9 %	307	136 661	60 276	4,4	2 476	33 617	17 015	5,1
August	6 %	12 %	96 %	10 %	10 %	304	137 321	60 439	4,4	2 953	40 103	20 984	5,2
September	6 %	11 %	96 %	11 %	11 %	315	140 431	63 719	4,5	2 028	34 564	18 168	5,3
Oktober	9 %	9 %	95 %	12 %	13 %	323	152 035	70 819	4,7				
November	5 %	9 %	95 %	11 %	16 %	284	126 729	61 763	4,9				
Desember	2 %	8 %	93 %	13 %	27 %	6	1 690	858	5,1				
Total	6 %	10 %	96 %	11 %	13 %	3 364	1 512 592	691 910	4,6	22 006	298 758	154 897	5,2

Sjåførrapporter

På samme måte som for lastebiler er det laget rapporter for sjåfører. Rapportene er bygd opp på samme måte med ett unntak. Last fra ordresystemet til Lerum Frakt BA er registrert for lastebiler og ikke for sjåfører. Derfor er ikke utkjørt last en del av rapportene for sjåførene slik de er for lastebiler.

Figur 37 viser en månedsrapport for sjåfør L. Figur 38 viser månedsrapport for samme sjåfør mens Figur 39 viser årsrapport for alle sjåfører.

Figur 37 Månedsrapport for sjåfør L

Periode	Sep2012			Måned	Sep	År	2012	Sjåfører		
								Årsoversikt		
Sjåfør	L		Prosentdel av køyretid					Sjåfør	Alle	?
		Målsetnad	Minimum	Dato	Maksimum	Dato	Gjennomsnitt	Sjåfør i høve målsetnad	Alle sjåførar i høve til målsetnad	Alle sjåførar gjennom snitt
Cruise kontroll	Meir enn	20 %	0 %	2. september 2012	35 %	6. september 2012	8 %	-12 %	-14 %	6 %
Utrulling	Meir enn	20 %	3 %	6. september 2012	10 %	16. september 2012	7 %	-13 %	-8 %	12 %
Automatisk gearskift	Meir enn	95 %	100 %	9. september 2012	100 %	2. september 2012	100 %	5 %	1 %	96 %
Mer enn 90 % maks kraftuttak	Maksimalt	8 %	1 %	7. september 2012	25 %	16. september 2012	9 %	1 %	3 %	11 %
Tomgang	Maksimalt	5 %	1 %	13. september 2012	21 %	21. september 2012	8 %	3 %	5 %	10 %
	L		Alle ?							
Antall dager	25									
Totalt antall km	12 366		123 120							
Totalt antall liter	4 666		55 390							
Gjennomsnitt liter pr mil	3,8		4,5							

Figur 38 Årsrapport for sjåfør L

2012	Sjåfør	L		Attende					
2012	Cruise kontroll	Utrulling	Automatisk gearskift	Mer enn 90 % maks kraftuttak	Tomgang	Antall dager	Totalt antall km	Totalt antall liter	Gj.snitt liter pr mil
Januar	2 %	7 %	100 %	13 %	16 %	14	5 866	2 817	4,8
Februar	2 %	8 %	100 %	12 %	10 %	25	10 974	4 835	4,4
Mars	2 %	8 %	100 %	12 %	11 %	15	5 933	2 517	4,2
April	4 %	8 %	100 %	12 %	8 %	22	11 252	4 646	4,1
Mai	9 %	7 %	100 %	9 %	6 %	20	9 623	3 602	3,7
Juni	5 %	7 %	100 %	9 %	8 %	22	8 706	3 342	3,8
Juli	4 %	8 %	100 %	12 %	8 %	23	10 591	4 356	4,1
August	8 %	7 %	100 %	9 %	8 %	25	12 366	4 666	3,8
September	5 %	7 %	100 %	9 %	12 %	21	10 665	4 188	3,9
Oktober	2 %	5 %	99 %	6 %	17 %	17	8 743	3 342	3,8
November									
Desember									
Totalt	4 %	7 %	100 %	10 %	10 %	204	94 717	38 310	4,0

Figur 39 Årsrapport alle sjåfører

2012	Sjåfør	Alle		Attende					
2012	Cruise kontroll	Utrulling	Automatisk gearskift	Mer enn 90 % maks kraftuttak	Tomgang	Antall dager	Totalt antall km	Totalt antall liter	Gj.snitt liter pr mil
Januar	7 %	9 %	95 %	9 %	15 %	257	110 667	52 104	4,7
Februar	6 %	10 %	96 %	10 %	15 %	276	118 722	56 274	4,7
Mars	8 %	10 %	97 %	11 %	11 %	325	142 513	64 943	4,6
April	7 %	11 %	96 %	11 %	11 %	284	121 229	54 650	4,5
Mai	7 %	11 %	97 %	11 %	9 %	318	136 128	60 584	4,5
Juni	6 %	11 %	96 %	12 %	10 %	298	125 311	56 111	4,5
Juli	7 %	11 %	96 %	11 %	9 %	299	127 337	56 110	4,4
August	6 %	12 %	96 %	10 %	10 %	304	131 503	57 755	4,4
September	6 %	12 %	96 %	11 %	10 %	287	123 120	55 390	4,5
Oktober	8 %	9 %	97 %	10 %	13 %	275	126 565	57 577	4,5
November	4 %	10 %	97 %	9 %	14 %	236	99 088	48 065	4,9
Desember	1 %	10 %	97 %	11 %	24 %	5	1 336	675	5,1
Totalt	6 %	11 %	96 %	11 %	13 %	3 164	1 363 519	620 236	4,5

Referanser

Høyer, K.G.: *Høyhastighetstog*, Høgskolen i Oslo, TDM-Rapport 1/09

ProBas - http://www.probas.umweltbundesamt.de/php/index.php.

Simonsen, M. : *Transport, energi og miljø*. VF-Rapport 2/2010, ISBN 978-82-428-0297-2
http://vfp1.vestforsk.no/sip/pdf/Felles/Sluttrapport.pdf

Simonsen, M.: *Godstransport med skip*, http://vfp1.vestforsk.no/sip/pdf/Skip/SkipGodstransport.pdf