Transportation Research Part F 77 (2021) 257–273

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Competence, equipment and behavioural adaptation on Norwegian winter roads: A comparison of foreign and Norwegian HGV drivers

Tor-Olav Nævestad *, Fridulv Sagberg, Gunhild Levlin, Torkel Bjørnskau

Institute of Transport Economics, Gaustadalléen 21, NO-0349 Oslo, Norway

ARTICLE INFO

Article history:
Received 13 November 2018
Received in revised form 20 December 2020
Accepted 1 January 2021

Keywords:
Heavy goods vehicles
Winter driving
Behavioural adaptation

ABSTRACT

There seems to be a widespread view that foreign lorry drivers' lack of competence on Norwegian roads, especially related to winter driving, is a significant safety problem. It has, however, been suggested that foreign heavy goods vehicle (HGV) drivers perform better than expected on Norwegian winter roads, as they feel less safe than Norwegian drivers, and adapt by driving slower and more carefully. The aim of the present paper is twofold. First, we examine whether foreign HGV drivers in Norway actually have poorer competence on, training for, experience with and equipment for winter driving than Norwegian HGV drivers. Second, we discuss whether the expected negative effect of these safety challenges is mitigated, as foreign HGV drivers adapt their behaviours. We use four data sources to shed light on the aims: (1) interviews, (2) roadside inspections, (3) small-scale survey and (4) towing incidents. Our data support the hypothesis about behavioural adaptation, indicating that foreign HGV drivers experience winter driving as more difficult or unsafe, as they have supposedly less suitable vehicles and equipment, less experience, training and competence for winter driving. They are therefore more likely to get stuck while driving uphill on winter roads, supposedly as they drive more carefully and slower than Norwegian HGV drivers. Norwegian HGV drivers feel safer and more confident while driving on winter roads, because of their equipment and their experience.

1. Introduction

1.1. Background

An increasing share of goods transport on Norwegian roads is carried out by heavy goods vehicles (HGVs) registered in foreign countries and with foreign drivers, who may not be sufficiently familiar with differences in driving conditions between their own country and Norwegian roads. Nævestad, Hovi, et al. (2014) assert that about six percent of the kilometres driven by HGVs is done by foreign hauliers. Most of this is international transport, in and out of Norway. Foreign HGVs are also allowed to engage in cabotage, as part of their international transports. According to EU-Regulation (EC) 1072/2009 (as of 14 May 2010), every transporter may perform up to three cabotage operations within a seven-day period starting the day after the unloading of the international transport. The purpose of this regulation was to reduce empty trips after the

* Corresponding author.
E-mail address: ton@toi.no (T.-O. Nævestad).

https://doi.org/10.1016/j.trf.2021.01.004
1369-8478/

unloading of international transport operations. The European Commission has, however, been pushing for liberalisation of the European goods market, as part of the implementation of the common market. Measures to liberalise cabotage have been planned (e.g. in January 2014), but the plans were put on hold, as several western EU member states protested. The main reasons given were social dumping and national competitiveness, while traffic safety was given little attention (European Parliament, 2013).

Little is known about the safety consequences of increasing shares of foreign HGVs in Norway. Previous research shows that the risk of HGV accidents varies considerably in European countries. Nævestad, Bjørnskau, et al. (2014) discuss eight studies in a literature review comparing the accident risk of domestic and foreign HGVs. These studies indicate that the HGV accident risk varies by a factor of up to ten in European countries and that the accident risk for foreign HGVs is approximately two times higher than it is for domestic HGVs in those European countries studied. Comparing Norwegian and foreign HGV drivers in Norway, Nævestad et al. (2017) find that foreign HGVs have a three times higher risk of single vehicle accidents, and twice the risk of head-on collisions. The study concludes that the main risk factors of foreign HGV drivers in Norway are lacking experience and competence and winter driving.

Despite common training and education standards across Europe, European countries offer different national and local challenges with repercussions for HGV safety. In Norway, this is especially related to winter driving. Foreign lorry drivers' lack of competence on Norwegian roads, especially related to winter driving, has been identified as a significant safety problem (Nævestad et al., 2017). Norwegian professional drivers must undergo a mandatory course in driving on slippery roads to get their professional driver's licence. Such courses are not required in other European countries further south. (Norway has, however, gained acceptance in the EU for increased requirements to HGV drivers' winter driving competence from 2020.) Another problem seems to be that foreign drivers have poorer equipment for driving on winter roads (e.g. two-axle tractors instead of three-axle tractors).

1.2. Behavioural adaptation

In spite of the winter driving challenges faced by foreign HGV drivers in Norway, experts have suggested that foreign HGV drivers may perform better than expected on Norwegian winter roads, as they feel less safe than Norwegian drivers, and adapt by driving slower and more carefully. Low competence and poor equipment are obvious risk factors, which are expected to result in increased crash risk. However, traffic safety research literature shows several examples of obvious risk factors that do not result in the expected risk increase, due to the fact that road users who appreciate the possibly increased risk, adjust their behaviour, and thereby counteract the expected negative effect of a risk factor. For, example, under conditions of reduced friction, be it a result of road, or tire condition, drivers may reduce their speed and/or pay more attention. And when drivers experience changes in the opposite direction, i.e., decreased subjective risk, for example due to use of studded tires or any other safety measure, they may adapt their behaviour by increasing speed or allowing themselves to engage in secondary task, like telephone use etc. The latter kind of behavioural adaptation was originally termed *risk compensation* (see e.g. Pless, 2016, for a critical discussion of this concept), but it is now commonly referred to as just behavioural adaptation (see e.g. OECD, 1990). Although the concept originally was used to explain failures to obtain planned or expected effects of safety measures, it can equally well be applied to smaller than expected negative effects of risk factors which is the topic of the present article.

A study of particular relevance to the present issue (Rumar et al., 1976) found that vehicles with studded tires kept higher speeds on winter roads than vehicles with non-studded tires. Another safety measure relevant to winter driving is antilock braking systems (ABS). Before ABS became standard equipment in all cars, some studies compared driving behaviour between drivers of cars with and without ABS and found that ABS-equipped taxi cars were driven with shorter time headways (Sagberg et al., 1997) or with a more offensive driving style also in other respects, like more frequent hard braking, sharper turns, and less accurate lane-keeping (Aschenbrenner and Biehl, 1994).

A third relevant study indicates the importance of training on perceived abilities, behaviours and accident involvement among heavy vehicle drivers. Christensen and Glad (1996) evaluation of the mandatory skid training concludes overall of an unfavourable effect of the course, as the course had a larger effect on the participants' beliefs in their own abilities than on their actual abilities. They conclude that this can lead to a more hazardous style of driving (for instance a higher speed) that may involve the driver in situations that he/she will not have the ability to handle. They suggest that this explanation is plausible for the results of their study, which found that the skid training course seemed to increase the winter accident risk of the participants. An implication of this conclusion is that the drivers without the skid training course had lower perceptions of their mastery of winter conditions, drove slower, and were less involved in winter accidents.

Although there are numerous examples of drivers changing their behaviour as a consequence of differences in driving conditions, there is yet no unanimously accepted theory to explain such behavioural adaptation or to predict type, direction, and amount of adaptation and under what conditions it may occur.

Different mechanisms may possibly trigger behavioural adaptation. Some theories emphasize perception of risk as the signal for behavioural adaptation, whereas others point at task difficulty or mental load. The Risk Homeostasis Theory (Wilde, 1982) assumes changes in 'perceived risk' compared to the person's 'target level of risk' to trigger a behaviour adjustment, resulting in minimizing the difference between perceived risk and target level, thus maintaining the presumed risk homeostasis. Although rejecting the idea of risk homeostasis, the early Zero Risk Model of Näätänen and Summala (1976)

and the Threat Avoidance Model of Fuller (1984) also focus on perception of risk as an important trigger of behavioural adaptation.

On the other hand, the Task-Capability Interface model by Fuller (2000) and the more recent Risk Allostasis Theory (Fuller, 2011) focus on task difficulty, including mental load, as an important determinant of behavioural adaptation, in addition to perceived risk.

Discomfort has also been invoked as a possible triggering mechanism. The Multiple Comfort Zone model (Summala, 2007) assumes that road users adapt their behaviour to maintain a certain level of comfort. This is achieved by monitoring various safety margins, and by adjusting behaviour when some margin or threshold is exceeded.

For a more comprehensive review and discussion of early theories and contemporary models, respectively, we refer to Carsten (2013) and Lewis-Evans et al. (2013).

Degree of adaptation has been a topic of argument in the research literature. The Risk Homeostasis Theory (Wilde, 1982) assumed that behavioural adaptation completely cancels out any effect of a safety measure, due to drivers' motivation to maintain a preferred risk level. The implication is that the only way to increase safety is to change drivers' preferred risk level, which means changing their safety motivation. As mentioned above, several researchers have disputed this idea, pointing out that there may be different degrees of adaptation. For example, Evans (1991) developed a formalism of "human behaviour feedback", which was the term he used to describe human behavioural reactions which modified the expected or intended effects of safety measures. According to Evans, the actual effect of a measure can be expressed by the formula $\Delta S_{Act} = (1 + f)\ \Delta_{Eng}$, where ΔS_{Act} is the actual observed change in safety, ΔS_{Act} is the expected effect of some engineering-related measure, given no change in behaviour, and f denotes the "human behaviour feedback" response to the measure. Evans (1991) presents empirical evidence from several studies demonstrating different values of f. For some measures f could even be less than -1, implying that a measure actually results in *reduced* safety. A positive value of f, which according to Evans (1991) is found for some measures, implies a larger-than-expected safety effect. The formalism suggested by Evans is atheoretical and is equally applicable whether human behaviour feedback is triggered by risk perception, task difficulty, mental load, or driving comfort, or any other mechanism.

Another issue in the behavioural adaptation literature is to what extent behavioural adaptation is based on conscious awareness of the safety measure in question. This issue is discussed extensively by Kinnear and Helman (2013) in their updating of the Risk Allostasis Theory (RAT) of behavioural adaptation. They conclude that "... until there is firm evidence that conscious awareness of the change in task demand is required for behavioural adaptation to occur, it would seem prudent to proceed with the expectation that it is not".

Whether consciously or not, we assume that a change in driving conditions must be *perceived* by the driver in order to trigger behavioural adaptation. Furthermore, we do not make any particular theoretical assumption regarding triggering mechanisms, whether they are related to risk, task demands, mental load or comfort. These are probably not mutually exclusive mechanisms, and consequently differences in competence and/or vehicle equipment and standards between foreign and domestic truck drivers may imply differences in any of the assumed triggering factors.

Thus, it is conceivable that foreign truck drivers perceive, whether consciously or not, some particular difficulties when driving on ice and snow, possible related both to their own competence and the equipment and technical condition of their vehicles, and that this affects their way of driving. Lower speed, and a generally defensive driving style, is the most likely type of adaptation, although other types of adaption also are possible (e.g. increased use of snow chains, if available).

Previous research from Norway and Sweden, comparing the speed levels of HGVs on dry roads versus winter roads indicate that HGV drivers adapt to winter conditions by slowing down (although not as much as the changes in friction levels would require) (Wallman, 2005; Giæver et al., 2006). This research indicates clear reductions in speed under winter conditions, especially on roads with snow, ice and slush. The research also finds that HGV drivers lower their speed even more under winter conditions on roads with lower standards, e.g. narrow roads with many turns and steep gradient (Giæver et al., 2006). It seems likely that the general mechanism triggering adaptation to the conditions is perception of risk. Moe (2003) found that the pulse of HGV drivers increased while driving under difficult driving conditions, e.g. icy and slippery winter roads, and that this persisted even though they reduced their speed under these conditions. For foreign HGV drivers in Norway, factors triggering adaptation, in addition to risk perception may be e.g. mental load and task difficulty (Fuller, 2000). Discomfort may also be a relevant trigger of adaption (Summala, 2007). Norwegian roads generally have a lower standard than roads on the European continent, as they are narrower, have more turns and steeper gradient, especially in the west, central and northern Norway (Rambøll, 2016). Thus, it is likely to be more demanding to drive on Norwegian roads, for foreign drivers, who are less accustomed to these conditions, especially in the winter. This has been coined as an explanation to the up to three times higher personal injury accident risk of foreign HGVs in Norway (Nævestad et al., 2017).

1.3. Aims

The aim of the present paper is twofold. First, we examine whether foreign HGV drivers in Norway actually have poorer competence on, training for, experience with and equipment for winter driving than Norwegian HGV drivers. Second, we discuss whether the expected negative effect of these safety challenges is mitigated, as foreign HGV drivers adapt their behaviours.

2. Method

We use four data sources to shed light on the study aims. First, we use data from qualitative interviews, roadside inspections, and a small-scale survey to fulfil the first aim of the study. More specifically, we use data from the interviews, roadside inspections and a survey to get information about the winter driving equipment. We use data from the interviews and the survey to compare competence, training and experience. Second, we use data from towing incidents to draw inference about the behavioural adaptation of foreign drivers, more specifically speed. Based on previous research (cf. Langeland & Phillips, 2016) and results from our qualitative interviews with sector experts, we presuppose that some types of incidents generally involve higher speed than others (e.g. "drive off the road" versus "getting stuck on winter road"). Existing research indicates that vehicle speed is the most critical factor influencing incident type and severity (Elvik et al., 2009). As we do not have direct measurements of speed, we use involvement in towing incident type as an indicator, or proxy for vehicle speed under demanding winter conditions. We also use data from the survey to draw inferences about the triggering mechanism related to behavioural adaptation, more specifically data about drivers' feeling of mastery of winter conditions and risk perception (cf. Fuller, 2011).

2.1. Qualitative interviews

We primarily use the interviews to fulfil aim 1, providing us with information about equipment, competence, training and experience, and secondarily to shed light on the relationship between speed and incident type (cf. aim 2). We have conducted 11 qualitative interviews with 12 sector experts representing employers, employees and authorities. The interviews mainly concerned safety outcomes of increasing internationalisation of HGV transport on Norwegian roads, potential risk factors and relevant preventive measures. Three interviews were conducted face-to-face, and 8 were telephone interviews. The interviews generally lasted for about one and a half hours. We used a semi structured interview guide. The questions in the interview guide concerned the following themes: winter driving, safety behaviour, organisational safety culture, national safety culture, technology and equipment, training and competence, rules and enforcement, organisation of transport, safety management systems, economy and competition, rules and enforcement. Each theme focused on potential differences between Norwegian and foreign HGV drivers on these issues.

Instead of recording the interviews, we took notes during each interview, and wrote comprehensive summaries after each interview. These summaries were analysed once we had conducted all the interviews. This analysis was conducted as a thematic analysis (Welsh, 2002), where we compared text and words from the interviews. We grouped individual answers into categories of viewpoints whenever several interviewees presented relatively similar views. These categories were to a great extent based on the themes in the interview guide, and thus it can be argued that much of the qualitative analysis started when we developed the interview guide. On the other hand, several new themes were also identified in the interviews, and the analyses also focused on developing analytical categories summing up these themes. In both cases, we focused on the identification of similar views and different views related to the identified themes. To ensure the quality of our analysis, we submitted texts summing up the results of our analysis to the interviewees, giving them the opportunity to comment, provide nuances and correct mistakes.

We present the results from the interviews together with some of the results of a project reference group meeting which was held at The Institute of Transport Economics (TØI) March 12. 2014. The reference group consisted of people representing relevant stakeholders, e.g. the Public Roads Administration, employer organisations, unions, the Accident investigation board, Labour Inspection Authority, the Police etc. The reference group was established solely for the project, focusing on the safety outcomes of internationalisation of road goods transport. As we got many important viewpoints and comments in the reference group meeting, we choose to also include some relevant highlights from this meeting together with the presentation of the interview results. We analysed the results from this meeting in the same manner as the interview results.

2.2. NPRA inspection data

We primarily use results from the annual winter equipment inspections (Oct. 16- Dec 31.) of the NPRA to fulfil aim 1, providing us with information about the winter driving equipment of Norwegian and foreign HGV drivers. We have data from 2012 to 2015. We present the following inspection results related to the truck and the trailer: winter tyres, snow chains and temporary prohibition of use ("midlertidig bruksforbud", "suspension") related to these deficiencies. Suspension follows from Directive 2014/46/EU of the European Parliament and of the Council of 3 April 2014 amending Council Directive 1999/37/EC on the registration documents for vehicles. Suspension can be used for instance if the vehicle has deficiencies which constitute an immediate traffic safety hazard (e.g. if it lacks required winter tyres in the winter).

2.3. Small-scale survey[1]

We use data from a small-scale survey to compare the competence, training and experience of Norwegian and foreign HGV drivers (cf. aim 1), and to get indications about perceived mastery levels and risk perceptions, which are known mechanisms motivating behavioural adaptation.

[1] The key formulations in Sections 2.3.1–2.3.3 are also provided in Nævestad, Phillips, Levlin, and Hovi (2017), which use data from the same survey.

2.3.1. Recruitment of foreign HGV drivers

The respondents were recruited in two different ways. The main reason for this is that previous experiences have shown that it may be difficult to recruit foreign HGV-drivers in Norway to participate in surveys, e.g. through foreign HGV companies operating in Norway. Additionally, we wanted to ensure that we actually recruited foreign drivers who actually were driving in Norway. Thus, we chose to recruit foreign drivers directly, while they stayed in their vehicles in Norwegian parking lots and resting areas etc. This is, however, a very resource-demanding method of getting survey responses. The Norwegian respondents were therefore recruited by means of a web-based survey distributed on websites. We chose this method rather than recruiting through Norwegian companies, as we wanted Norwegian HGV drivers from several different companies, to make them comparable to the foreign HGV drivers, who also were from several different companies. Other studies comparing foreign and Norwegian HGV drivers in Norway have employed similar approaches involving different recruitment methods for Norwegian and foreign drivers (e.g. Steen Jensen et al., 2014).

The foreign drivers were recruited by a research assistant/student at rest stops, terminals and parking lots in the South Eastern region of Norway in May 2014.[2] Including introduction and closure of the interviews, most of the interviews with the foreign drivers lasted for about one hour. The research assistant spent a total of 105 h looking for foreign drivers over a period of 15 days in May 2014, and she drove a total of 1327 km. As each interview lasted for about one hour, she spent approximately 74 h talking to 69 foreign drivers and five Norwegian drivers in or outside their vehicles.

Drivers were asked to answer the survey themselves by means of a tablet device connected to our online survey, or the assistant would interview them using the tablet. In both cases, the tablet was used to access survey links with the survey in Norwegian, English, Polish, Lithuanian (cf. Nævestad et al., 2016). There were introductory texts in the beginning of each web survey, explaining the purposes of the surveys and stressing that the surveys were confidential.

The composition of foreign driver in the survey sample was to some extent influenced by the language options available to the drivers. It was estimated that a share of 33% of the foreign drivers who were approached were unwilling to participate in the survey. Most of the drivers who turned down our request to participate in the survey, did so because the survey was not available in their language. This applies to 19% of the foreign drivers who were approached. The lacking languages were mainly: Russian, Latvian and Rumanian. We presuppose that the drivers who answered the survey were proficient in the language that they decided to complete the questionnaire in. This is also indicated by the field observations, including the share of drivers who were unwilling to participate due to lacking languages.

2.3.2. Recruitment of Norwegian HGV drivers

The Norwegian drivers in the sample were primarily recruited through a web link to the survey on the website of the Institute of Transport Economics. The web link was introduced on the website of the project "Work related transport accidents," which was a sub site on the Institute of Transport Economics website. A link to this site was also presented on the Facebook website to members of the "Norwegian cabotage study," which is a group for fans of a study attempting to map cabotage driving in Norway. We used this Facebook site, as we assumed that most of the members would be Norwegian HGV drivers. The website with the survey link was titled "Study of safety culture, winter driving and working conditions," which sums up the main themes in the survey.

Comparing Norwegian and foreign HGV drivers in Norway is ethically and methodologically challenging, as this is a politically debated issue, generating considerable incitement among the involved parties. The Norwegian and the foreign drivers in our survey are to some extent competing in the same market. Thus, each group of would potentially have interest in giving strategic answers in order to score better than the other group. Both groups were therefore only informed in the survey introductions that the study concerned "HGV drivers in Norway" in general (i.e., both Norwegian and foreign).

2.3.3. Description of the sample

Table 1 shows key characteristics of the drivers' nationalities, the country of registration of their vehicles, and their employment categories. There is also one category for unknown, as we lacked vehicle registration countries and employment countries in some instances.

Due to a relative low number of respondents in the small-scale survey (N = 130), we divided respondents into three groups: Norwegian, Central and Eastern European (CEE) drivers and Western European drivers (WE). Nearly half of the drivers and vehicles in the sample are Norwegian and half of the drivers are employed in Norway. The group of WE drivers is unfortunately too small to make any solid conclusions about this group in our analyses. The 17 WE drivers consist of 8 drivers from Nordic countries and 9 drivers from other European countries (mostly from The Netherlands). The small size of the WE group reflects the limited kilometres driven of these foreign drivers on Norwegian roads.

The survey included 11 self-developed questions related to winter driving e.g. exposure to Norwegian winter roads, need for towing assistance, drivers' perception of risk and feeling of mastery, winter tyres and snow chains, loading of the trailer on winter roads and winter driving training. These questions were developed by Tor-Olav Nævestad and Gunhild Levlin (cf. Levlin, 2014).

[2] The research assistant and student Meyer Levlin used the data on the foreign drivers in her bachelor thesis on Emergency and Risk Management at the Metropolitan University College in Copenhagen (Levlin, 2014).

Table 1
Nationality of drivers, vehicle registration country and driver employment country.

Region	Driver nationality		Vehicle reg. country		Driver employ. Country	
Norwegian:	47%	61	49%	64	49%	63
Western European Countries (WE):	13%	17	15%	20	15%	19
Central/Eastern European countries (CEE):	40%	52	28%	37	31%	40
Unknown:	0%	0	7%	9	6%	8
Total:	100%	130	100%	130	100%	130

2.3.4. Quantitative analyses

We subject the small-scale survey data to different quantitative analyses. We use Chi square tests to compare groups' distribution on particular variables in cross tables. The chi square test tests whether the actual distribution of groups on a variable is statistically significant different from a coincidental distribution, or an independent normally distributed sample. When comparing the mean scores of different groups, we use one-way Anova tests, which compare whether the mean scores are equal (the null hypothesis) or (significantly) different. We also conduct multivariate analyses to examine the controlled effect of several variables on the dependent variable: "I feel that I cope well with the driving conditions of Norwegian winter roads". As we analyse responses on a single Likert item with a small dataset, and as the answers on the dependent variable were not normally distributed, we conducted a binary logistic regression analysis. We constructed a dichotomous dependent variable of respondents who agree (totally, somewhat) that they cope well while driving on Norwegian winter roads with respondents who disagree (totally, somewhat) or who neither disagreed nor agreed. The former values were given the value 2 (78%), while the latter were given the value 1 (22%). Odds ratios are presented, and they indicate whether coping (no/yes) on winter roads is reduced (negative odds ratios) or increased (positive odds ratios), when the independent variables increase with one value. Of course, it is impossible to conclude about causality, as this is a cross-sectional and correlational study. The term predict is nevertheless used when the regression analyses are described.

2.4. Statistics from towing companies

We use data from towing incidents to draw inference about the behavioural adaptation of foreign drivers, more specifically speed (cf. aim 2). Vehicle speed is a critical factor influencing incident type and severity (Elvik et al., 2009). We do not have direct measurements of speed, and therefore use involvement in towing incident type as an indicator or proxy for vehicle speed under demanding winter conditions.

In 2011, the NPRA, an insurance company ("If Forsikring") and two towing companies ("Falck Redning AS" and "Viking") started a cooperation project in order to map where accidents occur on Norwegian roads. The goal of the project ("FOU Bilberging") was to establish a continuous identification of accident spots and roads with accidents. Certain towing company branches were given personal digital assistants (PDA's) from the NPRA to register information about towing assistance given to light and heavy vehicles, including the exact GPS coordinates of the incidents requiring towing assistance. The data collected focus only on towing assistance related to accidents, "stuck" vehicles, and other traffic safety events (i.e. not assistance related to e.g. engine failure).

The data were initially collected from some parts of central Norway ("Midt Norge"). As of Medio 2013, Falck Redning AS started to deliver data to the project from all over the country. It is likely that some towing assistance data for foreign HGVs are unrecorded in the project. Falck Redning AS is organized according to a franchise model. It is therefore possible for road users to pay local towing company branches directly for their services. This solution is often preferred by foreign HGV drivers, and when a local branch is paid directly, the incident is not reported to Falck Redning AS centrally. Moreover, some data is also unrecorded in the project, as the other participating towing company "Viking" encountered technical problems in their registration of incidents. A total of 54,843 cases were reported in the project from January 1st 2013 to November 2015. Of these cases, 3410 incidents involved heavy vehicles.

3. Results

3.1. Qualitative data on winter driving and behavioural adaptation

In the following, we present results from the qualitative data, to provide information about equipment, competence, training and experience (cf. aim 1). When asked about the main safety challenge related to foreign drivers in Norway, the interviewees pointed to winter driving. First, they mentioned that foreign HGVs are less suited to Norwegian winter conditions as they often have two axles, providing them with a poorer grip than three axle HGVs. The HGVs with three axles can lift the rear "boggi" axle and increase the weight on the driving axle, e.g. when driving uphill on slippery roads. Interviewees also said that winter equipment previously was a challenge, but that this has changed. Special Norwegian rules on mandatory winter tyres for the truck and the trailer were introduced January 1. 2015. In 2020, winter tyres are required on all the

axles of heavy vehicles, including the trailer. Additionally, it is a special Norwegian requirement that only the best winter tyres (i.e. with the alpine symbol) can be used.

Moreover, interviewees underlined that the training, experience and competence of HGV drivers is a key factor when it comes to winter driving. Driving safely under winter conditions is strongly dependent on drivers' experience, which allows them to judge situations correctly, evaluate risks and adapt their speed to conditions. Also driving uphill on winter roads without getting stuck and putting on snow chains requires competence and experience. Loading for winter conditions also requires competence. One of the interviewees summed the mentioned risk factors by giving the following explanation of accidents and incidents involving foreign HGVs:

> "They have less suitable vehicles and little knowledge about winter roads; they are not used to driving on snow. (. . .) This is related to experience. . .one thing is theory, while practice is something different."

We also use the qualitative data to shed light on behavioural adaptation, more specifically, the relationship between speed and incident type (cf. aim 2.). In the reference group meeting with sector experts, it was suggested that the foreign drivers seem to do well given the negative coverage they receive in the media. Reference group members said that, when we take into account the poor technical equipment that foreign drivers seem to have, these drivers may well drive safer than expected. A possible explanation that was introduced is "behavioural adaptation". Norwegian drivers drive faster on winter roads because they have good tyres and a lot of experience with driving under these conditions. The Norwegian drivers therefore feel safer and more confident. The foreign HGV drivers on the other hand, drive slower because they have poorer tyres, older vehicles, possibly less experience and thereby feel less safe. Several participants in the reference group meeting suggested that, because of behavioural adaptation, the foreign HGVs often get stuck while driving uphill, while the Norwegian HGVs tend to run off the road.

The interviewees mentioned several anecdotes from people in the field supporting this hypothesis, for instance:

> "If you want to know whether a HGV that has driven out of the road in the winter is Norwegian or foreign, you may look at its position: if it is located far off the road, it is probably Norwegian, if it is placed close to the road it is foreign."

The purpose of this story was to illustrate an assumption that foreign HGV drivers drive slower (adapting their behaviour) in the winter than Norwegian drivers, and thus end up closer to the road when they drive off it. In accordance with this, another interviewee asserted that he contends that foreign HGVs especially have a higher risk of towing incidents than Norwegian HGVs:

> "I believe that they have [a higher accident risk], but not necessarily for accidents with personal injuries. I believe that they have a higher risk of driving off the road, and for creating dangerous situations, as they get stuck [on winter roads]."

Interviewees and members of the reference group also asserted that competence on winter driving not only concerns how to judge situations, adapt speed to conditions, drive uphill without getting stuck and putting on snow chains; it also involves loading the truck optimally for winter roads. Equipment and loading influence how the HGV behaves on the road. They asserted for instance that loading the trailers to put extra weight on the driving axle gives the truck a better grip while driving under winter conditions. Interviewees and reference group members asserted, however, that foreign drivers seem to know less about this than Norwegian HGV drivers. It was suggested that foreign drivers (at least those who load themselves) may load the trailer with more weight further back, as they may fear to be fined for overweight if they put more than 10 tonnes on the driving axle. This is unfavourable, while driving under winter conditions.

3.2. NPRA data from winter equipment inspections

In the following, we present results from the annual winter equipment inspections (Oct. 16- Dec 31.) of the NPRA to fulfil aim 1, providing us with information about HGVs' winter driving equipment. We have data from 2012 to 2015. It is important to note that in a European context, Norway has a unique legislation on winter tyres and snow chains for HGVs. Winter tyres for the trailer were required in 2015 and winter tyres for the truck were required in 2013. In 2020, winter tyres with alpine symbol, are required on all the axles of HGVs, including the trailer.

In Table 2 we show the following inspection results related to the truck and the trailer: winter tyres, snow chains and temporary prohibition of use ("midlertitidig bruksforbud", "suspension") related to these deficiencies.

Other European trucks have the highest shares of deficiencies related to winter equipment. The Norwegian trucks generally have the least deficiencies, although Nordic trucks have fewer deficiencies related to snow chains. The group Other European trailers have the highest shares of deficiencies related to winter equipment. The Norwegian trailers generally have fewer deficiencies, but Nordic trailers have fewer deficiencies related to snow chains.

3.3. Results from the small-scale survey

In the following, we present data from the small-scale survey to compare the competence, training and experience of Norwegian and foreign HGV drivers (cf. aim 1).

Table 2
Results from the NPRA's heavy vehicle inspection of winter equipment, 2012–2015. Control results related to the truck and trailer: winter tyres, snow chains and temporary prohibition of use. Per cent. Data source: NPRA.

National group	Truck/trailer	Lacking winter tyres	Lacking snow chains	Temp. prohib. of use	Controls
Norwegian	Truck	1%	2%	1%	7368
	Trailer	2%	1%	1%	4982
Nordic	Truck	2%	1%	1%	992
	Trailer	5%	1%	2%	1205
Eastern Europe	Truck	3%	4%	2%	2204
	Trailer	5%	2%	2%	1856
Other European	Truck	6%	8%	2%	250
	Trailer	9%	5%	4%	255
Total	Truck	2%	3%	1%	10,814
	Trailer	4%	1%	1%	8298

3.3.1. Self-reported winter driving exposure and towing assistance

The respondents in the small-scale survey were asked 11 questions on winter driving. The first question we asked was how many days they had driven on Norwegian winter roads in total. The purpose of this question was to estimate the respondents' ''exposure" to Norwegian winter roads. Results indicate that nearly all (90%) of the Norwegian drivers had driven more than a hundred days on Norwegian winter roads. In comparison, 40% of the drivers from Central and Eastern European countries (CEE) had driven more hundred days on Norwegian winter roads, while the corresponding share among the Western European (WE) drivers was about 50%. Seven of the CEE drivers in the sample had never driven in Norway in the winter before and were therefore not asked about their experiences with winter driving.

We also asked the respondents whether they have ever been in need of towing assistance due to winter conditions. A total of 62% of the Norwegian drivers answered yes, 77% of the Western European answered yes, while 69% of the CEE drivers answered yes to this question. The question states ''have you ever been in need of towing assistance", and given this wording and our limited exposure measures, a comparison of Norwegian drivers and foreign drivers is slightly misleading. Many of the Norwegian drivers probably have several years of experience driving on Norwegian winter roads (20% of them were over 56 years old), and as the questions states ''have you ever", their towing assistance incident(s) could have been several years back in time.[3] It is therefore not unlikely that a fifth of the Norwegians in the sample have been HGV drivers for several decades. They therefore have vast experience with driving under winter conditions (90% >100 days).[4] Given their age and winter driving experience, the Norwegian drivers in the sample have been far more exposed to winter conditions than the foreign drivers in the sample. Despite this, the shares for drivers who report to have ever been in need of towing assistance due to winter conditions are not very different when we compare the three groups of HGV drivers. A Chi-square test shows that the differences are not statistically significant ($P = 0.507$). It should be noted that the actual numbers are small.

Although the exposure to winter days is very different (and probably far more different than we have measured, as > 100 days is the maximum value), the reported need for towing assistance is also fairly similar in the groups. Thus, it seems that foreign drivers and especially drivers from CEE countries have a far higher risk of being in need of towing assistance when driving on Norwegian winter roads than Norwegian drivers. This requires an explanation. Below we will examine different factors that may shed more light on this result. We will look at drivers' perception of risk and feeling of mastery of winter conditions, use of winter tyres and snow chains, competence on trailer loading under winter conditions and training for winter driving.

3.3.2. Drivers' perception of risk and feeling of mastery

We also use data from the survey to get indications of perceived mastery levels and risk perceptions that could motivate behavioural adaptation. We asked two questions about drivers' perception of risk while driving on Norwegian winter roads and their feeling of mastery related to winter driving (cf. Table 3): ''I feel that I cope well with the driving conditions of Norwegian winter roads" and ''I'm worried about ''getting stuck" when driving under winter conditions"

A total of 92% of the Norwegian drivers totally or somewhat agree that they cope well with the driving conditions of Norwegian winter roads, while 71% of the WE drivers and 63% of the CEE drivers agreed with this statement ($P < 0.01$). Thus, it seems that the Norwegian drivers have a stronger feeling of mastery of Norwegian winter conditions than foreign drivers (especially drivers from CEE).

Looking at the statement ''I'm worried about ''getting stuck" when driving under winter conditions", we see that 29% of the Norwegian drivers agreed and 12% of the WE drivers agreed. However, as many as 65% of the drivers from CEE agreed,

[3] We considered asking whether respondents had been in need of towing assistance in the last ''two years", but assuming that this occurs rarely, like accidents, we expanded the period to ''ever".

[4] The winter driving experience measure should perhaps have included much higher values, in order to take into account the winter driving experience of the Norwegian drivers who have been working as drivers for several decades. These drivers have been driving several hundred winter days. Nevertheless, this exposure measure works fairly well in accordance with its purpose, as it shows the relatively scarce winter driving experience of the foreign drivers.

indicating that these drivers are far more worried about "getting stuck" while driving under winter conditions than the other groups in the sample ($P < 0.01$).

3.3.3. Self-reported use of winter tyres and snow chains

We also asked the drivers questions about the snow chains and winter tyres of their vehicles. Comparing the national groups' distributions of answers regarding the wheels for which they have snow chains when driving on winter roads, 90% of the Norwegian drivers had snow chains for their front wheels, while the corresponding share for the WE drivers was 82%, while it was 58% for CEE drivers. Corresponding shares for the driving axle wheels were 98%, 88% and 78%, respectively, while it was 79%, 100% and 80% respectively for trailer wheels. This indicates that the Norwegian drivers to a greater extent than the other drivers report that they have snow chains for their front wheels and driving axle wheels, while all drivers from WE report that they have snow chains for their trailer wheels. Drivers from CEE generally reported of a lower number of snow chains at their disposal.

We also asked respondents about their use of snow chains (cf. Table 3): "When driving in the winter, I often use snow chains when I need to". A share of 84% of the Norwegian drivers agreed, while 58% of the WE drivers agreed and 53% of the CEE drivers agreed ($P < 0.001$). Thus, the Norwegian drivers are considerably more inclined than the two other groups to use snow chains, when they need to.

We also asked respondents about winter tyres, using the statements: "When I drive on winter roads, my vehicle has:". A share of 18% of the WE drivers answered: "summer tyres". A share of 85% of the Norwegian drivers answered: "Winter tyres on the truck and the trailer", while 71% of the WE drivers and 76% of the CEE drivers did. A share of 24% of the CEE drivers answered: "Winter tyres on the truck", while 15% of the Norwegian and 12% of the WE drivers did ($P < 0.001$). Summing up, we see that the Norwegian drivers generally report a higher incidence of winter tyres on their vehicles when driving on winter roads.

3.3.4. Winter driving competence and training

We included a question to compare drivers' competence on winter loading by asking them to respond to the statement: "In the winter, I load the trailer so that I get maximum weight on the driving axle" (cf. Table 3). A share of 80% of the Norwegian and 88% of the WE drivers correctly totally agreed with the statement, while only 40% of the CEE drivers did ($P < 0.001$). This indicates that the former groups have a better competence on loading for winter conditions.

Based on the results of the questions concerning competence and equipment above, it seems that we may conclude that the Norwegian drivers (and to some extent the WE) drivers have better equipment for and competence on winter driving. Additionally, the Norwegian drivers have a greater feeling of mastery and a lower perception of risks related to winter driving than foreign drivers.

This is probably related to both their experience with winter driving and their training. The survey includes two questions on winter driving training. The first question is: "I have been trained in driving on winter roads" (cf. Table 4).

While 20% of the Norwegian drivers answered "No", 65% of the WE drivers and 40% of the CEE drivers answered no. The shares answering "Yes, when I got my driver's license" are 48% for the Norwegian drivers (mandatory in 1993–94), 12% for the WE drivers and 10% for the CEE drivers.

We also asked the respondents whether they want more training in winter driving. This can give indications on the quantity and quality of the training that they already have, and it may also give indication of their experiences with or lacking experiences with winter driving. About 40% of the drivers from CEE totally agree with the statement (cf. Table 3) that they would like more training in winter driving. This is more than the double of the other groups (18%) ($P < 0.001$).

3.3.5. Regression analyses

As noted, we assume that perceived mastery of winter conditions is a key variable motivating behavioural adaptation in the present study. In Table 6, results from binary logistic regression analysis are shown, where variables are included to examine the variables predicting whether respondents feel that they cope well with the driving conditions of Norwegian winter roads, or not. We made a dichotomous variable of respondents who agreed (78%), and respondents who disagreed, or answered neither/nor (22%).

Before conducting the regression analysis, we examined the bivariate correlations between the independent variables, using Pearson's R analysis. These are shown in Table 5.

Table 6 presents the logistic regression analyses with perceived mastery of winter conditions as the dependent variable. We have conducted logistic regression analyses with all the variables in Table 5, but we only include variables contributing significantly in the final model displayed in Table 6.

Table 6 indicates two main results. The first is that respondents' winter driving experience, or the number of days that they have driven on Norwegian winter roads, significantly predicts whether respondents agree that they cope well with driving on Norwegian winter roads. Odds ratios, indicate that when the winter driving experience variable increases with one value, the odds of coping well on Norwegian winter roads increases with a factor of 2.203. As noted, this variable was coded with five values, with "more than hundred days" as the maximum value. Although this might have underestimated the vast experience of some of the older Norwegian drivers in the sample, results indicate the importance of respondents' winter driving experience. Winter driving experience is, as noted, closely related to nationality.

Table 3
National groups' distributions of answers on five statements Per cent. Norwegian (N = 61), Western European country (N = 17), Central/Eastern European country (N = 45).

Question	Nationality	Totally disagree	Disagree somewhat	Neither agree/ disag.	Agree somewhat	Totally agree	Chi square p value
Cope well	Norwegian	2%	0%	7%	44%	48%	<0.001
	WE	6%	12%	12%	6%	65%	
	CEE	18%	11%	9%	36%	27%	
Worried «getting stuck»	Norwegian	13%	33%	25%	16%	13%	<0.001
	WE	53%	29%	6%	0%	12%	
	CEE	11%	13%	11%	47%	18%	
Use snow chains	Norwegian	2%	3%	12%	41%	43%	<0.001
	WE	18%	18%	6%	29%	29%	
	CEE	4%	22%	20%	9%	44%	
Load the trailer	Norwegian	0%	0%	7%	13%	80%	<0.001
	WE	6%	0%	0%	6%	88%	
	CEE	11%	13%	13%	24%	40%	
Want more training	Norwegian	18%	8%	30%	26%	18%	<0.001
	WE	53%	12%	0%	18%	18%	
	CEE	19%	19%	12%	12%	39%	

Table 4
National groups' distributions of answers to the statement: "I have been trained in driving on winter roads". Per cent. Answer alternatives: 1) No, 2) Yes, when I got my driver's licence, 3) Yes, by the company where I am employed, 4) Yes, by colleagues, 5) Yes, by others.

	No	Yes, licence	Yes, company	Yes, colleagues	Yes, others	N
Norwegian	20%	48%	15%	8%	10%	61
WE	65%	12%	0%	12%	12%	17
CEE	40%	10%	21%	17%	12%	52

Table 5
Pearson's R correlations between the variable "I feel that I cope well with the driving conditions of Norwegian winter roads" and other key variables.

Variables	Pearson's R
Age group	0.197**
Days on Norw. winter roads	0.381***
I often use snow chains when needed	0.310***
Worried about «getting stuck»	n.s.
Have received towing assistance	n.s.
Competence on trailer winter loading	0.337***
Winter driving training (licence or company)	n.s.
Norwegian versus foreign driver	−0.309***

*$p < 0.05$, **$p < 0.01$.

The second main result is that respondents' behaviour, i.e. their assertion that they often use snow chains when needed, contributes to their feeling of mastery of Norwegian winter conditions. For each increase on the snow chain use variable (with five values), the odds of coping well on Norwegian winter roads increases with a factor of 1.773. It is important to note that this also applies when we control for days on Norwegian winter roads.

The variable competence on loading the trailer for winter conditions contributed significantly to perceived mastery, but not when the model also included the variable about snow chain use. This probably reflects the fact that these two variables are correlated. We chose to include the variable focusing on drivers' snow chain use, as it provided the highest Nagelkerke R2 value (0.280 versus 0.219 for the variable measuring winter loading competence).

Finally, the Nagelkerke R^2 value of the logistic regression presented in Table 6 is 0.280, indicating that the independent variables explain 28% of the variation in the dependent variable.

3.4. Results from towing company data

We use data from towing incidents to draw inference about the behavioural adaptation of foreign drivers, more specifically speed and driving style (cf. aim 2). In 2011, the NPRA, an insurance company ("If Forsikring") and two towing compa-

Table 6
Logistic regression. Regression coefficients, standard errors of coefficients, significance and 95% confidence intervals for binary logistic regression with dependent variable "I feel that I cope well with the driving conditions of Norwegian winter roads" (disagree, neither/nor = 1, agree = 2), for Norwegian and foreign HGV drivers.

Variables	β	S.E	Sig.	eβ	95% CI for eβ
Days on Norwegian winter roads	0.790	0.217	0.000	2.203	1.438–3.374
When driving in the winter I often use snow chains when I need to	0.573	0.191	0.003	1.773	1.220–2.577

* p < 0.1, ** p < 0.05, *** p < 0.01.
χ^2 = 24.722, df = 2, p < 0.001.
Hosmer and Lemeshow test χ^2 = 7.378, df = 5, p = 0.194.
Nagelkerke R2 = 0.280.
Correct classification: 79.7%.

Table 7
Cause of damage for HGVs that were given towing assistance and registered in the "FOU-Bilberging" project from January 1st, 2013 to November 2015. Source: Falck Redning AS.

Cause of damage	Share (%)	N
Stuck HGV	52	1781
Collision damage	5	161
HGV run off the road	37	1251
HGV overturned	6	217
Total	100	3410

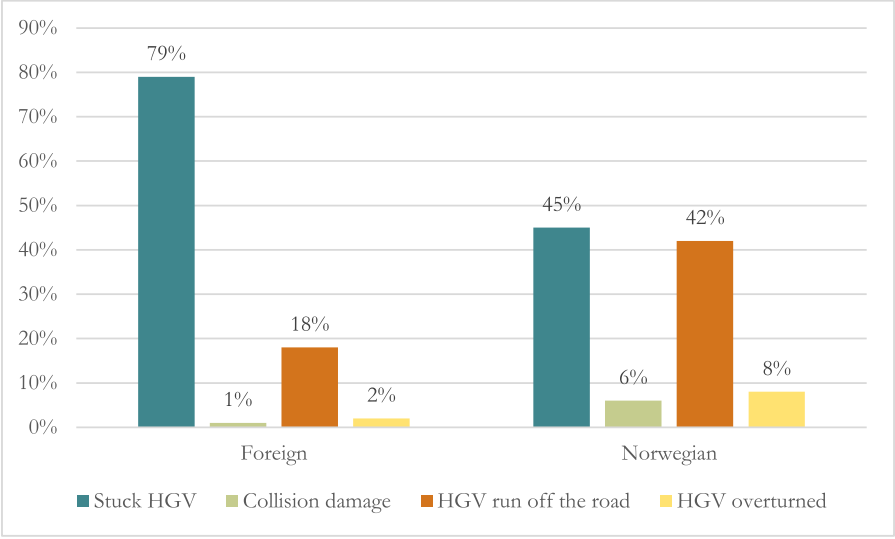

Fig. 1. Cause of damage for foreign (N = 747) and Norwegian (N = 2663) HGVs that were given towing assistance and registered in the "FOU-Bilberging" project from January 1st 2013 to November 2015. Source: Falck Redning AS.

nies ("Falck Redning AS" and "Viking") started a cooperation project in order to map where accidents occur on Norwegian roads. A total of 54,843 cases were reported in the project from January 1st, 2013 to November 2015. Of these cases, 3410 incidents involved heavy vehicles. Table 7 shows the share of Norwegian and foreign HGVs towed by cause of damage.

Fig. 1 shows the distribution of Norwegian and foreign HGVs towed by cause of damage.

Fig. 1 shows that foreign HGVs are more likely to "get stuck", while Norwegian HGVs are more likely to run off the road. A total of 33% (N = 590) of the 1781 HGVs which were "stuck" on winter roads were foreign, while foreign HGVs accounted for six per cent of the average domestic transport in Norway in 2009–2012.

4. Discussion

The present paper studies competence, equipment and behavioural adaptation on Norwegian winter roads, comparing foreign and Norwegian HGV drivers. The paper discusses whether foreign HGV drivers perform better than expected on Nor-

wegian winter roads. The aims of the paper were first to examine whether foreign HGV drivers in Norway actually have poorer competence on, training for, experience with and equipment for winter driving than Norwegian HGV drivers. The second aim was to discuss whether the expected negative effect of these safety challenges is mitigated, as foreign HGV drivers adapt their behaviours.

4.1. Competence, training, experience and equipment for winter driving

First, data from the small-scale survey indicates that Norwegian HGV drivers have a better competence on winter driving than foreign (CEE) HGV drivers. Competence on winter driving was operationalized as knowledge about how to load the trailer on winter roads. Survey data indicates that the differences in competence most likely is due to the fact that the foreign HGV drivers have less experience with winter driving on Norwegian winter roads and less training in winter driving. It must be noted, however, that the western European drivers had a high level of competence on winter loading and relatively little training in winter driving. This group is, however, heterogeneous (more than half of the drivers are Nordic) and too small (N = 17) to allow for any conclusions. Finally, it should also be noted that we only have one measure of competence, and that this only focuses on one specific aspect of competence, i.e. how to load the trailer when driving under winter condition.

Second, our data indicates that higher shares of Norwegian drivers in the sample generally report that they have received training on how to drive on Norwegian winter roads. Only 20% of the Norwegian drivers had no training, compared to 65% and 40% in the two foreign groups. In the regression analysis, we found that training was not significantly related to drivers feeling of mastery; experience was more important. Winter driving training became, however, mandatory for heavy vehicles in Norway in 1993–94, and several of the older Norwegian respondents did not receive winter driving training when obtaining their licence. Moreover, it should also be noted that Christensen and Glad (1996) found that the drivers' who had participated in the winter driving course had a higher winter accident risk than those who had not participated. We return to this.

Third, our results indicate a higher level of experience with driving on Norwegian winter roads among the Norwegian HGV drivers in the sample. Nearly all (90%) of the Norwegian drivers had driven more than a hundred days on Norwegian winter roads. Among the drivers from CEE countries, 40% had driven hundred days on Norwegian winter roads, while about half of the Western European drivers had done so.

Fourth, our data indicates that foreign HGVs in Norway have somewhat poorer winter equipment than Norwegian HGVs. This is indicated by the interview data, the inspection data from the NPRA and the self-reported data from the small-scale survey. The small-scale survey data also indicate that Norwegian HGV drivers report that they are more inclined to use snow-chains while driving under winter conditions, and the regression analysis indicates that this is closely related to their feeling of mastery while driving on Norwegian winter roads.

4.2. Are the expected negative effect of these safety challenges mitigated?

The second aim of the paper was to discuss whether the expected negative effects of the above-mentioned safety challenges (experience, training, equipment, competence) are mitigated, as foreign HGV drivers adapt their behaviours. We suggest that these challenges induce adaptation among foreign HGV drivers through various mechanisms, e.g. perceived risk, task difficulty and mental load (Fuller, 2011). Our data indicate the importance of at least the two first triggering mechanisms, as we found that foreign HGV drivers in Norway are more worried about getting stuck on Norwegian winter roads (perceived risk), and have a lower feeling of mastery related to these conditions (task difficulty). Given that they are foreign to Norwegian winter roads and seem to have a lower winter driving competence, we could also add mental load. These factors are known triggers of behavioural adaptation. Additionally, our results indicate that equipment (tyres, snow chains, boggi axle) also could be a mechanism triggering adaptation, as it seems to be related to perceived risk. The same applies to winter driving competence.

We use data from towing incidents to draw inference about the behavioural adaptation of foreign drivers, more specifically speed and driving style. Based on previous research (cf. Langeland & Phillips, 2016) and results from our qualitative interviews with sector experts, we presuppose that some types of incidents generally involve higher speed than others (e.g. "drive off the road" versus "getting stuck on winter road"). Existing research indicates that vehicle speed is the most critical factor influencing incident type and severity (Elvik et al., 2009). Thus, as we do not have direct measurements of speed or driving style, we use involvement in towing incident type as an indicator, or proxy for vehicle speed under demanding winter conditions. HGV "run off road" is a type of incident that is likely to be correlated with higher speed, than "stuck HGV".[5] We have seen the share of Norwegian HGVs that have run off the road is 2.3 times higher than the share for foreign HGVs, while the share of stuck foreign HGVs is 1.8 times higher than the Norwegian share. If the foreign HGV drivers had not adapted their driving style on Norwegian winter roads, it seems likely that their share for "run of the road" would have been higher. Moreover, the far higher share of "stuck HGV" among the foreign HGVs indicates lower speed in this group, although their lower experience, competence and equipment probably also increases their risk of getting stuck, e.g. while driving uphill.

[5] It could, however, be noted that "stuck HGV" probably not is as strongly correlated with speed as "HGV run off the road". This should be examined further in future research.

Thus, the towing incident data seem to indicate that foreign HGVs generally drive at lower speeds and more careful on Norwegian winter roads, than the Norwegian HGVs.

Previous research from Norway and Sweden indicate clear reductions in HGV speed under winter conditions for all HGV drivers, especially on roads with snow, ice and slush, and especially under winter conditions on roads with lower standards, e.g. narrow roads with many turns and steep gradient (Wallman, 2005; Giæver et al., 2006). In addition, our results also suggest that (foreign) drivers' experience, competence and equipment are important factors influencing adaptation, specified as lower speed and a defensive driving style. This indication needs however to be followed up in future studies of speed choice and driving styles under demanding winter road conditions. Norwegian roads generally have a lower standard than roads on the European continent, as they are narrower, have more turns and steeper gradient, especially in the west, central and northern Norway (Rambøll, 2016). It is likely that these conditions become even more challenging for foreign drives in the winter. These issues need, however, to be examined further in future research.

Future studies should also examine other types of behavioural adaptation to winter roads than speed. It is for instance, conceivable that a more frequent use of snow chains could be a type of behavioural adaptation to Norwegian winter roads. Another type of behavioural adaptation could be related to the choice of roads while driving under winter conditions, or e.g. aborting, or postponing assignments. These types of behaviours are, however, also likely to be influenced by several other factors, which means that it is complex to study their significance.

The behavioural adaptation hypothesis assumes that the foreign drivers perform better than expected given their point of departure (i.e. their risk factors). It is very difficult to conclude about this, based on the current data. The research of Nævestad, Phillips, Levlin, and Hovi (2017) indicates that foreign HGV drivers in Norway have up to three times higher risk of single vehicle accidents with personal injuries than Norwegian HGVs. Thus, the foreign HGVs' safety performance is lower than that of the Norwegian HGVs. The risk difference is in line with previous research from other countries, indicating about two times higher accident risk for foreign drivers (e.g. Leviäkangas, 1998; Nævestad, Bjørnskau, et al., 2014; Nævestad, Hovi, et al., 2014). Thus, this does not indicate that the foreign HGV drivers perform better than expected. Although we have not measured the risk of personal injury accidents in the winter, research indicates that non-Scandinavian HGVs have a higher share of their HGVs in accidents in the winter (Nævestad et al., 2017). This could indicate a higher accident risk in the winter, but we lack unfortunately exposure data for months or season.

We have not estimated the risk of towing incidents, but comparing the shares, we see that the foreign HGVs, which make up 6% of the driven kilometres, comprise 11% of personal injury accidents (Nævestad et al., 2017) and 33% of the stuck vehicles. This seems to indicate that foreign HGV drivers have a higher risk of getting stuck on winter roads, than being involved in personal injury accidents. Moreover, if we assume that they get stuck as they drive slower, and that a higher speed could have resulted in more severe accidents, and thus a higher risk of personal injury accidents, it would be justifiable to say that they perform better than expected. A consequence of this is that they would have a far higher risk of accidents in the winter if they had not adapted their speed and driven more carefully. As we lack data on their speed and driving style, we cannot conclude about this.

Although it is difficult for us to draw solid conclusions about the existence of behavioural adaptation, the traffic safety research literature shows several examples of obvious risk factors that do not result in the expected risk increases, as drivers recognize the possibly increased risk, adjust their behaviour, and thereby counteract the expected negative effect of one or more risk factors. Previous research has found that this argument also applies to winter driving. As noted, Rumar et al. (1976) found that vehicles with studded tires kept higher speeds on winter roads than vehicles with non-studded tires. Studying antilock braking systems (ABS), which also are relevant to winter driving, Sagberg et al. (1997) found that ABS-equipped taxi cars were driven with shorter time headways or with a more offensive driving style. We may perhaps argue that the same was the case with the heavy vehicle drivers who had not been subjected to the skid training course in Christensen and Glad (1996) study. An implication of the authors' conclusion is that these had lower perceptions of their mastery of winter conditions, drove slower and were less involved in winter accidents.

4.3. Policy implications

It is important to note that several of the challenges met by foreign HGV drivers in Norway also can be found in other European countries. Winter driving is also a common challenge in Nordic and alpine countries. As a consequence, the Norwegian minister for transport took an initiative to make winter training mandatory for HGV drivers in certain EU/EEA countries, together with his colleagues in Sweden, Switzerland and Austria. As noted, Norway has,gained acceptance in the EU for increased requirements to HGV drivers' winter driving competence from 2020.

Our survey data indicate that the foreign and Norwegian HGV drivers' competence on winter driving varies. Our interviewees also suggested that foreign HGV drivers are more likely to lack the required competence for driving heavy vehicles on Norwegian winter roads. Mandatory training may be a relevant policy response to this, but as noted we did not find a significant relationship between perceived mastery of winter roads and winter driving training. It is, however, likely that this is due to the fact that mandatory winter driving training was introduced in 1993–94 in Norway, and that the most experienced Norwegian HGV drivers in our sample had no such training. On the other hand, we found a significant relationship between perceived mastery of winter driving and winter driving experience. Thus, winter driving experience seems more important than training.

Winter driving training may refer to different things; e.g. skid training, training in putting on snow chains, loading for winter roads, defensive driving etc. Discussing the safety effects of training, Elvik et al. (2009) concludes that it seems that HGV drivers' skid training courses actually increase their accident risk (best estimate is 22% increase in accidents). In their evaluation of the mandatory skid training course for heavy vehicle drivers Christensen and Glad (1996) conclude, as noted, that the courses increase drivers' feeling of mastery while driving on winter roads, and that this is the likely reason that drivers who had participated in the course had a higher winter accident risk than those who had not participated. This argument is in line with the behavioural adaptation hypothesis that we study in the present paper. More defensive driver training courses, e.g. aiming to reduce drivers' confidence in their own behaviours, on the other hand, seem to reduce their accident risk with about 20% (Elvik et al., 2009; Gregersen et al., 1996).

Based on the previous studies (e.g. Christensen & Glad, 1996) on the effects of skid training courses on accident involvement, it seems that skid training increasing foreign HGV drivers' confidence in their own abilities actually could increase their accident risk in the winter. This is also in line with the key premise of the present paper: that the negative consequences of their poor(er) training, experience, equipment and competence is mitigated by their higher risk perception and behavioural adaptation. Thus, if these drivers are to be subjected to winter driving training, it is important that this training should not reduce the seemingly positive effects of their (higher) risk perception.

4.4. Methodological limitations and future research

We use four data sources to shed light on the aims: 1) interviews, 2) roadside inspections, 3) small-scale survey, and 4) towing incidents.

4.4.1. Interview data

The main strength of our interview data is that they involve viewpoints from experts from different relevant organizations, with vast knowledge about the haulier industry. The main weakness with these data is that they are based on a relatively low number of people.

4.4.2. Roadside inspections

The main strength of the roadside inspection data is that they give objective information based on a high number of inspections. These data would have been even better if they had included information about e.g. drivers' abilities to use snow chains and frequency of use.

4.4.3. Small-scale survey

The main strength of the small-scale survey data is that they allow us to compare the drivers' feelings of mastery and relate these to their experience with winter roads, their age, training etc. A weakness with the small-scale survey is that it is based on small samples. This especially applies to the Western European drivers. Future studies should examine our studied relationships in larger samples of Norwegian and foreign drivers. The main weakness of the small-scale survey data (and our study) is that we unfortunately lack data on the actual speed and driving styles of Norwegian and foreign HGVs on Norwegian winter roads. This important piece of information was also lacking in the interesting study of Christensen and Glad (1996), who also turned to (presumably) different speed levels and driving styles to explain differences in the accident involvement of the groups they studied. Thus, future research should collect data on the speeds and driving styles of Norwegian and foreign HGVs on winter roads. The small-scale survey could have included information about speed, which could be analyzed in light of drivers' feelings of mastery. However, it would be even better to have objective data on drivers' speed from e.g. speed cameras, radars. Moreover, the small-scale survey data also include limited measures of e.g. competence, which is a key variable. It is evident that we also should have measured other aspects of competence, e.g. how to adapt the speed to different surfaces on winter roads, how to drive uphill without getting stuck, how to detect possible dangers while driving on roads with ice and snow, how-to put-on snow chains etc. We could also have measured drivers' experience with winter roads better, with higher maximum values. Moreover, analyzing the outcomes of training, we could also have excluded the older drivers who had not been subject to the mandatory training from the analyses. These are issues for future research.

The use of different recruitment approaches for Norwegian and foreign drivers may have implications on the survey outputs related to the potential biasedness of the results. As indicated in section 2.3, the foreign drivers were recruited on site to ensure that we recruited foreign drivers who were actually driving in Norway, while the Norwegian drivers were recruited online. We chose the latter, first, as it is very resource demanding to recruit and interview onsite, second to include Norwegian drivers from several different companies, to make them as comparable as possible to the foreign drivers, who also were from several different companies. The different recruitment approaches and administration of the survey could potentially have implications for the comparability of the samples in the study. This concerns the potential self-selection and representatively of both the foreign drivers and the Norwegian drivers.

When it comes to the Norwegian drivers, we could suspect a certain level of self-selection of drivers interested in safety culture, winter driving and working conditions for HGV drivers. Based on this, it is reasonable to ask whether the recruited Norwegian drivers are representative. We can check this by comparing with samples of Norwegian HGV drivers from other studies with a known and relatively high response rate (e.g. Nævestad et al., 2020). Table 8 compares the Norwegian driver

Table 8
Comparison of the study samples with the Norwegian driver sample in Nævestad et al. (2020).

Groups	<26	26–35	36–45	46–55	56+	N
Norwegian sample:	8%	18%	28%	26%	20%	63
Other Norwegian sample:	11%	21%	22%	30%	17%	533
Central/Eastern European countries:	10%	27%	23%	33%	8%	52

sample with the sample of Nævestad et al. (2020), which included 533 HGV drivers from 17 Norwegian trucking companies, including a sample of 80 drivers recruited from a Norwegian drivers' union. The total response rate from the drivers in the 17 companies was 38%.

The comparison in Table 8 shows that the age distribution is relatively similar in the two Norwegian samples: both have a relative high proportion of drivers older than 56 years, and a total of 46% and 47% of drivers older than 46 years old. This indicates that the sample of Norwegian drivers in the present study is relatively representative, at least when it comes to the age distribution of the drivers. The table also shows that the drivers from Central/Eastern European countries are somewhat younger than the Norwegian drivers. The survey in the current study did not include questions about sex, as previous studies indicate that nearly all Norwegian HGV drivers are men: 96% of the drivers in Nævestad et al. (2020) were men. All of the foreign HGV drivers in the present study were men.

When it comes to the foreign drivers, the selection of respondents was mainly limited based on the languages that we had available, and subsequently our resources. Thus, the sample of foreign drivers in the present study is biased, due to the survey languages we had available. The interviewer estimated the response rate to be 67%, and calculated that 19% of the foreign drivers who were approached turned down our request to participate in the survey, because the survey was not available in their language. The lacking languages were mainly: Russian, Latvian and Romanian. This is an important shortcoming of the present study. Covering drivers from the omitted countries is an important issue for future research. There may also be systematic patterns among the included foreign drivers, which may further increase the bias of the survey. They were for instance recruited in the South-East part of Norway in a particular period. Thus, future studies should include more languages, and cover larger parts of Norway to arrive at more robust conclusions about foreign HGV drivers in Norway.

Our data sources are partly based on information about the nationality of the vehicles (e.g. NPRA inspection data, towing data, personal injury accident data) and partly based on information about the nationality of the drivers (survey data). Thus, for the different data sources to be compatible, we need to make sure that the nationalities of vehicles and drivers match. First, it can be discussed whether the drivers of non-Norwegian trucks are exclusively non-Norwegian. A previous study indicates that this is the case (Hovi, Bråthen, & Hjelle, 2014). In the study, all trucks driving into Norway on a main road on one particular day were stopped and invited to participate in a survey asking about their nationality, the truck's nationality, country of employment, wage conditions etc. The reason that drivers of non-Norwegian trucks are exclusively non-Norwegian is probably that the wage conditions for truck drivers in European countries are different; with substantially lower wages for drivers employed in e.g. Eastern European countries. Second, based on this, it is perhaps more relevant to ask whether the drivers of the Norwegian trucks are exclusively Norwegian. In 2015, 10% of the Norwegian HGVs that were inspected by the Norwegian Public Roads Administration, were driven by foreign HGV drivers (Nævestad et al., 2017). This indicates that a certain proportion of the Norwegian registered HGVs in the NPRA inspection data and the towing incident data were driven by foreign HGV drivers employed by Norwegian companies. However, as these foreign drivers drive in Norway, and are employed by Norwegian companies, we may hypothesize that their experience, perception of risk and road safety behaviours are more similar to that of Norwegian drivers. This hypothesis could be examined in future research. Third, as the main discussion in the paper concerns driving under winter conditions, we should expect that drivers from some countries are well experienced with this. This applies for instance to drivers from Sweden, Finland etc. Unfortunately, numbers are too small e.g. in the survey data to examine this further, but as noted, the group of Western European drivers in the survey include several drivers from Nordic countries, and we see that these seem more comparable to the Norwegian drivers in several respects.

We conducted logistic regression analyses to examine factors influencing drivers' perceived mastery of winter conditions. Considering that different factors may affect Norwegian and foreign drivers' perceived winter driving mastery, likelihood ratio tests were also conducted, comparing regression models involving: a) both Norwegian and foreign drivers, with separate models involving b) only foreign and c) only Norwegian drivers. We tested whether the differences between the log likelihoods for each of the models were significantly different from each other; to determine whether any of the models fitted the data significantly better. The differences between all the models were significant, indicating that the model with both groups (and the highest log likelihood) fitted the data best. Thus, this indicated that we should keep our regression model involving both foreign and Norwegian drivers, and not make separate models.

It would nevertheless have been impossible to make separate models for Norwegian and foreign drivers, as Norwegian drivers are in the "top end scale" of the key variables that we study. This applies to the dependent variable; perceived mastery: only four of the Norwegian drivers report that they do not (agree to) cope well with Norwegian winter conditions, while 57 report that they cope well. It also applies to the independent variables, where vast majorities of Norwegian drivers say that they often use snow chains when needed (84%), load the trailer with maximum weight on the driving axle (93%), have

more than hundred days experience of driving on Norwegian winter roads (90%). Thus, correlation analyses involving only the Norwegian drivers show non-significant correlations on the variables displayed in Table 5. The situation is, however, different for correlation analyses involving only the foreign drivers, which show results relatively similar to those in Table 5. (This is due to the variation between the more experienced Nordic drivers and the less experienced CEE drivers in the foreign drivers sample.) This indicates that the included variables are "scaled" to capture the difference between Norwegian and foreign drivers, i.e. the presumably lower experience and perceived mastery of foreign drivers. Thus, we include both groups in the logistic regression in Table 6.

An additional potential shortcoming of the survey data is unobserved heterogeneity. This is an important issue that needs to be addressed in the modeling process of survey-based data, as various unobserved elements, such as subjectivity, personality traits and characteristics, and preferences of the respondents may influence critical outcome variables. Although we have not examined this issue in the present study, there are specific modeling techniques that can explicitly account for this (cf. Hezaveh et al., 2019).

4.4.4. Towing incident data

The main strength with the towing incident data is that they provide a comprehensive overview of generally less serious incidents (i.e. towing incidents), which not are registered in accident statistics, and that they also include information about vehicle nationality. A critical point which has been raised to the towing incident statistics is that foreign HGVs that run off the road in some cases acquire help from foreign towing companies, as these are less expensive than Norwegian companies. If they run off the road, they do not stop the traffic, and they can possibly wait for foreign towers. If so, they are not included in our Norwegian towing incident data. When stuck on the road, they stop traffic, and the police is likely to call the closest (Norwegian) towers. If so, they are included in our data. It is difficult to assess the prevalence of this. Our towing company contact mentioned that it sometimes may happen. We have heard a few accounts about this, but we do not have information indicating that it happens at a large scale. Moreover, the consequence of this effect would not influence foreign HGVs share of the total number of HGVs that are stuck on the road, only the share of HGVs that have run off the road.

CRediT authorship contribution statement

Tor-Olav Nævestad: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Writing - original draft, Writing - review & editing. **Fridulv Sagberg:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Writing - original draft, Writing - review & editing. **Gunhild Levlin:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Writing - original draft, Writing - review & editing. **Torkel Bjørnskau:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Writing - original draft, Writing - review & editing.

Acknowledgements

The present paper has been written as an extension of the Safe Foreign Transport project (2013-2015), which was financed by the Norwegian Research Council. We are grateful to the TRANSIKK program of the Norwegian Research Council for funding this research (Grant 224841). The paper is based on a larger study of the safety outcomes of internationalization of road transport of goods which is presented in a comprehensive report: Nævestad et al. (2016) and a paper: Nævestad, Phillips, Levlin, and Hovi (2017). Both the interview guide and the survey that the present study is based on are provided in the 2016 report. We are very grateful to Arnfinn Eriksen at the Norwegian Public Roads Administration (NPRA), who have given us data presenting the results from all heavy vehicle inspections in Norway for the period 2012-2015. We are also very thankful to Fredrik Bergmann at Falck Redning AS for providing us with statistics on towing assistance given to Norwegian and foreign HGVs.[6]

References

Aschenbrenner, K. M., & Biehl, B. (1994). Improved safety through improved technical measures? Empirical studies regarding risk compensation processes in relation to anti-lock braking Systems. In R. M. Trimpop & G. J. S. Wilde (Eds.), *Challenges to Accident Prevention: The Issue of Risk Compensation Behaviour*. Groningen: Styx Publications.

Carsten, O. (2013). Early theories of behavioural adaptation. In C. M. Rudin-Brown & S. L. Jamson (Eds.), *Behavioural adaptation and road safety* (pp. 23–34). Boca Raton, FL: CRC Press.

Christensen, P., & Glad, A. (1996). *Obligatorisk glattkjøringskurs for førere av tunge biler. Effekt på ulykkesrisikoen*. Oslo: Transportøkonomisk institutt.

Elvik, R., Høye, A., Vaa, T., & Sørensen, M. (2009). *The handbook of road safety measures* (2nd ed.). Bingley: Emerald Insight.

European Parliament. (2013). Directorate General for Internal Policies, Policy Department B: Structural and Cohesion Policies; Transport and Tourism; Development and Implementation of EU Road Cabotage: Annex, Hong Kong, China.

Evans, L. (1991). *Traffic safety and the driver*. New York: Van Nostrand Reinhold.

Fuller, R. G. C. (1984). A conceptualisation of driving behaviour as threat avoidance. *Ergonomics, 27*, 1139–1155.

Fuller, R. (2000). The task-capability interface model of the driving process. *Recherche Transports Securité, 66*, 47–57.

[6] The statistics and data on the project "FOU Bilberging" is based on a presentation held by Bergmann in Karlstad November, 12. 2015. Confer: http://www.nvfnorden.org/hemsida/utvalg/ts-risker-med-eu-trailer-pa-hala-vagar/

Fuller, R. (2011). Driver control theory: From task difficulty homeostasis to risk allostasis. In B. Porter (Ed.), *Handbook of traffic psychology* (pp. 13–26). London: Academic Press.
Giæver, T., Jørgensen, E., Moe, D., Sakshaug, K., Stene, T. M., & Ytrehus, I. (2006). Tunge kjøretøy og fartsvalg (STF50 A05136).
Gregersen, N. P., Brehmer, B., & Morén, B. (1996). Road safety improvements in large companies. An experimental comparison of different measures. *Accident Analysis and Prevention, 28*, 297–306.
Hezaveh, A. M., Nordfjærn, T., Everettc, J., & Cherrya, C. R. (2019). The correlation between education, engineering, enforcement, and self-reported seat belt use in Tennessee: Incorporating heterogeneity and time of day effects. *Transportation Research Part F, 66*, 379–392.
Hovi, I. B., Bråthen, S., Hjelle, H. M., & Caspersen, E. (2014) Rammebetingelser i transport og logistikk, TØI-rapport 1353/2014.
Kinnear, N. A. D., & Helman, S. (2013). Updating risk allostasis theory to better understand behavioural adaptation. In C. M. Rudin-Brown & S. L. Jamson (Eds.). Behavioural adaptation and road safety (pp. 87-110). Boca Raton, FL: CRC Press.
Langeland, P. A., & Phillips, R. O. (2016). *Tunge kjøretøy og trafikkulykker – Norge sammenlignet med andre land i Europa, TØI-report 1494/2016*. Oslo: Institute of Transport Economics.
Leviäkangas, P. (1998). Accident risk of foreign drivers- the case of Russian drivers in South-Eastern Finland. *Accident Analysis and Prevention, 30*(2), 245–254.
Levlin, G. M. (2014). Utenlandske vogntog på norske vinterveger, Bacheloroppgave, Katastrofe- og risikomanagerutdannelsen KAT2011F Metropolitan University College Copenhagen.
Lewis-Evans, B., de Waard, D., Brookhuis, K.A. (2013). Contemporary Models of Behavioural Adaptation. In Eds. C. Rudin-Brown, S. Jamson, Behavioural Adaptation and Road Safety: Theory, Evidence and Action.
Moe, D. (2003). Stressmålinger av vogntogsjåfører under kjøring på tørr asfalt og på glatt vinterføre (STF22 A03316).
Näätänen, R., & Summala, H. (1976). Road user behaviour and traffic accidents. Amsterdam: North Holland.
Nævestad, T.-O., Bjørnskau, T., Hovi, I. B., & Phillips, R. (2014). (2014) Safety outcomes of internationalisation of domestic road haulage: A review of the literature. *Transp. Rev., 34*, 691–709.
Nævestad, T. -O., Phillips, R. O., Levlin, G. M., & Hovi, I. B. (2016). Internationalisation in Road Transport of Goods: Safety Outcomes, Risk Factors and Measures; TØI Rapport 1487/2016; TØI: Oslo, Norway.
Nævestad, T. O., Hovi, I. B., Caspersen, E., & Bjørnskau, T. (2014). *Ulykkesrisiko for tunge godsbiler på norske veger: Sammenlikning av norske og utenlandske aktører, TØI rapport 1327/2014*. Oslo: Transportøkonomisk institutt.
Nævestad, T. -O, Phillips, R., Levlin, G. M. & Hovi, I. B. (2017). Internationalisation in Road Transport of Goods in Norway: Safety Outcomes, Risk Factors and Policy Implications, Safety 3(4), 22.
Nævestad, T.-O., Blom, J., & Phillips, R. O. (2020). Safety culture, safety management and accident risk in trucking companies. *Transportation Research Part F: Traffic Psychology and Behaviour, 73*, 325–347.
OECD Scientific Expert Group (1990). *Behavioural adaptations to the road transport system*. Paris: OECD.
Pless, B. (2016). Risk compensation: Revisited and rebutted. *Safety, 2*(16), 1–9.
Rambøll (2016). Kvaliteten På Det Norske Veinettet 2016 DEL 1—Sammenligning Med Europa, Opplysningsrådet for Veitrafikken: Oslo, Norway.
Rumar, K., Berggrund, U., Jernberg, P., & Ytterbom, U. (1976). Driver reaction to a technical safety measure - studded tyres. *Human Factors, 18*, 443–454.
Sagberg, F., Fosser, S., & Sælensminde, K. (1997). An investigation of behavioural adaption to airbags and antilock brakes among taxi drivers. *Accident Analysis and Prevention, 29*(3), 293–302.
Steen Jensen Bråten, R. M., Jordfald, B., Dotterud Leiren, M., Nævestad, T.-O., Skollerud, K. H., Sternberg, H., & Tranvik, T. (2014). Arbeidsforhold I gods og turbil. *Fafo rapport, 2014*, 58.
Summala, H. (2007). Towards understanding motivational and emotional factors in driver behaviour: Comfort through satisficing. In C. Cacciabue (Ed.), *Modelling Driver Behaviour in Automotive Environments* (pp. 189–207). London: Springer.
Wallman, C. G. (2005). Mätning av fordonshastighet och flöde vide olika väglag, VTI meddelande, 953-251.
Welsh, E. (2002). Dealing with data: Using Nvivo in the qualitative data analysis process. *Forum: Qualitative Social Research, 3 No. 2*.
Wilde, G. J. S. (1982). The theory of risk homeostasis: Implications for safety and health. *Risk Analysis, 2*, 209–255.