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Traffic safety effects of economic driving in trucking companies

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Highlights

- We first test the relationship between economical driving and traffic safety at the driver level and find a clear relationship.
- Drivers with high scores in the fleet management systems which record key aspects of economic and safe driving style have a lower accident risk.
- We then test the relationship between economical driving and traffic safety at the organizational level, using the Eco Ladder for energy management.
- Results indicate a lower accident risk for companies at the top level in the Eco Ladder for long-distance and regional transport.
- We find relationships between focus on economy and safety at both driver, technology and company level.
- We also discuss potential conflicts between economical driving and traffic safety.

Abstract

The present study examines the relationship between economic driving and road safety in trucking companies that have received support to work with economic driving, and a Reference sample of drivers from assumed average companies. The study is based on survey data (N=366), and qualitative interviews (N=26) with managers and employees. We first test the relationship between economic driving and traffic safety at the driver level (aim 1) and find a clear relationship: drivers with high scores in the fleet management systems, which record key aspects of economic and safe driving style, have a lower accident risk than drivers with lower scores. We then test the relationship between economic driving and traffic safety at the organizational level (aim 2), using the Eco Ladder for energy management approach to describe companies with different levels of measures to facilitate economic driving. Results indicate a lower accident risk for companies at the top level in the Eco Ladder for long-distance and regional transport (but not in distribution transport). This is due to the fact that the companies at the top of the Eco ladder have the most measures to facilitate economic driving, and thus the largest proportion of drivers with high scores in the fleet

management system. We find relationships between focus on economy and safety at both driver, technology and company level. We also discuss potential conflicts between economic driving and traffic safety.

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1. Introduction

1.1. Background

Accidents with heavy goods vehicles (HGVs) represent an important societal challenge. These accidents generally have high proportions of killed and severely injured people, because of the weight of the heavy vehicle. In the EU, about 3040 people were killed in road accidents involving HGVs in 2019, making up about 14 % of all road fatalities (European Commission 2021). In the US, 4965 people were killed in accidents involving large trucks in 2020, and 71 % of these were other road users (NSC, 2023). In Norway, 20 % of the people who were severely injured or killed in traffic in the period 2007–2016 could be attributed to accidents involving HGVs (Nævestad et al 2020). Most of the people who were severely injured or killed were other road users. There is thus a huge and largely untapped road safety potential in improving road safety in trucking companies. Norwegian research indicates, however, that trucking companies often have few organisational safety management measures (Nævestad et al., 2015). Similar tendencies have been found in research from other countries (e.g. Mooren et al., 2014).

Previous research suggests that this is probably related to the size, resources and expertise of the companies, and the fact that the results of the measures, for example for safety and economy, are not well known (Nævestad et al., 2018). Most measures aimed at organisational safety management are comprehensive, and they require a good deal of time, resources and expertise (Nævestad et al., 2018; Murray et al., 2012, Wallington et al., 2014). In other words, there seems to be a great need for road safety measures that require few resources, that are easy to implement and that have clearly quantifiable results in the form of reduced accidents and saved costs.

In an earlier study of safety culture in transport companies (Nævestad et al., 2018)), we found that several of the goods transport companies that we studied had received financial support to introduce measures to reduce fuel consumption through Enova's programme for Energy Management in Land Transport. Enova is a Norwegian government enterprise responsible for promotion of environmentally friendly production and consumption of energy. In the period 2012–2018, Norwegian goods transport companies could apply to Enova for financial support for measures aimed at economic driving through Enova's programme for energy management in land transport. The energy management program is based on the ISO standard for energy management: ISO:50001. Almost 100 companies applied during the project period, most with assistance from the Norwegian Truck Owners' Association.

The studied companies emphasised a close relationship between measures for economic driving and road safety, and one of the companies reported that the company had saved about 300000 Euro over a one-year period through measures focusing on economic driving, and also experienced a 40% decrease in accidents as a result of these measures (Nævestad et al., 2018)). These results are in accordance with previous studies of economic driving with HGVs, which find reductions in fuel consumption of 6.8% (Díaz-Ramirez et al., 2017), 5.5 % Ayyildiz et al. (2017), 27% (Symmons et al. 2008). Such reductions give rise to large economical savings for companies that often face small economical margins. Although there are few studies of traffic safety effects of economic driving for cars in general and heavy vehicles in specific, the few existing studies' estimates in reductions in accident risk vary between 0% (Af Wåhlberg 2007) and 35% reduction (cf. Haworth and Symmons 2001). Thus, measures focusing on economic driving may also involve considerable reductions in costs related to traffic accidents and reduced downtime for vehicles. A typical single accident with HGVs may involve costs of e.g. 50000 Euro for the company, excluding potential lost assignments etc.

The main mechanism behind the relationship between economic driving and traffic safety is certain driving style aspects. Economic driving is defensive, anticipatory and slow driving, which is often related to increased road safety (Huang et al., 2018, Dekhordi et al., 2019, Li et al., 2019). Previous studies mainly measure such aspects through in vehicle data recorders (IVDR), which typically focus on abrupt acceleration and deceleration and other movements that trigger g-forces, e.g. too high speed in curves. We refer to the IVDR used in HGVs as fleet management systems. Using such technology in passenger cars, Toledo and Shiftan (2016) that feedback from fleet management systems can lead to a reduction of between 3 and 10% in fuel consumption and an 8% reduction in safety incidents (Toledo and Shiftan 2016). The most important driving style aspects (and proxy for economy and safety) in the study of Toledo and Shiftan (2016) was abrupt acceleration/deceleration.

Based on the above-mentioned results, it can be asked whether economic driving also is an effective road safety measure. It is probably easier to motivate transport companies to introduce such measures than pure road safety measures, because reduced fuel consumption has direct financial benefits for the companies. The importance of this argument should be even greater in a period of increasing fuel prices, as we currently have in Europe. In addition, reduced fuel consumption is directly linked to lower emissions.

Economic driving is generally defined as a decision-making process that affects fuel consumption and emissions from vehicles to reduce the impact on the external environment (Sivak and Schoettle 2012). In this study, we define economic driving both at the driver level and at the company level. Economic driving at the driver level refers to an economic driving style, as we have defined it above (cf. Huang et al., 2018, Dekhordi et al., 2019, Li et al., 2019). Economic driving at the company level refers to systematic managerial implementation of organisational measures to facilitate economic driving at the driver level. We use an approach that is called the Eco ladder for energy management in goods transport to define economic driving at the company level (Nævestad and Hagman 2020). The Eco Ladder describes three levels of energy management, with increasing numbers of measures. We tested the Eco Ladder model empirically in 14 companies in Nævestad et al. (2020), and found the highest fuel reductions (around 10% in a year for the whole fleet) in companies at the highest level in the Eco Ladder, where the most measures are also implemented. In the present study, we test whether we see similar positive relationships with road safety.

Studying this, we also control for the importance of work-related factors that influence the driving style of professional drivers in manners that may constrain the possibilities to drive economically. Previous studies indicate that professional drivers are a group considered particularly at risk of stress and fatigue, following from excessive amounts of demands (i.e., time pressure, long, and irregular work schedules) (Useche et al., 2019a, Useche et al., 2019b). These are factors which are known to influence driving styles (Useche et al., 2019a, Useche et al., 2019b). Stress and time-pressure may lead to a more aggressive driving style (Nævestad, Phillips, Laiou et al., 2019), which might be seen as the opposite of an economic driving style. Useche et al (2020) find that the job strain of professional drivers is positively associated with occupational traffic crashes, and that this association is stronger for drivers with "angry & hostile" driving styles. In an analysis of fatal accidents, Nævestad et al (2015) find that professional drivers experiencing stress and time-pressure are more likely to trigger fatal road accidents.

1.2. Aims

The study has two objectives:

1) To examine relationships between economic driving and road safety at the driver level, and mechanisms that explain this.

2) To examine relationships between economic driving/energy management and road safety at the organisational level and mechanisms that may explain this.

2. Previous research

2.1. Measures for economic driving

The use of fleet management technology, also referred to as IVDR, is the most basic element of companies' work on economic driving (Díaz-Ramirez et al., 2017; Ayyildiz et al., 2017; Sanguinetti et al. 2020). This is a system mounted in the vehicles, which records a number of aspects of the drivers' driving style. The systems used in HGVs measure a number of characteristics of the drivers' driving style, which are combined into five or six main aspects, to which the fleet management systems provide feedback (e.g. idling, anticipatory driving, braking, roll out, cruise control use and speed) (Nævestad et al., 2018, Walnum and Simonsen 2015). The system gives scores for the various main aspects, and the scores for the main aspects are combined into a general score that the drivers get based on their driving (for example: E-A, 1–100). The composition of the scores and is based on algorithms, which weight different aspects. First, these aspects measure an economic driving style. A fleet management system expert interviewed in Nævestad and Hagman (2020) said that the vehicle supplier states that an improvement from mark E to A on average involves an 11% reduction in fuel consumption. Second, the aspects measured in the fleet management system also measures a safe driving style. Experts interviewed by Nævestad and Hagman (2020) mentioned that indicators of safe driving (speed, anticipatory driving) count the most when the algorithms in the fleet management systems weigh different driving style aspects to calculate driver marks/scores (Nævestad & Hagman 2020). Drivers can see their own scores after each trip (or day, week, etc.) on display in the vehicles, or on mobile phone applications. Managers in transport companies can see all the drivers/vehicles' scores, and often make compilations of these, which are more or less regularly distributed to the drivers. The calculations of the drivers' scores in the system are based on a number of different limit values (for example for the number of hard decelerations, proportion of time at idle, proportion of time with cruise control). How drivers score on these parameters will also depend on the type of driving they have, where and when they drive, etc. This can make it complicated to compare drivers' scores in the system. However, there are settings for this in the system, for example for long-distance transport and distribution driving. Another measure of company-level economic driving is individual feedback to drivers from the systems. Individual feedback to drivers about their scores in the fleet management system is fundamental, because it is a prerequisite for drivers to learn from the feedback and change their driving style (Ayyildiz et al., 2017). A third measure is training in economic driving. Most studies of economic driving with heavy vehicles include some form of training of drivers in economic driving style (Strömberg and Karlsson, 2013, Symmons et al., 2008). A fourth measure is formal or informal competitions between drivers in having as economical a driving style as possible. Various incentives (competitions and bonuses) to change driving style and achieve high scores seem to be important measures (Diaz-Ramirez 2015; Ayyildiz et al., 2017). The reason is that drivers' motivation is a fundamental factor for economic driving. Informal competitions, whether against oneself and one's own previous scores or others' scores, therefore seem to be an important motivating force. A fifth measure that is implemented to increase driver motivation is bonuses associated with having as economical a driving style as possible (Diaz-Ramirez 2015; Ayyildiz et al., 2017, Nævestad and Phillips, 2018)).

2.2. Energy management systems

Management systems that aim to reduce the environmental impact of organizational activities are often referred to as environmental, emissions or energy management systems (EMS). We generally refer to these as EMS (Johnson et al 2013; Comoglia and Botta 2011). In the road sector, ISO 50001 and ISO 14001 represent the most relevant examples of international EMS standards, which focus on energy and the environment, respectively. Implementation of the ISO 50001 standard involves the creation of a formal organizational energy policy with defined goals for reduced consumption, energy planning for how the goal is to be achieved and methods for monitoring one's own goal achievement, continuous monitoring of the situation using an internal audit system, measurement and analysis, identification of discrepancies, followed by corrective and preventive measures to ensure goal achievement (Johnson et al. 2013). The key element in EMS is the continuous improvement, achieved through the Plan-Do-Check Act (PDCA) (Comoglio and Botta 2011). Although there are few scientific studies of such measures, "business cases" indicate that companies may achieve around 20% energy reduction on average by implementing energy management systems, even more than is usually achieved by focusing solely on driving style (FCC Environment, 2000).

2.3. Effects on road safety

2.3.1. Traffic safety effects of fleet management system and driving style

There are few studies examining the road safety effects of economic driving, especially with heavy goods vehicles, and it is therefore also relevant to include studies of passenger cars. In a systematic literature review of the relationship between economic driving and road safety, Haworth and Symmons (2001) refer to studies indicating up to 35% reductions in accident risk. We have found five studies that contain separate empirical investigations of the relationship between economic driving and road safety (Af Wåhlberg, 2007, Symmons et al., 2008, Jamson et al., 2015, Toledo, 2016, Nævestad, 2022). The first study finds no effects on road safety, presumably due to the low effect of the studied measure of economic driving: only 2% fuel reduction (Af Wåhlberg 2007). A similar effect on accidents would be too small to identify. The second study measures road safety as drivers looking far ahead (measured by passengers observing this manually) and finds no effects (Symmons et al. 2008). The third study does not focus on road safety effects (Jamson et al. 2015), but on what type of feedback has the greatest effect, and whether the test subjects focus on economy or safety when they have to choose. The fourth study finds effects on both road safety and fuel consumption. The study concludes that feedback from fleet management systems can lead to a reduction of between 3 and 10% in fuel consumption and an 8% reduction in safety incidents (Toledo and Shiftan 2016). This is a study involving 150 private cars used by over 350 drivers over a year. Nævestad (2022) includes three companies studied on three occasions, in: 1) 2013, 2) 2018 and 3) 2020. Two of the companies introduced fleet management systems after the first measurement, and results indicate considerable reductions in accident risk over time. An important underlying hypothesis in all the evaluated studies focusing on traffic safety effects of economic driving at the driver level seems to be that a defensive, slow driving style, focusing on smooth acceleration/deceleration, avoiding hard braking, driving at the highest possible gears and anticipating the pending traffic conditions, is both economical and road-safe (Huang et al. 2018). Driving style is the most important mechanism mediating the relationship between economic driving and road safety in the majority of the studies evaluated.

Some studies also highlight potential conflicts between economic driving and traffic safety. Alam & McNabola (2014) state that although some studies indicate a 40% lower risk of accidents at the individual driver level, these studies do not take into account the interaction on the roads, which the economical drivers create. They stress that economic driving may lead to other drivers taking risks, because of their irritation, leading to dangerous overtakings. They also state that economic driving may also lead to distraction and impaired attention.

2.3.2. Traffic safety effects of energy management system

There are few studies of road safety effects of economic driving at the company level or related to energy or environmental management systems. Nævestad, Phillips, & Milch (2019) find that bus companies that were certified according to ISO: 14,001 said that the ISO "way of thinking" and the approach to continuous improvement also had been transferred to their work on road safety. They also mentioned that it was relatively uncomplicated for them to eventually implement the ISO39001 standard when they were already certified according to ISO:14001. In line with the results mentioned above, other studies also conclude that the threshold for implementation of safety management systems are lower for companies that already have environmental management systems or quality management systems, and that the continuous improvement approach applied in these systems may spill over to safety management (Ackerknecht et al., 2005, Jørgensen and Remmen, 2006, Hamidi et al., 2012). These studies also find often a certain consistency in studied companies' focus on avoiding externalities (emissions, accidents), through the approach to continuous improvement provided by such systems, and use it as an argument for "integrated management systems", focusing on safety, quality and environment.

2.4. The Eco Ladder for energy management in trucking companies

The studied companies have implemented different levels of measures related to economic driving and energy management. To categorize these measures in the companies, defining their level of implementation of measures, we use the Eco Ladder for energy management.

Previous research shows that it is challenging for road goods transport companies to start implementing systems for economic driving and energy management (Díaz-Ramirez et al., 2017). Such systems often require considerable resources and expertise at various levels, and this can be a challenge for many goods transport companies, because they are small. In Norway, 86% of them have fewer than five employees, while 80% have fewer than 10 employees at the EU level (European Commission 2009). It is reasonable to think that small goods transport companies have fewer resources (time, economy, expertise) than larger companies, and that this may pose a significant barrier to introducing systems for energy management and economic driving at the organisational level (cf. Nævestad et al., 2020).

The Eco Ladder describes an approach with gradual introduction of specific measures, where companies will start with the measures that have the greatest effect and are easiest to implement before moving on to the next level.

Based on previous research in Norway and internationally, we have concluded that three main measures aimed at economic driving and energy management have the greatest potential and are most realistic to implement for ordinary goods transport companies (Nævestad and Hagman 2020). These measures can be arranged on a ladder (cf. Fig. 1), where you start at the lowest level, before proceeding to the next step. In contrast to the other three levels, we have also included a "level 0" in the model, which denotes a "traditional attitude" to fuel consumption. This attitude involves managers and drivers thinking that "the vehicle uses the fuel it has to use", and that the drivers' driving style has little influence. Experts interviewed believed that this "traditional" attitude was the norm before, and that it still exists in several transport companies today (Nævestad and Hagman 2020).

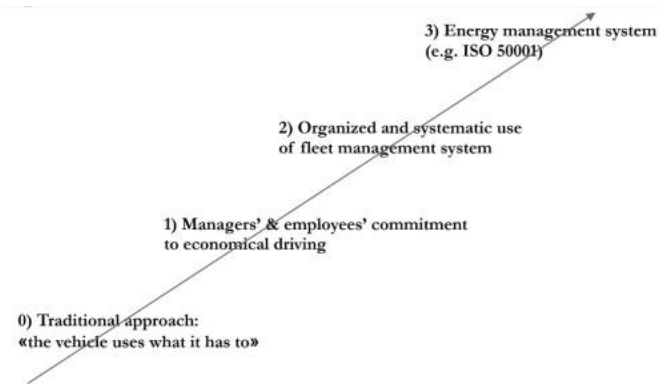

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Fig. 1. The Eco Ladder for energy management.

Level 1 refers to the commitment of managers and employees to economic driving, since this is a prerequisite for the introduction of organisational measures aimed at economic driving and a system of energy management. Since the introduction of such measures requires considerable resources, it requires a significant commitment from both managers and employees.

Level 2 refers to organised and systematic use of fleet management systems to map the driving style of the drivers, provide feedback so drivers can learn and change driving style, training and incentives (competitions and bonuses).

Level 3 refers to system of energy management of type ISO:50001, or implementation of the most important principles in such systems. This level is important, because it is the level that is believed to lead to the largest reductions in fuel consumption. At the same time, this system level is the most demanding to work with, because it requires systematic analyses of large amounts of numbers, and continuous follow-up and improvement.

2.5. Hypotheses

We test six hypotheses in this study, based on the research outlined above:

1) ***Hypotheses on effects and relationships at the driver level:*** Drivers with high scores in the fleet management system have a higher level of road safety than drivers with low scores (*Hypothesis 1*). The reason for this is a hypothesis that an economic driving style is often the same as a safe one, because it is defensive, controlled and calm (*Hypothesis 2*), and that fleet management systems reward both safe and economic driving *(Hypothesis 3*).

2) ***Hypotheses on effects and relationships at the organisational level:*** The road safety level increases for the companies at each level of the Eco Ladder for Energy Management in goods transport (*Hypothesis 4*). These companies will have several measures aimed at economic driving and energy management and thus more drivers with high scores in the fleet management system (*Hypothesis 5*). In addition, we assume that companies that work systematically with continuous improvement aimed at environmental management often also do so with the aim of safety management (*Hypothesis 6*).

3. Methods

3.1. Design of the study

The study is based on two methods and data sources. The first is qualitative interviews with 26 company representatives: We interviewed 16 managers and 10 representatives of employees in 14 trucking companies in companies that have received support from Enova to work on economic driving. We used information from the interviews to categorize and rate the work on economic driving in the companies and place them at a level in the Eco Ladder. The second method is survey among drivers in 14 companies that have received support from Enova (N=225) to work on economic driving, and a Reference group (N=169) of drivers from supposedly average companies. We used the survey results to test our hypotheses among drivers in different companies that were placed at different levels in the Eco Ladder based on the interviews.

3.2. Qualitative interviews

3.2.1. Topics

We have conducted qualitative interviews with 16 managers and 10 employees. The interviews were conducted over the telephone, and they lasted mostly between 60 and 90 min. The main purpose of the interviews was to obtain information about how companies work with economic driving, energy management and road safety, and their perceived results of this.

We started by asking about the company: the number of employees, what is transported, etc. Then we asked when the company started to implement measures for economic driving/energy management. We then asked which elements are the most important in the company's measures for economic driving, for example: goals, policies, fleet management, feedback to the drivers, training for improvement (from supplier, in-house, others), work with engagement, motivation and knowledge, competitions and bonuses.

We then asked about the companies' use of fleet management systems in the work on economic driving, e.g. which parameters they focus on. We then asked about perceived results of the work of economic driving and energy management, on fuel consumption, company economy, drivers' driving style, road safety etc. Finally, we asked about safety management at the various levels of the Safety Ladder (Nævestad et al., 2020). We also asked for certifications related to energy management, safety management etc.

3.2.2. Analysis

We used the interviews to place the companies at a level on the Eco Ladder for Energy Management (Nævestad and Hagman 2020) and on the Safety Ladder for safety management in goods transport (Nævestad et al., 2020). In the interviews, we placed great emphasis on obtaining specific examples of practices in the companies; how often particular practices and incidents occur. We also asked for more detailed examples of the situations, how often certain events happen in a year etc. This information is important in order to analyse the results from the companies and place them at the right level. We classify the companies at the Eco Ladder to map their level of measures related to economic driving and energy management in the "Enova campaign periods", and we classify the companies at the Safety Ladder to control for their safety measures when we assess the road safety impacts of the economic driving measures.

We place the companies on the Eco Ladder for Energy Management and Safety Management based on criteria that we give the companies points for. The Eco Ladder for Energy Management has three levels, but we only operate with criteria for levels 2 and 3. Table 1 presents 10 criteria. If we divide 10 points into a three-level scale, we might assume that level 2 companies score between 3.5 and 6.7 points, and that level 3 companies score between 7 and 10 points. It is important to accept that these criteria must not be interpreted "mechanically". The criteria are used to obtain a simplified overview. In some cases, we give the score 0.5. This means that the company to some extent meets the criterion, or meets parts of it.

Table 1. Criteria for classifying the companies' level on the Eco Ladder.

LEVEL 2	1	The company has a fleet management system on all vehicles and a system for analysing the data
	2	The company has routines for regular individual feedback to drivers (e.g. daily), about their economic driving style and fuel consumption, based on data from the fleet management system
	3	The company has a system for training drivers in economic driving

	4	The company has routines/systems to motivate drivers to drive economically, through organised competitions between the drivers
	5	The company has routines/systems to motivate drivers to drive economically, through bonuses related to economic driving
LEVEL 3	1	The company has a policy of stated goals for reduced energy use in general and fuel consumption in particular (and the manager regularly informs drivers how they are doing in relation to the goal).
	2	Management has a good overview of all key figures, such as diesel consumption, energy use, costs, development and scores in the fleet management system, and investigates the effects of measures taken.
	3	The company has a systematic (analytical/mapping) focus on saving fuel through optimising vehicles and equipment.
	4	The company maps transport and works actively to optimise routes and organise transport (transport the most goods for the fewest km)
	5	The company conducts comprehensive analysis and takes measures aimed at all energy use in the company.

Table 2 presents criteria for classifying the companies' level on the Safety Ladder. See Nævestad et al. (2018) for a detailed account of what these criteria entail in practice in goods transport companies.

Table 2. Criteria for classifying the companies' level on the Safety Ladder.

LEVEL 2	1	Speed, driving style and seat belt policy that is known by drivers
	2	Fleet management system in place and continuously follows up on drivers' speed and driving style.
	3	Drivers regularly receive feedback (weekly, monthly) on speed and driving style from the system.
LEVEL 3	1	Wage system set up with a view to minimising drivers' stress and fatigue.
	2	Drivers are encouraged to abort or postpone assignments if they believe they are not safe to carry out, and do in fact do so.
	3	When planning assignments, the fatigue and stress impacts that a new assignment will entail on drivers is mapped
LEVEL 4	1	The company has a functioning reporting system, which is used both by employees (reports) and managers.
	2	The company regularly conducts formal risk analyses for all its assignments
	3	The company has a good training programme, with predefined, theoretical and practical sequences of activities and a plan for knowledge goals and activities to achieve and assess the objectives.

If we divide the nine criteria by 4 to set a scale, we can assume that level 2 companies score between 2.25 and 4.5 points, companies at level 3 score between 4.5 and 6.75 points, while level 4 companies score between 6.75 and 9 points.

3.3. Quantitative survey

3.3.1. Recruitment of trucking companies

We asked all 100 companies that had received financial support from Enova for the Energy Management Program to participate in our study, and we worked to recruit companies and respondents to the study over a period of about six months. In an attempt to get a high response rate from the drivers in the companies that participated in the survey, we informed the respondents that we were drawing winners of two gift cards of NOK 3000 each among those who responded to the survey. Those who provided their name or telephone number at the end of the survey had the opportunity to participate in this draw.

3.3.2. The Reference sample

Since the purpose of our study was to compare companies at different levels of the Eco Ladder for Energy Management (companies that have received support from Enova) with companies that work less with economic driving and energy management, we needed to “balance” the data by also including drivers from more “average” Norwegian goods transport companies on the road. One possible option could be to try to recruit companies from what we refer to as “Level 0″. However, in previous research we have found that such recruitment works poorly, because there is often a strong correlation between working actively on a particular issue and wanting to participate in a survey on the same topic. Our contact person in a drivers’ union suggested that organised drivers from companies without a collective agreement would correspond to a relatively good ”industry average“. and that these would be closer to what we could assume would be the average for Norwegian goods transport than the respondents we already had in the survey. In this way, we could better balance our sample and have better opportunities to test our hypotheses. Since this assumption proved correct in an earlier survey (Nævestad et al., 2020), we chose the same solution to balance our sample in the present survey. We refer to the respondents from companies without collective agreements as ”The Reference Sample“.

3.3.3. Topics in the survey

(1) **Background questions.** The survey includes eight background questions: Sex, age, experience, seniority in the company, number of 1000 km of heavy vehicle driving over the past two years, what kind of transport drivers work with the most (long-haul transport of goods, distribution, regional transport, all three), industry type (construction, timber, piece goods, ADR, bulk, thermo, other), the nationality of the drivers.

(2) **Training in economical driving.** The survey contains five questions about training in economic (and safe) driving, including drivers' perceived effects of such training.

(3) **The use of fleet management systems and cruise control.** We also ask the respondents if they use a fleet management system. We ask those who answer yes to consider the following questions:

- I pay attention to my scores/marks in the fleet management system
- I change aspects of my driving style to improve my scores/marks in the fleet management system
- I follow the instructions of the fleet management system while driving
- I use the fleet management app on my phone.

The response options range from: 1) never/not applicable, 2) Monthly, 3) weekly, 4) daily to 5) several times a day. We merge these questions into a sum score index that measures active use of fleet management systems (min: 4, max: 20 points). (Cronbach's Alpha: 0.801). We also ask the respondents to describe their score/mark in the fleet management system. Five answer alternatives ranged from scores equalling E (lowest) to A (highest).

(4) Measures aimed at economic driving and energy management in the respondent's own company. Five statements measure this:

- We have a clear goal for reduced fuel consumption
- Management regularly provides information on how we are doing in relation to the goal of reduced fuel consumption
- Drivers regularly receive information about (other drivers in the company's) high and low scores/marks from the fleet management system
- Management weekly checks drivers' scores for economic driving
- Drivers get a bonus/reward for reducing their fuel consumption

Answer alternatives range from 1 (totally disagree) to 5 (totally agree). We merge these into a sum score index that measures (formal aspects of) environmental management (min: 5, max: 25). (Cronbach's Alpha: 0.780). We also use a short environmental management scale, in the analyses of factors predicting driver's use of the fleet management system. This index is comprised of two statements.

- We have a clear goal for reduced fuel consumption
- Drivers regularly receive information about (other drivers in the company's) high and low scores/marks from the fleet management system

Answer alternatives range from 1 (totally disagree) to 5 (totally agree). We merge this into a sum score index (min: 2, max: 10) (Cronbach's Alpha: 0.610).

(5) **Environmental culture in the respondent's own company.** The survey contains four questions about environmental culture in the respondents' own company. The purpose of these questions is to measure informal aspects of energy management and economic driving in the companies: how managers and employees actually work with this on a daily basis. We measure this with the following questions:

- Management often gives praise to drivers who have an economic driving style
- Management often emphasizes that we must have as low fuel consumption as possible
- In my company it is considered high status to have an economic driving style
- Drivers in my company compete over who has the most economic driving style

Answer alternatives range from 1 (totally disagree) to 5 (totally agree). We merge these into a sum score index that measures (formal aspects of) environmental management (min: 4, max: 20). (Cronbach's Alpha: 0.780).

(6) **Working conditions.** The survey also contains questions about the extent to which drivers experience customers pushing and stressing drivers; the extent to which customers emphasise safety over deadlines; working environment, pressure and stress from managers. We have made an index based on three statements:

- In my job, I experience that customers push/stress drivers
- In my job I experience that managers push/stress drivers
- In my job, I experience that time pressure and deadlines may impede road safety.

Answer alternatives range from 1 (totally disagree) to 5 (totally agree). We merge these into a sum score index that measures work stress and pressure (min: 3, max: 15) (Cronbach's Alpha: 0.819).

(7) **Questions that measure safety management in the respondent's own company.** We have included four questions about safety management, based on Nævestad et al. (2018):

- In my company we have clear and well-known guidelines for speed and driving style,
- The management emphasizes that the drivers should not drive faster than the speed limits and conditions allow
- In my company we have a strong focus on how the drivers' private life (e.g. little sleep, stressful life situation) may affect traffic safety
- In my company, it is common for drivers to postpone assignments if they feel tired or unfit

Answer alternatives range from 1 (totally disagree) to 5 (totally agree). We merge these into a sum score index that measures safety management (min: 4, max: 20) (Cronbach's Alpha: 0.836).

(8) **Organisational safety culture.** We have included seven questions about organisational safety culture, based on the GAIN index for safety culture (GAIN, 2001). These measure informal aspects of safety management in the companies:

- The drivers encourage each other to drive safely
- Safety in this company is better than in other companies
- Everyone is informed of changes that may affect safety
- In this company, driving safely is more important than delivering on time
- All new employees receive adequate training for the tasks they will be doing
- Regular safety checks are carried out of vehicles
- The management is aware of the most important safety problems in the company

Answer alternatives range from 1 (totally disagree) to 5 (totally agree). We merge these into a sum score index that measures organisational safety culture (min: 7, max: 35) (Cronbach's Alpha: 0.906). We selected the most important GAIN (2001) questions from a previous study (Nævestad et al., 2018), based on "scale if item deleted" analyses and correlations with road safety behaviours.

(9) **Perceived results of work on economic driving in the respondent's own company.** For example, driving style changing self-esteem, pride as a driver, stress and time pressures in the work, dangerous situations in traffic, accessibility, the reputation of the company.

(10) **Road safety behaviours.** The survey contains four questions about drivers' behaviour in traffic:

- I sometimes accept a little risk because "the situation demands it" (e.g. due to time pressure, bad weather)
- I am often unable to keep a three-second distance to the vehicle in front
- I sometimes disregard the speed limit on the motorway
- I sometimes violate traffic rules to get faster to the destination

Answer alternatives range from 1 (totally disagree) to 5 (totally agree). We merge these into a sum score index that measures road safety behaviours (min: 3, max: 15) (Cronbach's Alpha: 0.786).

(1) **Safety outcomes.** The survey also contains questions about several safety outcomes, e.g. accident involvement as a professional driver in the last two years, type of accident (damage to equipment, personal injury, fatal accident) and near misses (situation where the driver has

had to brake hard to avoid accidents or dangerous situations).

3.3.4. Reliability and validity

Alpha estimates were all above the usual 0.7 criteria, suggested by methodological sources (Morera and Stokes, 2016), indicating adequate internal reliability. The only exception to this is the short environmental management index (Cronbach's Alpha: 0.610). This is, however, only comprised of two items. We made this index to identify the most important environmental management variables predicting drivers' systematic use of fleet management system. In spite of the fact that it is only comprised of two items, this short index significantly predicts drivers' use of fleet management system. Thus, we keep this shirt index, despite its Alpha value of 0.610. We assessed convergent validity by examining the bivariate correlations between key variables. The main indexes we include in the survey showed significant and coherent correlation sizes and directions, compared with previous applications of them (e.g. Nævestad et al., 2020, Nævestad et al., 2020) and the theoretical model that the questionnaire is based on. We found significant correlations between organisational safety culture and road safety behaviour (Pearson's R: -.235**), between road safety behaviour and work stress and pressure (Pearson's R: .372**), between environmental management and safety management (Pearson's R: .541**) and between fleet management system use and environmental management (Pearson's R: .210**).

3.3.5. Analysis

We have carried out three regression analyses. Regression analysis is a multivariate analysis used to calculate the effects of various independent variables on a single dependent variable. In the first, we examine factors influencing whether the respondents have been involved in accidents during the last two years while driving a heavy vehicle. We use logistic regression analysis, since the dependent variable is dichotomous, which means that it has two values (Accident: no, yes). In the second regression analysis, we examine factors influencing drivers' scores in the fleet management system. In the third, we examine factors influencing drivers' use of fleet management systems. We have used linear regression in the last two analyses, since these two dependent variables are continuous. The regression analyses show the effects of the independent variables that we include, controlled for the other variables in the analysis. It must be pointed out that we cannot say anything about causality in these analyses, and that some of the connections we see may be due to so-called "un-measured" third variables.

4. Results

4.1. Characteristics of the respondents

4.1.1. Response rates at the different levels of the Eco Ladder

We have classified eleven companies at level 2 in the Eco Ladder, and three companies to be at level 3 in the Eco Ladder. Table 3 shows the response rates in companies at the various levels of the Eco Ladder. The response rate is based on the number of drivers the survey was sent to in the company.

Table 3. The response rates in companies at the various levels of the Eco Ladder.

	Number	**Percent**
Reference	169	24%
Level 2	115	39%
Level 3	82	40%
Total	**366**	30%

Table 3 shows that the survey has a general response rate of 30%. However, Table 3 indicates that the response rate would be around 40% if we disregard the Reference Sample, which has a lower response rate than the companies.

4.1.2. Respondents at the different levels

Table 4 shows the respondents' age in different groups.

Table 4. Respondents' age distributed on the different levels in the Eco Ladder for energy management.

	<26years	**26–35**	**36–45**	**46–55**	**56+**	**Total**
Reference	8%	20%	26%	29%	18%	169

	<26years	26–35	36–45	46–55	56+	Total
Level 2	10%	29%	24%	26%	12%	115
Level 3	16%	15%	32%	24%	13%	82
Total	10%	21%	27%	27%	15%	**100%**
Total	37	78	97	99	55	**366**

We do not see a clear pattern when we look at the age distributions between the groups, except that the proportions in the youngest group are twice as large in the companies at level 3 as in the Reference Sample. The differences are not significant (P=0.154). It should also be mentioned that 6% of the respondents are female.

Respondents at the different levels on the Eco Ladder are relatively comparable when it comes to the types of transport that they are involved in. Looking at long distance transport, the shares are 29% (Reference), 37% (Level 2) and 24% (Level 3). The shares for distribution transport is 25% 20% and 21% respectively, while it is 17%, 16% and 27% for regional transport, respectively and 29%, 28% and 28% respectively for mixed transport.

4.2. Driver-level relationships and mechanisms

4.2.1. The relationship between fleet management scores and accident risk

The first aim of the study is to examine relationships between economic driving and road safety at the driver level, and mechanisms that explain this. Fig. 2 shows a comparison of accident risk among drivers with different marks/grades in the fleet management system.

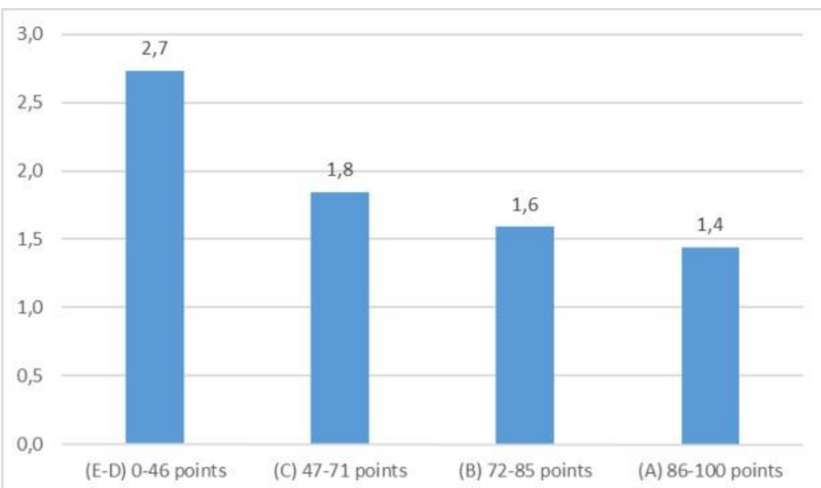

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Fig. 2. Comparison of accident risk among drivers with different marks/scores in the fleet management system. Y axis: material damage accidents per million km driven.Xaxis: Drivers with a mark/score (E-D) 0–46 points (N=16) Mark/score (C) 47–71 points (N=36), Mark/Score (B) 72–85 points (N=82) and Mark/Score (A) 86–100 points (N=119).

Fig. 2 shows a clear relationship between the respondents' marks/scores in the fleet management system and accident risk. However, we must make reservations for small numbers in the groups with low marks/scores: only 16 drivers have marks equal to E-D and only 36 drivers state that they have marks equal to C. The figure indicates a clear relationship between an economic driving style and drivers' accident risk, as the risk decreases for each increased score, and as the accident risk at the A-level is 48% lower than on the E-D level.

4.2.2. Potential conflicts between economic and safe driving

The survey also includes several questions related to potential conflicts between economic and safe driving, e.g. "I sometimes experience that focus on free rolling can create dangerous situations in traffic (e.g. too high speed in roundabouts and in curves)", "I sometimes find that my economic driving style can lead to dangerous situations because other road users get irritated" and "I experience fewer dangerous situations in traffic (after my company started working with economic driving)". Respondents' answers to these questions are shown in Fig. 3.

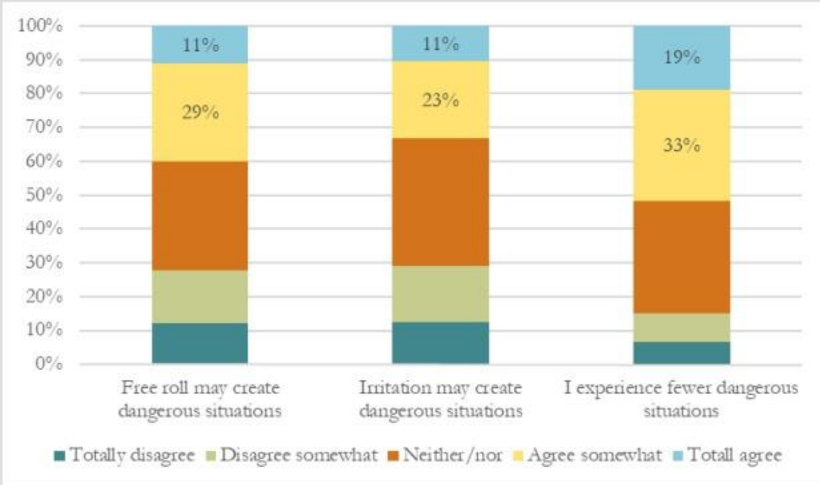

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Fig. 3. Respondents' answer to questions about potential conflicts between economic and safe driving.

Fig. 3 indicates that respondents find that economic driving also may create dangerous situations in traffic, e.g. related to free rolling, and irritation. At the same time, a higher share of drivers reported that they experience fewer dangerous situations because of their company's focus on economic driving. We generally found less agreement with the negative questions among Level 3 drivers compared with the other groups. On the question about free roll, for instance 40% agreed in the Reference group compared to 32% among the Level 3 company drivers ($p=0.203$).

In Fig. 4, we examine another potential source of conflict between economic and safe driving: the use of cruise control. Experts interviewed in Nævestad and Hagman (2020) asserted that the use of cruise control could lead to too high speed in curves and before junctions, and that a frequent use of cruise control therefore is related to a higher risk of accidents. In Fig. 4, we compare the accident risk for drivers who use cruise control to different extents.

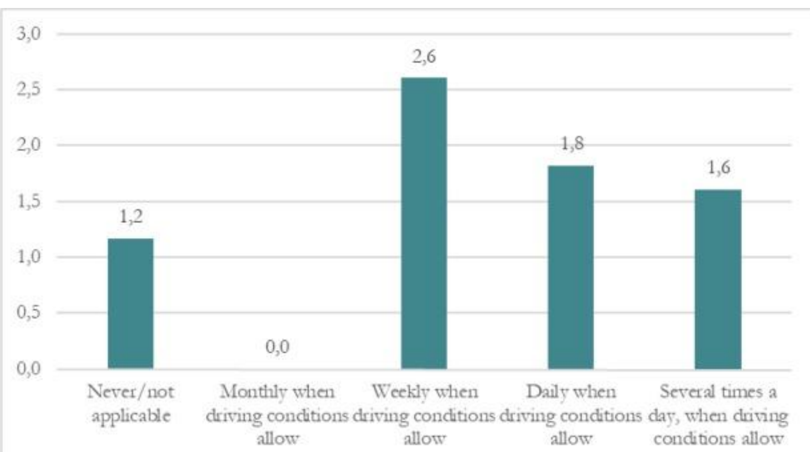

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Fig. 4. Accident risk among drivers who use cruise control to varying degrees, based on self-reported involvement in accidents last two years and kms driven with heavy goods vehicle last two years. Answer options: 1) Never / not relevant (N=20), 2) Monthly, when driving conditions allow it (N=17), 3) Weekly, when driving conditions allow it (N=36), 4) Daily, when the driving conditions allow it (N=106), 5) Several times a day, when the driving conditions allow it (N=214).

The main conclusion to draw based on Fig. 4 is that we cannot conclude that frequent use of cruise control is related to higher accident risk.

4.3. Company-level relationships and mechanisms

The second aim of the study was to examine relationships between economic driving/energy management and road safety at the organisational level and mechanisms that may explain this.

4.3.1. Accident risk at different levels on the Eco Ladder

Fig. 5 shows a comparison of accident risk in the Reference Sample[1] and the companies at different levels on the Eco Ladder for Energy Management among drivers who work mostly in long-haul transport, distribution transport, and regional transport. We also had a category for mixed transport, but we took it out, as the dominant type of transport within the mixed may vary according to the different levels.[2]

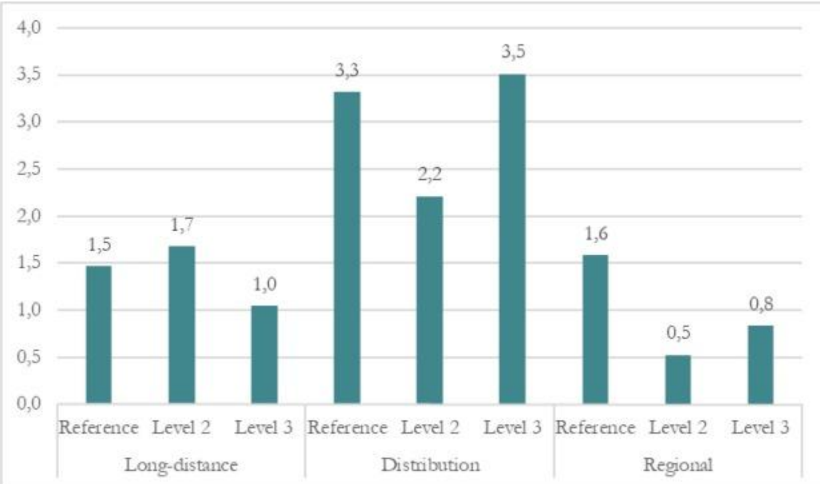

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Fig. 5. Comparison of accident risk in the Reference Sample (N=169), and companies at Level 2 (N=115) and Level 3 (N=82) on the Eco Ladder for Energy Management, among drivers who work mostly in long-haul transport, distribution transport, and regional transport and drivers who work mostly with all three types.

Fig. 5 shows a 33% lower risk at level 3 compared to the Reference Group for long-haul transport, and 50% lower for regional transport. We see approximately equal risk in the Reference Group and Level 3 for distribution transport. The former result is in accordance with *Hypothesis 4*, while the latter result is not.[3]

4.3.2. Mechanisms at the organisational level

In this section, we examine mechanisms related to the relationship between economic driving and safety at the organisational level. We first test Hypothesis 5; that the companies at level 3 of the Eco Ladder have the highest road safety level among the studied groups, because they have more measures aimed at economic driving and energy management, and thus more drivers with high scores in the fleet management system.

4.3.2.1. Measures on economic driving and energy management

We have classified eleven companies at level 2 in the Eco Ladder (five score low at level 2, six high), and three companies to be at level 3 in the Eco Ladder, based on the criteria in Table 1. The measures describe their one-year "Enova campaign" period.

The most important eco driving measure in all the studied companies is the fleet management system which registers the drivers' driving style and which generates feedback to the drivers. All the studied companies have fleet management system in all or most of their vehicles, but the companies at level 3 used this system more systematically. The companies at level 3 had the most frequent intervals with feedback on scores from managers to drivers, they had organized training of the drivers and more use of incentives (e.g. driver competitions to get good scores in the system and bonuses). The companies at level 2 had some of these measures, but they were not employed systematically.

The companies at level 3 also had all or most of the elements characterizing energy management systems in place (cf. Table 1). They had an explicit goal of 10% reduction in fuel consumption in the one-year Enova "campaign period". Two of the level-to companies also had such a goal. All three companies at level 3 had a relatively good overview of the key figures related to energy management in their company, e.g. related to driving style and scores for the parameters in the fleet management system, vehicle parameters (engine, tires, axles, software), cargo/tonnage, roads types, kilometres driven, accidents, incidents etc. Several of the companies that score high at level 2 also had an overview of some of the key figures, while few of the companies that score low at level 2 had a good overview of key figures. The companies at level 3 also spend a lot of time optimizing vehicles, equipment and transport routes, based on a recognition that driving style is only one of several factors influencing fuel consumption. These companies also had a holistic view on all of the company's energy consumption.

4.3.2.2. Systematic work results in more drivers with top marks/scores

Drivers with high scores/marks in the fleet management system had a lower accident risk than those with lower marks (cf. Fig. 1). We have also seen that the companies at level 3 in the Eco Ladder have more measures aimed at economic driving and energy management than companies at level 2. This is probably the reason why there is a higher proportion of drivers with high scores/marks in the fleet management system among the drivers in the level 3 companies. Figure 6 shows a pattern with increasing shares of A scores in the fleet management system ranging from the Reference group to Level 3. Differences between the groups are, however, not statistically significant (p=.146). In the interviews, most company representatives at both level 2 and 3 emphasised that average scores in the fleet management system improved significantly since they started working actively on economic driving. We do, however, not have an overview over the scores in all studied companies, as information were lacking about this. Good scores were, however, mentioned by interviewed level 3 company representatives. The representative from Company M stated for instance that in his company, there were 10% A level drivers and 80% B level drivers. Thus, qualitative data seem to support Hypothesis 5.

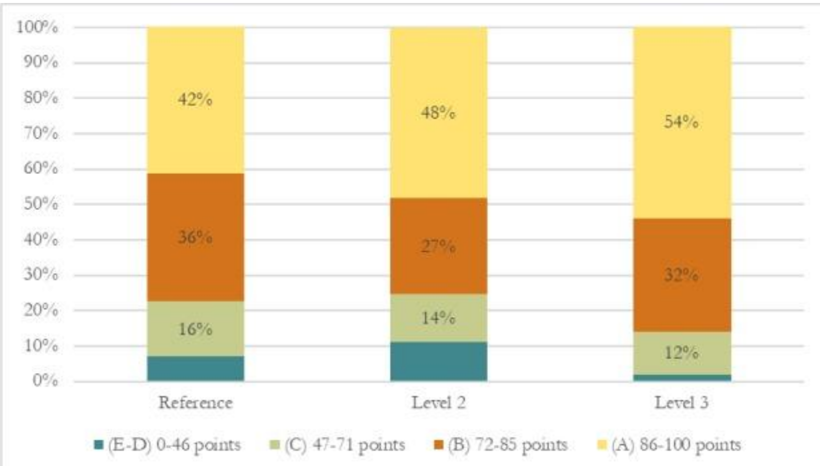

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Fig. 6. Respondents' responses concerning their own scores in the fleet management system. The Reference Group (N=89), Level 2 (N=81), and Level 3 (N=59).(It can be noted that Fig. 6 indicates a bias with respect to fleet management system scores in the Reference sample. This group has 78% A and B scores. In a typical industry average, the driver scores would have been more normally distributed around score C, according to the manufacturers of the systems. We expand more on this in section 5.5.).

Fig. 6 shows a clear tendency of increased scores in the fleet management system by increasing the level on the Eco Ladder. The share with A marks at Level 3 is 12 percentage points higher than in the Reference Group. Chi square test show, however, that the differences between the groups are not statistically significant (p=0.146). Thus, the survey data do not support Hypothesis 5.

4.3.2.3. Systematic approach to management

In this section, we test Hypothesis 6, which is that companies that work systematically with continuous improvement aimed at energy management often also do so with safety management. Our data support this hypothesis. We divided the Safety Ladder into three levels to make it comparable to the Eco Ladder, by merging levels 2 and 3. When we compared the companies on the Eco Ladder (criteria in Table 1) and the Safety Ladder (criteria in Table 2), we saw that there were only two companies that did not end up on the same level on the two ladders: two of the companies that we placed at level 2 on the Eco Ladder ended up at top level of the Safety Ladder. These two companies did not have sufficient measures aimed at economic driving and energy management to be ranked at the top of the Eco Ladder, but they had sufficient measures aimed at safety management to be ranked at top of the Safety Ladder.

In Fig. 7, we compare scores on an index for environmental management and safety management for companies at different levels in the Eco Ladder. The environmental management index is based on five questions (Cronbach's Alpha: 0.780) measuring Eco Ladder management practices, e.g. “We have a clear goal for reduced fuel consumption”, “Management checks employees' economic driving scores/marks every week”, “Drivers regularly receive information about high and low scores/marks from the fleet management system”. The safety management index (Cronbach's Alpha: 0.836) consists of four questions, which measure Safety Ladder management practices, e.g. “In my company we have clear and well-known policies for drivers' speed and driving style", "Management emphasises that drivers should not drive faster than the speed limits and conditions allow", "In my company, we focus closely on how drivers' private life (e.g. little sleep, stressful life situation) can affect road safety", "In my company, it is common for drivers to postpone assignments if they feel tired or unfit". Since the indexes consist of an unequal number of questions, we have made the scores comparable by converting the scores into percentages of the maximum score.

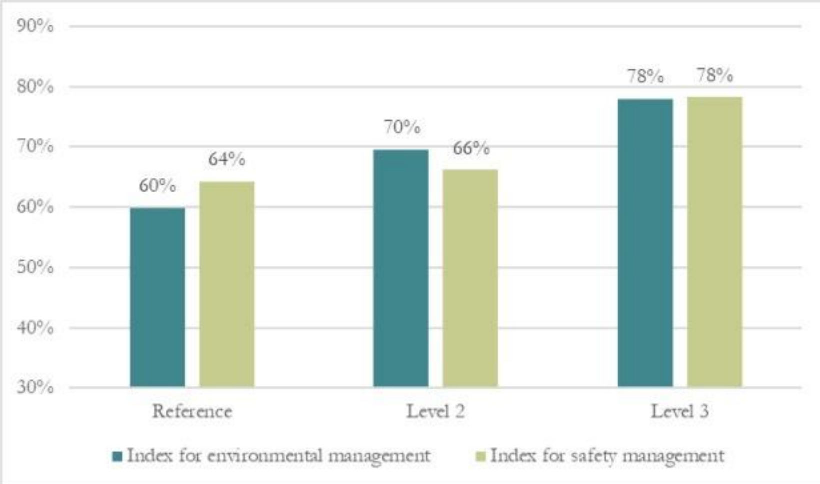

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Fig. 7. Comparison of percentage of maximum scores for index for environmental management (maximum 25 points) and index for safety management (maximum 20 points) in the Reference Sample (N=169), and companies at Level 2 (N=115) and Level 3 (N=82) of the Eco Ladder for Energy Management.

Fig. 7 shows a clear relationship between the environment and safety at the system level in the companies. The two indexes are moderately correlated (Pearson's R: 0.552). The results indicate that companies that work systematically with measures aimed at environmental management are also working systematically with measures aimed at safety management. In addition, we see the highest level of perceived environmental and safety management among the companies at level 3.

4.4. Multivariate analyses

4.4.1. What predicts drivers' self-reported accident involvement?

We conduct a logistic regression analysis of the factors that predict variation in accident involvement over the past two years among the respondents. We use logistic regression because we have turned the accident variable into a dichotomous variable, i.e. whether one has experienced an accident (1) or not (0). Table 5 shows the results of nine regression models with the respondents' accident involvement during the last two years as dependent variable.

Table 5. Logistic regression. Dependent variable: Accident involvement in the last 2 years (No=0, Yes=1). B values.

Variable	Mod. 1	Mod. 2	Mod. 3	Mod. 4	Mod. 5	Mod. 6	Mod. 7	Mod. 8	Mod. 9
Age (<26=0.>26=1)	−0.292	−0.372	−0.347	−0.312	−0.358	−0.405	−0.410	−0.527	−507
Km driven in thousands		**0.004****	**0.005****	**0.005*****	**0.005*****	**0.005*****	**0.005*****	**0.005*****	**0.005*****
(ADR=0, NON-ADR=1)			0.721	0.699	0.686	0.720	712	0.578	0.621
Pressure and stress			−0.347	0.052	0.067	0.071	0.069	0.047	0.048
Risky driving				−0.312	−0.084	−0.123	−0.111	−0.186	−0.200
Fleet management system score					−0.358	−0.230	−0.245	−0.282	**−0.303****
Environmental management						−0.405	0.018	0.065	0.068
Safety management								**−0.112****	**−0.109****
Cruise control									−19.8
Nagelkerke R^2	0.005	0.044	0.052	0.055	0.057	0.071	0.073	0.105	0.128

* $p<0.1$ ** $p<0.05$ *** $p<0.01$.

Table 5 shows, as expected, that respondents' kilometres driven over the past two years influence their accident involvement.

Second, we see that the respondents' scores/marks in the fleet management system represent the variable that contributes most strongly to explaining the respondents' accident involvement over the past two years. The effect is negative, and this means that drivers with high scores have a lower chance of getting involved in accidents than drivers with low scores. This is in line with Fig. 2, where we saw a correlation between drivers' scores or marks in the fleet management system and their accident risk. In the analyses in Table 5, we also see this correlation when we control for a number of other relevant variables.

Third, we see that safety management contributes significantly and negatively. This variable is an index consisting of four statements regarding safety management in the respondents' companies. The index is an indicator of the implementation of the Safety Ladder for Safety Management in goods transport.

The Nagelkerke R^2 value in model 7 is 0.128, indicating that the model explains approximately 13% of the accident involvement of the respondents in the sample.

4.4.2. What influences drivers' scores in the fleet management system?

In our analyses of what influences drivers' accident involvement, we saw that the drivers' scores in the fleet management system was the variable with the greatest importance. Table 6 examines the factors that influence drivers' scores in the fleet management system. We examine the importance of eight variables:

Table 6. Linear regression. Dependent variable: Drivers' scores in the fleet management system. Standardised beta coefficients.

Variable	Mod. 1	Mod. 2	Mod. 3	Mod. 4	Mod.5	Mod. 6	Mod. 7	Mod. 8
Experience	−0.016	−0.016	−0.024	−0.033	−0.040	−0.047	−0.044	−0.045
Long-haul transport		−0.022	−0.028	−0.031	−0.036	0.022	0.025	0.023
Pressure and stress			−0.042	−0.039	−0.047	**−0.070****	**−0.069****	**−0.068****
Environmental management				**0.044*****	**0.057*****	**0.035****	**0.035****	0.034
Safety management					−0.029	−0.037	−0.037	−0.038
Fleet management use						**0.146*****	**0.146*****	**0.145*****
Additional training							0.066	0.066
Bonus for financial								0.049
Adjusted R^2	−0.004	−0.008	−0.006	0.020	0.022	0.227	0.224	0.222

* $p<0.1$ ** $p<0.05$ *** $p<0.01$.

The first and most important result shown in Table 6 is that drivers' active use of fleet management systems is the variable that has the greatest impact on their scores in the fleet management system. Thus, drivers keeping track of their scores in the fleet management system, changing aspects of their driving style in order to get higher scores, follow instructions, etc. is related to higher scores in the fleet management system.

The second main result in the table is that the variable pressure and stress contributes significantly at the 5% level and slightly negative to scores in the fleet management system. This indicates that stress and pressure may hamper measures related to economical and safe driving.

The third main result in the table is that Environmental Management contributes positively to drivers' scores. Environmental management is a sum total scoring index consisting of five statements about measures on economic driving and energy management at the company level. The positive correlation we see suggests that drivers who are employed by companies that score high on this index and that thus have implemented more measures aimed at economic driving tend to have higher fleet management system scores than drivers who work in companies with fewer measures implemented. We also see that the effect of the variable environmental management is weakened when we include the variable fleet management use. This is probably due to the fact that the two variables are strongly correlated; because an important purpose of environmental management measures is to help drivers with their use of the fleet management system and help them to achieve high scores. In line with this, we see that the effect of environmental management also weakens and gradually disappears when we take in the variables additional training and bonus for economic driving. These are also variables that are strongly related to and included under what we define as environmental management.

The adjusted R^2 value in the Model 8 is 0.222, which suggests that the model explains 22% of the variation in drivers' self-reported scores in the fleet management system.

4.4.3. What influences drivers' use of fleet management systems?

In Table 6 above, we saw that drivers' use of fleet management systems is the variable that has the greatest impact on their scores in the fleet management system. In Table 7, we carry out an analysis to investigate the factors that influence drivers' use of the fleet management system.

Table 7. Linear regression. Dependent variable: Drivers' use of the fleet management system. Standardised beta coefficients.

Variable	Mod. 1	Mod. 2	Mod. 3	Mod. 4	Mod.5	Mod. 6	Mod. 7	Mod. 8
Ages 36–45	**0.165******	**0.168******	**0.158******	**0.158******	**0.158******	**0.158******	**0.147****	**0.146****
Thermo-transport		0.097	0.088	0.075	0.076	0.076	0.093	0.081
Short environmental management			**0.273******	**0.264******	**0.263******	**0.262******	**0.261******	**0.212******
Training YSK				−0.117	−0.115	−0.115	−0.112	−0.105
Additional training					0.008	0.008	0.009	0.004
Safety management						0.000	−0.024	−0.052
Bonus for financial							0.119	0.111
Drivers compete								**0.138****
Adjusted R^2	0.023	0.029	0.100	0.110	0.106	0.103	0.112	0.123

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

The first and most important result shown in Table 7 is that the variable “Short environmental Management” is the variable that is most strongly related to drivers' use of fleet management systems. This variable consists of two statements: “We have a clear goals for reduced fuel consumption” and “Drivers regularly receive information about high and low scores/marks from the fleet management system”. Drivers who are employed by companies with clear goals for reduced consumption and where drivers receive regular information about high and low scores seem to be using the fleet management system more actively to improve their own scores. The short environmental management variable was developed based on bivariate analyses of the environmental management practices that were most strongly correlated with drivers’ use of the fleet management systems.

The second main result from Table 7 is that the variable age 36–45 is the variable that has the second greatest impact on drivers' use of fleet management systems to improve their own economic driving style. The variable has two values: 1) All other age groups, and 2) 36–45years. We made this variable, as drivers aged 36–45 had the highest scores on the index that measures drivers' use of the fleet management system.

The third main result from the table is that the variable “Drivers in my company compete over who has the most economic driving style” is the one that has the third greatest impact on drivers' use of fleet management systems to improve their own economic driving style. This indicates that internal competition between drivers can help drivers use the fleet management system more actively to improve their own scores.

The adjusted R2 value in model 8 in Table 6.3 is 0.123, which suggests that the model explains 12% of the variation in drivers' use of fleet management systems. This is relatively low, indicating that there is a great deal of variation that we have not been able to measure with our questions.

5. Discussion

5.1. Relationships at the driver level

The first aim of the study was to examine relationships between economic driving and safety at the driver level, and mechanisms that explain this. Previous studies examining economic driving and safety at the driver level vary from no reduction in accident risk (afWåhlberg 2007) to a 35% reduction in accident risk (Haworth and Symmons, 2001) following from measures aimed at economic driving. To our knowledge, there are no previous studies that have examined fleet management scores and accident risk. Our study therefore contributes to this research field, and it indicates a clear relationship between drivers’ grades/scores in the fleet management system and accident risk. In multivariate analyzes, we found that the drivers 'scores in fleet management systems was the variable that has the strongest effect on accident involvement, followed by the companies' safety measures. The fleet management system score can be used as a proxy for fuel use, as an improvement from mark E to A on average involves an 11% reduction in fuel consumption (Nævestad and Hagman 2020). Similarly, our results also indicate that driver's score in the fleet management system may be used as a proxy of their safety level, as the drivers with scores equaling an A have a 48% lower accident risk than drivers with E scores.

We test two hypotheses at the driver level that can explain the relationship between economic driving and traffic safety. The first is that an economic driving style is often the same as a safe one, because it is defensive, controlled and calm (*Hypothesis 2*). This mechanism has been indicated by several previous studies (e.g. Huang et al., 2018, Dekhordi et al., 2019, Li et al., 2019). Toledo and Shiftan (2016) find, for instance, that abrupt acceleration/deceleration can be used as a proxy for both economical and safe driving. Our data seem to support *Hypothesis 2*, because we find that anticipatory driving is a key aspect of economic driving. It is, however, important to remember that numbers in our study are small and relationships are complex, in the sense that our analyses indicate that more variables influence drivers' accident risk. Thus, more research is needed to examine this.

The second mechanism is that the fleet management system rewards both safe and economic driving style (Hypothesis 3) (cf. Nævestad and Hagman 2020). Our data also support this hypothesis. The studied fleet management systems measure idling, anticipatory driving, braking, roll out, cruise control use and speed. The systems give scores for these aspects and a general fleet management score (Nævestad and Hagman 2020). As noted, some of these aspects may be in conflict with road safety. However, calculating the fleet management system score, algorithms weigh different aspects. In interviews with people who are experts in the systems, we learned that if drivers are to get high scores, they must score high on both safety and economy parameters (Nævestad & Hagman 2020). It was also mentioned that safety parameters count the most. The importance of the fleet management system in economic driving in the studied companies, and the fact that it focuses on both economy and safety, indicates that the present study is not only a study of economic driving, but also a study of fleet management system. Our results indicate that the algorithms weighing the different driving style aspects seem to be crucial when it comes to explaining our results. More research is needed to examine the importance of each of the aspects measured by the fleet management system for safety and fuel use. Knowledge about this can be used to optimize these systems. Such optimisation is also the topic of several studies describing algorithms taking both safety and economy into account. A driving style that is both economic and safe is referred to as optimal driving style, EcoSafe driving style etc. (Dekhordi et al., 2019, Huang et al., 2018, Li et al., 2019).

Our data also show the importance of potentially negative mechanisms between economic driving and road safety. This is related to the irritation of other drivers and potentially dangerous overtaking, driver inattention or distraction due to a high focus on economic driving (cf. Alam & McNabola, 2014), high speed in curves, downhill or before junctions, because of free rolling and/or use of cruise control (Nævestad and Hagman 2020). In accordance with previous studies, our results also indicate that economic driving may induce dangerous situation because of other drivers' irritation (Alam & McNabola, 2014) and because of free rolling (Nævestad and Hagman 2020) (cf. Fig. 3). We might hypothetically assume that focus on economic driving, and maintaining a high fleet management system score, in some cases could take drivers' attention away from the main driving tasks related to road safety (Alam and McNabola, 2014, Jamson et al., 2015). We have seen that economic driving involves a strong competitive element among drivers in the companies, which is related to driver self-esteem and identity. Moreover, increased use of driver assistance systems, e.g. adaptive cruise control and GPS-based cruise control systems which automatically optimises speed and gear shifts to the topography, and also to curves, intersections etc. may require less attention from the driver. This could lead to behavioural adaptation. If drivers experience changes involving decreased subjective risk, or perceive decreased task difficulty and reduced mental load, e.g. due to driving assistance systems, they may adapt their behaviour by allowing themselves to engage in secondary task, like telephone use, reduce attention, increasing speed etc. This kind of behavioural adaptation was originally termed risk compensation (e.g. Pless, 2016, for a critical discussion of this concept), but it is now commonly referred to as just behavioural adaptation (e.g. OECD, 1990). The concept of behavioural adaptation was originally used to explain failures to obtain planned or expected effects of safety measures, as people adapt their behaviour in manners that reduce the effect of the safety measures. Different mechanisms may possibly trigger behavioural adaptation. Some theories emphasize perception of risk as the signal for behavioural adaptation (to maintain a presumed risk homeostasis) (Wilde 1982), whereas others point at task difficulty or mental load (Fuller 2011). Behavioural adaption (and potentially adverse road safety outcomes) related to increased vehicle automation is an important issue for future research. Although it is important to identify possible conflicts between economic driving measures and safety, and implement measures to reduce their impact, our results suggest that these issues generally are less important than the positive mechanisms. The reason is that the data from the survey show a clear correlation between high scores in the fleet management system (where cruise control use is a central parameter) and low accident risk at the driver level. We have also specifically examined the accident risk among drivers who use cruise control to different degrees (cf. Fig. 4) and stated that we cannot conclude that frequent use of cruise control is related to higher accident risk.

5.2. Relationships at the company level

The third aim of the study was to examine relationships between economic driving/energy management and road safety at the organisational level, and mechanisms that may explain this. Results indicate a lower accident risk for companies at level 3 in the Eco ladder for goods transport on long-distance and regional transport. In accordance with *Hypothesis 4*, we can therefore conclude that it appears that the companies at level 3 on the Eco Ladder have on average a lower accident risk level than the Reference Group on these types of transport. To our knowledge, there are no other studies which have compared traffic safety effects, or fuel consumption effects, of measures related to economic driving and energy management at the company level like we do in the present study. Thus, our study contributes to the research field and practitioners, as it identifies the impact of specific practices. There is one recent exception to this. Nævestad (2022) reports results of a natural before and after study of economical driving and use of fleet management system recording driving style as a traffic safety measure. The study includes three companies studied on three occasions, in: 1) 2013, 2) 2018 and 3) 2020. Two of the companies (Company B and C) started working actively with the fleet management system as a measure for economical driving between measurement time points 1 and 2. The accident risk in Company B and C decreased considerably in the post-measurement in 2018, and the safety culture improved. Nævestad (2022) concludes that results cannot be explained by referring to other safety measures in the companies, changes in framework conditions, demographic changes or a decrease in the risk of property damage accidents in Norway.

The lower risk for the level 3 companies does, however, not apply to distribution driving. This result seems to be in line with previous research, which shows that it is more difficult to achieve good results for economic driving in more urban driving, with many slowdowns and a high degree of acceleration and idleness (Strömberg and Karlsson, 2013, Ayyildiz et al., 2017). We may assume that these results also apply to safety effects, which also are related to these aspects of driving style (cf. Toledo & Shiftan 2016). One of our main conclusions is thus that it is important to control for the type of driving when examining the road safety effects of economic driving (cf. Liimatainen, 2011, Pinchasik et al., 2021).

It is also important to control for working conditions work-related factors that influence the driving style of professional drivers in manners that may constrain the possibilities to drive economically, e.g. stress and fatigue, following from excessive amounts of demands (i.e., time pressure, long, and irregular work schedules) (Useche et al., 2019a, Useche et al., 2019b, Nævestad et al., 2015). In line with this, our study indicates that drivers' experienced stress and time pressure negatively influence their scores/grades in the fleet management system. Thus, facilitating economic and safe driving in companies also involves limiting time pressure and stress.

We have discussed two mechanisms at the organisational level, which may help explain why companies at level 3 on the Eco Ladder have on average a lower accident risk. First. we found a tendency of increased scores in the fleet management system for each increased level on the Eco Ladder. Although the tendency in the survey data was non-significant, results from company interviews indicate higher fleet management system scores in the level 2 and 3 companies, compared with the industry average, which is normally distributed around mark C. This result is in line with Hypothesis 5: the companies at Levels 2 and 3 of the Eco Ladder have more drivers with high scores in the fleet management system, because they have several measures aimed at economic driving and energy management, and for this reason they have better road safety. Our study indicates that the companies at higher levels in the Eco Ladder are better at "cultivating" high fleet management scores among their drivers, through their measures focusing on economic driving and energy management. This result, and the concrete studied management practices is the main contribution of the present study. There are few to no studies of road safety effects of economic driving at the company level, or relating to energy or environmental management systems.

Second, in line with *Hypothesis 6*, we found a clear relationship between focus on the environment and safety at the system level in the companies, indicating that companies that work systematically with measures aimed at environmental management are also working systematically with measures aimed at safety management. The relationship between environmental management and safety management in companies in in line with previous studies from Norway (cf. Nævestad, Phillips, & Milch, 2019) and internationally (Ackerknecht et al., 2005, Jørgensen and Remmen, 2006, Hamidi et al., 2012). In line with our results, these previous studies also find often a certain consistency in studied companies' focus on avoiding externalities (emissions, accidents), through the approach to continuous improvement provided by management systems. This line of research is often referred to as "integrated management systems" (Jørgensen and Remmen, 2006, Hamidi et al., 2012), indicating an important area for future research.

5.3. Model of relationships

Fig. 8 provide a conceptual illustration of the strongest and most significant correlations from the multivariate analyses of the relationships between economic driving and road safety at the driver and organisational level.

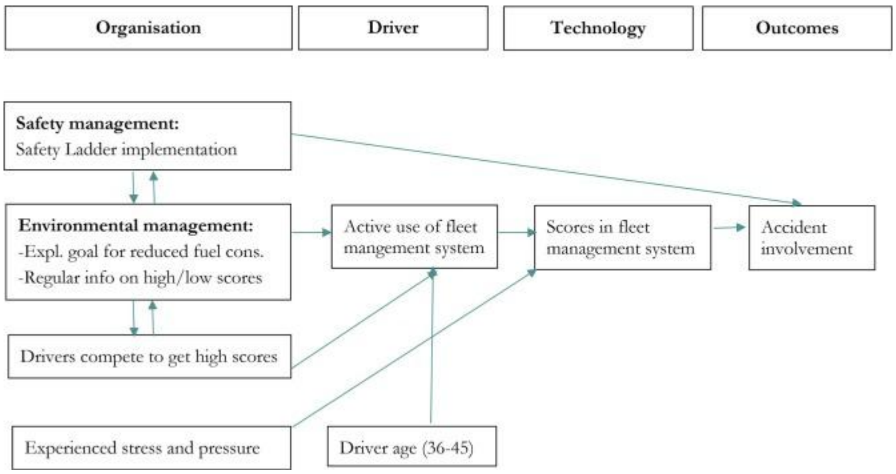

Fig. 8. Conceptual illustration of significant correlations from four regression analyses with the following dependent variables, a) Accident involvement in the last 2 years, b) Score in fleet management system, c) Drivers' active use of fleet management system and d) Environmental management.

The model shows that the relationship between economic driving and road safety can be divided into relationships between factors at technology level, driver level and organisational level. Drivers' scores or marks in the fleet management system is the variable that helps to explain the respondents' accident involvement. Drivers' active use of fleet management systems is the variable that has the strongest impact on drivers' marks in the system. The analyses suggest that companies that work well with environmental management, for example at level 3 of the Eco Ladder, are better at “cultivating” drivers with top scores in the fleet management system.

5.4. How important is safety management?

One of the main conclusions is that it is difficult to distinguish between measures for economic driving and measures for road safety. At the driver level, we have seen a clear correlation between an economical and a road-safe driving style. We have seen the same at the technology level: the fleet management system rewards a driving style that is both economic and road-safe, and the parameters for road safety were weighted most strongly by the algorithm that calculates the overall score in the system. We see the same tendencies at the organisational level: there is a large degree of correlation between the companies' levels in the Safety Ladder and the Eco Ladder. However, we cannot say for this reason that measures aimed at economic driving and energy management lead to more measures aimed at safety management.

This suggests that there are more factors in the companies than drivers' scores (and driving style) that have an impact on road safety. The effect of safety management on drivers’ accident involvement indicates that the companies' systematic organisational facilitation of safety is also of great importance for the safety level in the companies. These are factors that we have defined in previous studies as being at levels 3 and 4 in the Safety Ladder for Safety Management in goods transport. Level 3 of the Safety Ladder applies to the company's focus on work-related factors that affect drivers' stress levels, fatigue, etc., while Level 4 of the Safety Ladder deals with companies' systematic learning about safety incidents, reporting systems, risk analyses, etc. (Nævestad et al 2017). Level 2 of the Safety Ladder is about the drivers' driving style. Based on this, we can conclude that economic driving as a measure seems to overlap with what we define at level 2 of the Safety Ladder (driving style), and that this is the main reason why we see positive road safety effects from working with economic driving. Based on previous research, however, we know that goods transport companies experience even greater road safety effects from also working with measures aimed at work-related factors with an impact on road safety (level 3 of the Safety Ladder) and the safety management system (level 4 of the Safety Ladder).

5.5. Methodological weaknesses and strengths and issues for future research

Low response rate in several companies and small numbers in some groups. The study is based on relatively small numbers. Although we asked all the companies that had been supported by Enova to participate, only a selection of them wanted to participate. Thus, we do not know anything about those who did not want to participate. In addition, we have a low response rate in some groups (e.g. in the Reference sample). With a low response rate, it can be asked how representative respondents in the different groups are.

Recruitment bias: The study includes relatively few drivers with low scores. We have small numbers in the groups with low marks/scores. Only 16 drivers state that they have marks equal to E-D and only 36 drivers state that they have marks equal to C. The manufacturers state that the scores in Norway in general are more normally distributed. Thus, the study shows a sampling effect among participants: among the respondents, there is an over-representation of drivers with high scores. There are two possible explanations for this. The first explanation is related to self-selection: We can assume that drivers who are very enthusiastic about economic driving and fleet management systems are more likely to want to participate in a study on this. In addition, we can also assume that these drivers also have high scores in the fleet management system, and that this is related to their enthusiasm. The second explanation for the bias in drivers' scores is that we recruit drivers among companies that work very actively with economic driving and fleet management and with energy management. Thus, we may expect a high share of drivers with high scores in level 2 and 3 companies, but not in the reference sample.

The Reference Sample is not representative. The Reference Sample should have represented a typical industry average, with which we can compare the companies which received funding from Enova. In an industry average, however, the marks for drivers would have been more normally distributed. That is not what we see. Almost 80% of the drivers in the Reference Group have top marks in the fleet management systems: A or B. This indicates significant self-selection in this group, which is not surprising, given the topic of the survey. A Reference Group with drivers with normally distributed scores in the fleet management system, would have resulted in a 31% higher risk in this group, i.e. a risk of 2.0 property damage accidents per million vehicle kms for long distance and 2.1 for regional transport, a risk of 4.3 for distribution transport. This risk level is similar to the risk level of the Reference group in Nævestad et al., 2020, Nævestad et al., 2020. Thus, future studies should try to recruit more drivers with lower scores in order for Reference samples to be more representative. Higher variation in the outcome variables would probably also increase the robustness of the analyses.

Our conclusions are largely based on self-reported numbers. Another possible limitation is that our conclusions are based on self-reported numbers, with the possible biases that this may entail. Respondents may remember incorrectly or incompletely, they may potentially over report positive things about themselves and underreport negative things, etc. However, we do not have indications of significant effects of these types in our data.

Cross-sectional design. The main methodological limitation of the study is that it has a cross-sectional design. Although we focus on measures and effects that have been occurring over time, we collected data about this over a limited time period. This makes it challenging to draw inferences about cause and effect when we study the relationship between economic driving and safety, at both the individual level and the organisational level. We have seen relationships e.g. at the organisational level, but we do not know what comes first: i.e. organisational environmental management or organisational safety management. With a longitudinal design, with before and after measurements, one can control for the companies' work on road safety before introducing measures for economic driving. Most of the previous studies are cross-sectional studies, which mainly use data from one measurement time point, or from short experiment periods (Af Wåhlberg, 2007, Symmons et al., 2008, Toledo, 2016). Few of the previous studies are systematic before and after studies of companies, with experiment and control groups. They also do not control for company safety measures during the experiment periods, before and after measures for economic driving have been implemented. This study is unique, as we control for organisational safety measures. Longitudinal designs are also important, as effects of economic driving measures may decrease (Zarkadoula et al 2007) and increase over time (Sullman et al 2015). It is important to identify the reasons for such different developments, and longitudinal designs might disentangle mechanisms influencing trajectories over time. There are, however, a few examples of studies with a longitudinal design. Nævestad (2022), for instance, reports results of a natural before and after study of economical driving and use of fleet management system recording driving style as a traffic safety measure. The study includes three companies studied on three occasions, in: 1) 2013, 2) 2018 and 3) 2020. The few studies with a longitudinal design indicate the need for such a design in future studies.

More knowledge about possible conflicts between road safety and economic driving. The results of the interviews and survey suggest that the focus on economic driving may have negative road safety effects (cf. Alam & McNabola, 2014). We have discussed some of these, e.g. related to attention, behavioural adaptation, use of different driver assistance systems, conflicts with other road users. It is important to gain more knowledge about such conflicts, to learn how they can be minimised and avoided.

6. Conclusion

The study provides two main findings. The first is that we find a relationship between economic driving and road safety at the driver level, presumably as an economic driving style often is the same as a safe one, because it is defensive, controlled, calm and anticipatory, and because fleet management systems reward both road-safe and economic driving. The second main finding is that we find a relationship between economic driving and road safety at the organisational level, presumably as companies that work systematically with environmental management often also do so with safety management, and as companies at the top of the Eco Ladder have more measures in place to “cultivate” drivers with high scores. These companies have both the largest reductions in fuel consumption (around 10%) and the best road safety. Our study contributes to the research on economic driving, because there are few studies of the road safety effects of economic driving at the organisational level. It also contributes to the research on road safety in transport companies, as it provides an example of measures that seem to have beneficial effects for road safety, fuel consumption, emissions and economy. Finally, our study has important practical implications for the trucking company sector (and companies with drivers at work in general), as it provides concrete management practices that may lead to both improved safety and reductions in fuel consumption (and subsequently lower emissions and fuel expenses).

CRediT authorship contribution statement

Tor-Olav Nævestad: Conceptualization, Formal analysis, Investigation, Project administration, Funding acquisition, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Vibeke Milch:** Formal analysis, Investigation, Writing – original draft. **Jenny Blom:** Investigation, Supervision, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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1 It should be mentioned that the Reference Sample is not representative of average drivers (cf. section 5.5).

2 This was indicated by the fact that the average mileage was far higher in the Reference sample, indicating a higher share of long-distance driving in the mixed category for this group. This also suggests a lower accident risk for the Reference sample in the mixed category (cf. the lower accident risk for long distance transport in Fig. 5), which we also found.

3 The differences in Fig. 4, Fig. 5 have been significance-tested, and none of them are statistically significant, due to small numbers. The numbers of accidents that the calculations are based on are very low, as the total number of accidents in the sample is 55. We should therefore not place decisive emphasis on the significance tests, which compare risk for the Reference group, Level 2 companies and Level 3 companies within different types of transport. Numbers within each subcategory is very small. A significantly higher number of accidents is needed to test whether the differences between groups are statistically significant.