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The Eco Ladder for energy management: a literature review of economic driving and energy management

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Transport accounts for nearly 25% of man-made emissions of greenhouse gases, and goods transport by road accounts for 45% of the total energy consumption in transport. Measures within goods transport will therefore be a good starting point for reducing greenhouse gas emissions. Existing research shows that trucking companies' measures to facilitate an economic driving style can achieve between 5% and 10% reduction in fuel consumption. They can probably reduce their energy consumption even more, by focusing on factors additional to driving style. However, existing recipes for such measures (e.g., ISO: 50001) seem to be relatively complicated, resource-intensive, and to a small extent adapted to transport. Previous research shows low implementation of such management systems in trucking companies, because most of them are small (<5 employees), and probably have few resources when it comes to economy, time and expertise. The aim of the study, is therefore to develop a research-based model of how trucking companies can work with economic driving and energy management at the organizational level. The model is based on a systematic review of measures for economic driving and energy management in trucking companies. The model is referred to as the Eco Ladder for energy management, and describes an approach with gradual introduction of specific measures. Companies must start with the measures that are assumed to have the greatest effect, and which are easiest to implement, before moving on to the next level. Based on existing research, we discuss expected effects for economy, emissions, traffic safety and working environment.

KEYWORDS

truck transport, economic driving, energy management, Eco ladder, transport companies

1 Introduction

1.1 Background

Truck transport is the dominant means of goods transport in Norway (Hovi et al., 2014) and worldwide (Rodrigue 2020). However, truck transport has several negative effects in our society. Nearly 25% of energy-related global greenhouse gas emissions come from transport and these emissions are projected to grow substantially in the years to come (UN, 2022). CO2 accounts for between 93% and 95% of the man-made greenhouse gases from truck transport (Piecyk, 2009). In the 2030 United Nations Agenda for Sustainable Development, sustainable transport is mainstreamed across several sustainable development goals and targets. The importance of transport for climate action is further recognized under the

United Nations Framework Convention on Climate Change (UNFCCC), and the transport sector will be playing a particularly important role in the achievement of the Paris Agreement (UN, 2022). As a result of this agreement, the EU submitted its updated and enhanced nationally determined contribution (NDC) target in December 2020 to reduce emissions by at least 55% by 2030 from 1990 levels, and information to facilitate clarity, transparency and understanding of the NDC (EU, 2022).

Emissions from truck transport can be reduced in several different ways, for instance through new fuel technologies and energy sources, new forms of production that require less transport, new infrastructure, alternative forms of transport, etc. (Sullman et al., 2015). However, several of these measures will require significant investments in new infrastructure, and will involve the replacement of existing vehicles (Figenbaum et al., 2019). Pending the implementation of such measures, which can revolutionize energy consumption considerably, working with economic driving and energy management in trucking companies will be an effective measure to reduce emissions from road transport (Sullman et al., 2015). Economic driving is generally defined as a decision-making process that influences fuel consumption and emissions from vehicles to reduce the impact on the external environment (Sivak and Schoettle, 2012). First, we define economic driving at the driver level. This concerns driving style and involves, for example, reduced engine idling, smooth and low speed, free rolling as much as possible, avoiding hard decelerations and sudden acceleration, driving in the highest possible gear, etc. (cf. Huang et al., 2018; Dekhordi et al., 2019; Li et al., 2019). Sivak and Schoettle (2012) refer to this as economic driving at the operational level.

Driving style is of great importance for fuel consumption. Sivak and Schoettle (2012) mention, for example, that an uneconomic driving style can increase fuel consumption by up to 45%. Most studies of economic driving generally show average reductions in fuel consumption of between 5% and 10% (Ayyildiz et al., 2017). Some studies show larger reductions, for example, 16% in bus transport (Sullman et al., 2015) and a 27% reduction for heavy goods vehicles (HGVs) (Symmons et al., 2008). Sullman et al. (2015) therefore point out that systematically facilitating economic driving for all cars in the EU could significantly contribute to the EU being able to achieve its goal of a 20% emission reduction in transport. Additionally, it means clear benefits for transport companies, because they can often save between 5% and 10% of their fuel costs. Despite this, Sanguinetti et al. (2020) emphasize that driver behaviour historically has been treated as a "random error" in models of motor vehicle fuel economy and neglected in energy and environmental policy-making regarding fuel efficiency.

In addition to defining economic driving at the driver level, we also define it at the organizational level. This concerns how companies can systematically facilitate their own drivers' economic driving style. This involves, e.g., installing a fleet management system that records the above mentioned aspects of driving style, and facilitating the systematic use of it through feedback, training, bonuses, etc. (Nævestad et al., 2020).

Companies can also work more holistically with the company's energy use by implementing a system for energy management (e.g., ISO: 50001) (BSI Group, 2000). This involves defining explicit objectives for reduction of energy use, comprehensive mapping of energy use and identifying potential for reductions in energy use within given areas, plans for measures, follow-up of effects, and adjustments of measures (BSI Group, 2022). Working with an energy management system in road goods transport involves working systematically with factors additional to driving style, e.g., planning the transport to reduce mileage and fuel consumption, optimizing choice of vehicle. Sivak and Schoettle (2012) refer to this as economic driving at the «tactical» and «strategic» level, respectively. They conclude that economic driving at these levels has a far better effect than measures at the operational level, which only focus on driving style. They point out, for example, that the most fuel-efficient private car for sale in the United States uses nine times less than the least fuel-efficient car. Studies from heavy vehicle transport also show that factors at road and vehicle level have a far more influence on fuel consumption than driving style (Ayyildiz et al., 2017; Diaz Ramirez et al., 2017).

However, introducing energy management systems like, e.g., ISO:50001, and working systematically to facilitate economic driving seems to be demanding. In previous studies, we have seen that Norwegian trucking companies have significant barriers to working systematically with organizational measures and formal management systems, because the companies are mainly small (Nævestad and Phillips, 2013). Research shows that 86% of the companies in road goods transport in Norway have fewer than five employees (Steen-Jensen et al., 2014), while 80% have fewer than 10 employees at the EU level (European Commission 2022). It is natural to think that the small trucking companies have fewer resources (time, economy, competence) than larger companies, and that this can constitute a significant barrier to introducing a system for energy management and economic driving at an organizational level.

Given the potential that lies in working systematically with economic driving and energy management in trucking companies, both at the societal level (reducing emissions) and the company level (reducing fuel costs), there is a clear need to create a research-based model for how trucking companies can work with economic driving and energy management at the organizational level. Such a model should describe what measures and management practices this often entails, and what effects they can expect.

1.2 Aims

The main aim of the present study is to develop a simple, research-based model for how trucking companies can work with economic driving at the organizational level; what measures and management practices it entails, and what effects they can expect. We do this through a systematic literature study.

The goals of the literature study are to:

1) Examine factors that influence the fuel consumption of HGVs,
2) Examine measures to promote economic driving and energy management in trucking companies and their effects on fuel consumption (and other relevant outcomes),
3) Create an analytical model ("Eco ladder for energy management") that describes different levels of increased organizational facilitation of economic driving and energy management in trucking companies, and

TABLE 1 The combinations of keywords used in the literature search.

Subject	Keywords
Economic driving	"Ecodriving," "Eco-driving," "Eco driving," "Ecological driving." "Economic driving," "Fuel economy," "Fuel efficient," combined with "Heavy," or "Bus"
Fleet management	"In vehicle data recorder" (IVDR), "driver feedback," "fleet management"
Energy management system	"ISO:50001"combined with "road"; "ISO:14001"combined with "road," "energy management" combined with "road"

4) Define specific measures and practices at each level of the Eco ladder.

2 Methodological approach

2.1 Search strategy and keywords

In our literature search, we have used words related both to driver-level and to organisational-level economic driving, combined with words for heavy vehicles, such as heavy vehicles, HGVs, buses, etc. We have used general keywords, because there are not many studies of this, and to minimise the risk of missing relevant studies. Fleet management system is the most important organisational measure used to facilitate economic driving in transport companies. This is the most important measure in economic driving (Sanguinetti et al., 2020), and it is used to a considerable extent by Norwegian transport companies (Nævestad et al., 2020). We have therefore also used keywords related to "fleet management" and "In vehicle data recorder." As different systems for energy and environmental management appear to be the most systematic and holistic way to work to reduce energy use in companies, we have also used keywords related to this.

We searched the ScienceDirect and TRID databases.

The combination of keywords is presented in Table 1. We searched for combinations of the words in Table 1 in keywords, title and abstracts.

We have not done a separate literature search for factors that influence the fuel consumption of HGVs (cf. sub-goal 1), but we have looked for such factors in the identified studies.

2.1.1 Criteria for including or excluding studies

We used five criteria when considering which publications to include:

- Scientific publication (scientific report, book chapter or article).
- Published after 1995.
- Empirical study focusing on the effects of the following measures: economic driving at the driver, or organisational level, fleet management system or energy management system.
- Examines the effects of measures on fuel consumption, economy, emissions and other relevant outcomes, e.g., road safety, working environment.
- Focuses on heavy vehicles (buses or HGVs).

2.1.2 Selection of relevant studies

Studies that meet these five criteria were identified through a three-stage selection process (cf. Figure 1). In the first step, we excluded conference papers and non-scientific articles. In the second step, we reviewed the hits we received using the combinations of keywords specified in Table 1. The purpose of this review was to identify studies that focus on economic driving or energy management system in general. We reviewed the titles of the studies. Excluded studies typically focused on road design, engine construction issues, measures related to sub-groups of road users (e.g., teen drivers) etc. The purpose of the third step was to identify studies focusing on the effects of economic driving, fleet management system or energy management system on heavy vehicles' fuel/energy use, traffic safety, etc. We read abstracts and all the texts or parts of them, such as result chapters, to investigate this. Finally, we also added studies that we had identified in other ways than through the literature search and the mentioned keywords. These were studies that we were familiar with from other projects, or that we found by examining the reference lists in the identified studies.

2.1.3 Criteria for comparing the identified studies

We use the following six points as a checklist in our presentations of empirical studies of economic driving and systems for energy management with heavy vehicles:

I) Study, country and vehicle type and what aspect(s) of economic driving or energy management are studied?
II) Method, selection and design. What kind of method and research design is used? How many respondents, interviewees or subjects are involved?
III) Effects on fuel consumption.
IV) Other relevant effects, for example: economy, emissions, road safety, working environment.
V) Which factors inhibit/promote the implementation of economic driving and energy management?
VI) Strengths and weaknesses of the study.

3 Results

3.1 Overview of the studies

In Table 2, we provide an overview the identified empirical studies focusing on the effects of economic driving and energy management with heavy vehicles.

3.1.1 The quality of the studies

Table 2 shows that there are few studies of economic driving with heavy vehicles in general (buses and trucks) and few studies involving HGVs. We have identified 16 studies of economic driving with heavy vehicles in general, and five that deal with HGVs. The

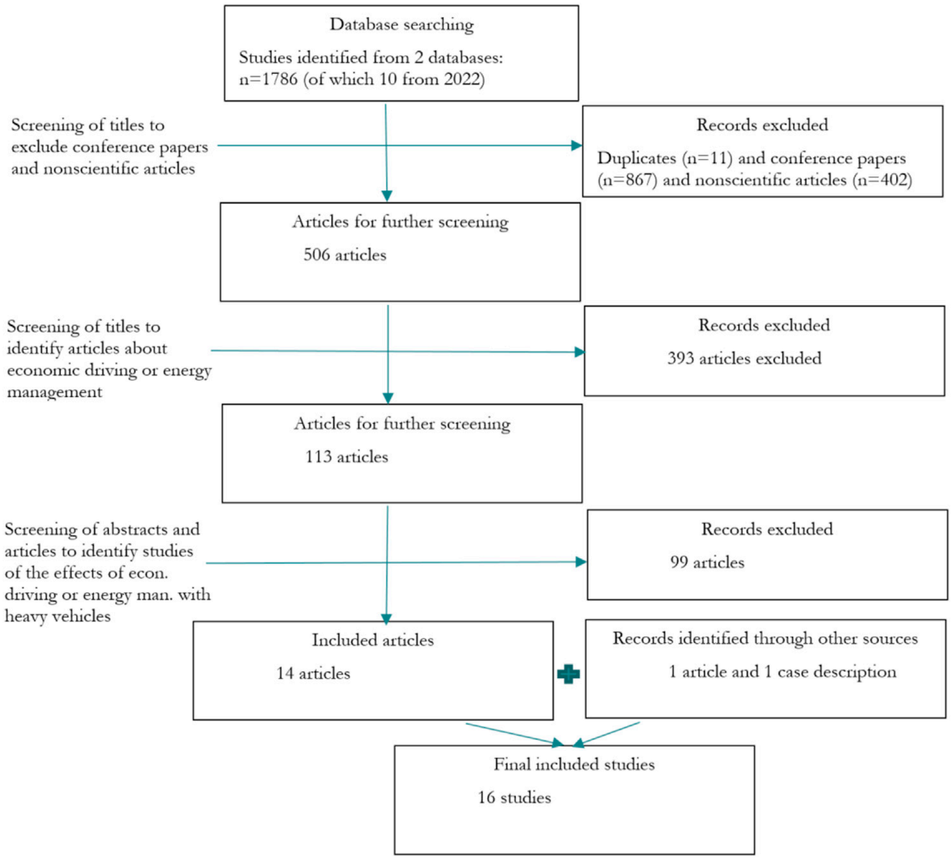

FIGURE 1
Search flow diagram.

number for the last group is strictly speaking four, since the primary purpose of Nævestad et al. (2020) is not economic driving, but safety management. In addition, Table 2 shows that few of the studies have a robust design, with experiment and control groups and before and after measurements.

3.1.2 Factors influencing the fuel consumption of HGVs

The first goal of our literature review is to examine the factors influencing the fuel consumption of HGVs. We provide factors, ranked according to their importance, as indicated by the reviewed studies. The first factor influencing fuel consumption of heavy vehicles is roads and infrastructure. Discussing results for light goods vehicles, Ayyildiz et al. (2017) suggest that is more difficult to see effects on driving in urban environments, as here there are many other vehicles, which means frequent use of the brakes, a lot of acceleration and a lot of idling. Walnum and Simonsen (2015) conclude that infrastructure and terrain have a 10–12 times higher impact on consumption than driving style, but that driving style also is important, controlled for this. Similarly, Diaz-Ramirez et al. (2017)'s study from Colombia concludes that roads with a lot of steep ascents and descents make economic driving more challenging. Walnum and Simonsen (2015) also find that season (winter) has an impact on consumption, partly due to the rolling resistance that snow and ice provide. Other studies also indicate the importance of season (e.g., Duarte et al., 2013).

The second factor that influences fuel consumption of heavy vehicles is the load and weight of the vehicle. Diaz-Ramirez et al. (2017) find that the weight of the load was the most important factor influencing fuel consumption, followed by driving style. This study and the other studies of HGVs therefore control for the weight of the vehicles and the weight of the load when they examine the effects of various measures aimed at economic driving.

The third factor that influences fuel consumption of heavy vehicles is the features of the vehicle and engine size. Walnum and Simonsen (2015) find, for example, that a truck with 700 horsepower on average uses 0.58 L more per 10 km than a truck with 500 horsepower when everything else is equal: for example, the route, time of year, the weight of the load, driving style, etc. With a consumption of 5.1 L of fuel per mile, this will amount to 11%, and thus more than what is often reported in studies on the effects of driving style. It indicates a greater effect on consumption of optimizing engine size than optimizing driving style, and not least it points to the potential of combining both of these strategies. Walnum and Simonsen (2015) argue that it is important for truck owners to find an optimal engine size for their assignments; if they use engines with too low capacity, it will lead to more driving at high rpm and higher consumption. Walnum and Simonsen (2015) also find that semi-trailer trucks use

TABLE 2 An overview of 16 identified empirical studies that focus on the effects of economic driving and energy management system with heavy vehicles.

Study, country, vehicle type and measures	Method, selection, design	Effects on fuel	Other relevant effects?	Inhibits/promotes?	Strengths and weaknesses
FCC Environment, 50001 Business Case (2020). Heavy and light vehicles. published by the British Standards Institution (BSI) Renovation company with transport, United Kingdom. Measure -Goal for reduced energy use -Environmental policy -Mapping of factors influencing energy use	This is one of several “business cases” that describe companies’ experiences with and results from ISO:50001 The company has 2,400 employees	The company has seen an 18% reduction in energy use per tonne of refurbished waste. Consumption of fuel will also be included here, because it is of great importance for energy use	The company has an integrated management system, where ISO: 50001 is included together with ISO:9001 (quality), ISO:14001 (environment) and ISO:450001 (health and safety)	Prior implementation of the other ISO standards made it easier to implement ISO:50001 Management commitment	This is only a “business case”, but in the absence of other empirical studies, it is relevant also to report results from these. The company is also involved in transport with heavy and light vehicles
Nævestad et al. (2020) HGVs. Norway Measure -Fleet management system -Feedback -Competitions -Bonuses	Study of work with safety culture in 17 trucking companies. Most companies also worked with economic driving	At least one of the companies had reduced total consumption by about 10% in a year	The same company reported a 40% decrease in injuries, less stress, more wellbeing and fewer sick leave	Management focus is fundamental. So is the use of fleet management systems	The study is about safety management. The majority of the companies also worked with economic driving
Huertas et al. (2018) Mexico. Bus transport Measure -Training in best practices for economic driving	Follow 15 transit buses on a 72 km route for 8 months. Identify the most economic driving style. Focus on RPM and speed	A driver using the best practices for economic driving obtained up to 10% reduction	No.		Strong focus on optimal RPM and speed. Not a systematic empirical study of the effects of training
Diaz-Ramires et al. (2017) HGVs, Colombia Measure Theoretical and practical training Bonuses/incentives Development of scorecard KPIs	Long-distance, heavy and medium-weight goods vehicles in hilly terrain. 18 drivers for 4 months	An average of 6.8% reduction in litres per km and 5.5% reduction per tonne km	The training has a particular effect on acceleration, braking and over-speed (up to 96% reduction per trip)	Management commitment (on several levels) is a fundamental prerequisite More is required for older drivers to change their driving style Hilly terrain The weight of the goods is most important, followed by driving style	Is particularly relevant for driving in hilly terrain, as in Norway. Does not have a control group

(Continued on following page)

TABLE 2 (*Continued*) An overview of 16 identified empirical studies that focus on the effects of economic driving and energy management system with heavy vehicles.

Study, country, vehicle type and measures	Method, selection, design	Effects on fuel	Other relevant effects?	Inhibits/promotes?	Strengths and weaknesses
Ayyildiz et al. (2017)	15 HGVs and 10 light goods cars in a Chinese logistics company (Linsen)	An average of 5.5% reduction for the heavy vehicles. No significant effect for light ones	Focus on idling, acceleration and hard braking	Commitment is the fundamental precondition	The lighter vehicles were used during a very hectic period (Chinese New Year) in a city environment with high traffic and probably a great deal of stress. No control group
HGVs, China				Feedback is a prerequisite	
Measure				Systematic work with key figures	
Training				Harder in the urban environment	
Fleet management system					
Feedback					
Bonuses					
Competition					
Sullman et al. (2015)	Twenty-nine bus drivers were given courses in economic driving, 18 drivers were in the control group. Tested in simulator before and after the course, and in real driving	An average of 11.6% reduction immediately after training and 16.9% 6 months after training	Suggests that simulator training can be an effective tool	Stress and time pressure impedes. ("Timetable")	Higher effects than the other studies, which focus only on real driving, and not simulator
Buses. Finland				Future studies should also investigate motivation	
Measure					
Training					
Lai (2015)	Before and after study. Experimental bus company with 319 buses and control company with 125 buses	Improvement of more than 10% reduction in fuel use	CO_2 emissions	Bonus as an important incentive. It is difficult to establish objective standards for fuel consumption, due to the multitude of influencing factors (e.g., vehicle model, such as type, year and engine size; and route characteristics, such as passenger load, running speed and number of traffic signals stops)	Before and after study with experiment and control group
US, bus transport					
Measure					
-Monetary reward system					
Walnum and Simonsen (2015)	Analysis of fleet management system (Dynafleet) data from 15 HGVs, 18 drivers and 3 transport planners at Lerum	Infrastructure and terrain have a 10–12 times higher impact on consumption than driving style. But when this is controlled for, driving style is significant	The importance of infrastructure and terrain for consumption indicates that the choice of routes ("organisation of transport") is of great importance for consumption	Management focus is a prerequisite and regular (daily) systematic analysis of data and KPIs	Good study, which is very relevant for a Norwegian context. Not intervention study. Studies the use of fleet management system

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TABLE 2 (*Continued*) An overview of 16 identified empirical studies that focus on the effects of economic driving and energy management system with heavy vehicles.

Study, country, vehicle type and measures	Method, selection, design	Effects on fuel	Other relevant effects?	Inhibits/promotes?	Strengths and weaknesses
HGVs, Norway					
Measure					
-Fleet management system					
-Organisation of transport					
-Choice of engine: 500 horsepower is optimal					
Foytik, P. and R. M. Robinson (2015)	The potential gains of emissions-based route choice were assessed by integrating the U.S. Environmental Protection Agency motor vehicle emission simulator with a macroscopic regional traffic demand model	Focus on emissions	One example where the total system's truck emissions were reduced by up to 0.61% (88.8 tons)	Difficult to say based on this, but the study indicates that further improvements in route choice are possible	Although it is based on a simulation example, it seems to be based on a large amount of data
Measure					
- Route choice considerations					
Rolim et al. (2014)	Study 100 buses with fleet management technology, which is used by about 600 drivers in Lisbon	Average 4.8% reduction	CO_2 emissions reduced by 6.56 g/km	Feedback with a beep was effective in avoiding unwanted behaviour (speed, abrupt acceleration, hard braking, idle)	Also has some conclusions about training, but these are very uncertain
Buses, Portugal	Two phases: 1) With sound for unwanted behaviour and 2) Without sound				
Measure					
Training					
Fleet management system					
Duarte et al. (2013)	Case studies from two bus companies in Portugal. Each with 375 and 671 buses	Between 1% reduction and 6% reduction in fuel use	Also measures CO_2 emissions, passenger comfort and safety indicators	Seasonal effects on fuel use	Case study from two companies
Measure					
-Fleet management system					
-Training					
Strömberg and Karlsson (2013)	54 drivers in three groups: 1) feedback, Feedback and training, 3) Control	Average 6.8% reduction in group 1 and 2	Sharp decrease in the number of hard braking and over-speeding incidents	Management commitment is important. The work tasks influence the success: Drivers must "follow the timetable". (stress)	This study also has a control group
Buses, Sweden				Shows that feedback is most important, since training does not cause an additional effect	
Measure					
Training					
Feedback					

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TABLE 2 (*Continued*) An overview of 16 identified empirical studies that focus on the effects of economic driving and energy management system with heavy vehicles.

Study, country, vehicle type and measures	Method, selection, design	Effects on fuel	Other relevant effects?	Inhibits/promotes?	Strengths and weaknesses
Liimitainen (2011) Bus, Finland Measure -Incentive system -IVDR	Follow 12 buses in Tampere City. Survey with 341 drivers	Between 1% and 5% reduction		The main challenge with incentive system is that it is difficult to establish fair criteria for assessment of performance, as several factors influence fuel consumption	An interesting study, focusing on how to ensure motivation to make eco-driving habits last
Symmons et al. (2008) HGVs (68 tons, 25 m). Australia Measure Training	Study of 12 drivers. Drove in a 30 km test route with mixed road type Three groups: 1) Full course, 2) Classroom only, 3) Control	An average of 27% lower consumption in the group that received full course training. Stable decline after 12 weeks. Some also even larger reductions	Significant (41%) decrease in decelerations The travel time did not increase. speed did not decrease Also mentions effects on economy and CO2	The study is done in an experimental situation	The average reduction in fuel consumption is higher than the other studies. But only four drivers in each of the three groups. Experiment setting. Some data is registered by person observing and not technology
Zarkadoula et al. (2007) Buses, Greece Measure Training Fleet management	Three bus drivers, who were driving a 15km test route, and then in real traffic afterwards	An average of a 4.35% reduction	Corresponding decrease in pollution. Probably also for noise and maintenance Also discusses and illustrates effects for the economy	The training causes an effect. First larger (10%) in tests immediately afterwards, and then 4.35% in real traffic over 2 months afterwards	Only three bus drivers. No control
Af Wåhlberg (2007) Buses, Sweden Measure Training Fleet management system	Bus drivers in an urban environment. The study included five buses	Two percent reduction 12 months after training. Fleet management feedback yielded an additional 2%	Examined the effect on road safety, but did not find such effects. Either way, it would have been difficult to observe a 2% improvement	Strong effects on the day of training, but these were not easy to transfer to the work of the drivers	To what extent can we expect lower effects of economic driving on buses in urban environments? Only five buses, but over several years. No control

less fuel on average than trucks with trailers, because it requires more energy to tow the latter.

The fourth factor that influences the fuel consumption of heavy vehicles is driving style. Although this is often the main focus of measures aimed at economic driving, it is important to point out that the evaluated studies show that driving style is not the most influential factor on fuel consumption.

The fifth factor influencing fuel consumption of heavy vehicles is driver characteristics. Several of the evaluated studies find, for example, that it takes more for older drivers to change driving style due to training, and that it can also be challenging to influence the driving style of completely inexperienced drivers (e.g., Rolim et al., 2014; Sullman et al., 2015; Diaz-Ramirez et al., 2017). We are unsure of the ranking of this factor, compared with the four factors mentioned above, as none of our studies compare the importance of driver characteristics versus the four abovementioned factors.

The sixth factor that influences fuel consumption of heavy vehicles is organizational facilitation of economic driving and energy management. We have found few studies of how transport companies can facilitate economic driving at driver level (for example, Ayyildiz et al., 2017; Rolim et al., 2014), and no studies examining the effects of an energy management system in heavy goods transport. We are also unsure of the ranking of this factor, as none of the studies compare its importance systematically versus other factors.

3.2 Effects of measures

In this section, we focus on the second goal of the study, which is to examine the effects of various measures to promote economic driving and energy management in trucking companies. We first look at the effects in the studies, on fuel consumption and other performance measures, then we review the effects of specific measures.

3.2.1 Effects on fuel consumption, emissions, and economy

Eight of the eleven studies in Table 2 examining the effects of driving style on fuel consumption, find reductions of between 5% and 10%. The point in time when effects are evaluated is also important. Some studies indicate that effect of measures aimed at economic driving decreases over time (Sanguinetti et al., 2020), while others show the opposite (Sullman et al., 2015). It seems that most studies find that the effects diminish over time, but these studies focus on personal car drivers (Sanguinetti et al., 2020).

None of the evaluated studies make systematic analyses of effects on economy, but reductions in fuel use is directly related to this. Zarkadoula et al. (2007) for instance find a decrease in fuel consumption of 4.35%. As the buses in the studied company use around 60,000 L of diesel per year, an average annual reduction of 4.35% in fuel consumption will result in an annual saving of 2,610 L of diesel per bus. If the average cost of diesel is 0.65 euro per liter, the annual saving for each bus will be 1,697 euro. For the entire bus fleet of 1,700 buses in the company, this will amount to 29 million euro. None of the studies make systematic calculations of what economic driving can mean for savings related to vehicle maintenance. Zarkadoula et al. (2007) suggest, however, that one can expect that the reductions in maintenance costs will correspond to the percentage reductions in fuel consumption.

Only a few of the studies make systematic calculations of reductions in emissions related to the observed fuel reductions (Rolim et al., 2014; Foytik and Robinson, 2015; Lai, 2015; Ayyildiz et al., 2017). These focus on CO2 emissions, which account for between 93% and 95% of the total greenhouse gas emissions from truck transport (Piecyk, 2009). When 1 L of diesel is burned, 2.66 kg of CO2 is formed. The reductions in emissions will be the same as the reduction in fuel consumption (Ayyildiz et al., 2017).

3.2.2 Effects on safety and working environment

None of the evaluated studies examine systematically the effects of economic driving on working environment, for example, measured as drivers' perceived stress and pressure. However, several studies show that stress and time pressure are important factors that may impede economic driving, especially in bus transport (Strømberg and Karlsson, 2013; Sullman et al., 2015), but also truck transport (Ayyildiz et al., 2017). Additionally, one of the companies in the study of Nævestad et al. (2020) report of less stress among drivers and less sick leave following the measures focusing on economic driving. Duarte et al. (2013) also measure effects of passenger comfort in bus transport.

Two of the studies also include effects on traffic safety (af Wåhlberg, 2007; Symmons et al., 2008). Af Wåhlberg (2007) found no effects on road safety, but concludes that an improvement of 2%, corresponding to the reduction in fuel consumption, would have been too small to observe. Symmons et al. (2008) also found no effects on road safety, despite large reductions in fuel consumption of 27%. This may be due to the indicator they used for traffic safety, which was self-reported distance to the driver in front, looking far ahead, etc. It can be mentioned that a previous study of personal cars find correspondence between an economic and safe driving style (Toledo and Shiftan, 2016).

3.2.3 Effects of specific measures

3.2.3.1 Fleet management system

All but one of the evaluated studies of economic driving (Symmons et al., 2007) have a fleet management system, i.e., in vehicle data recorder (IVDR), as the most central measure or aid for contributing to economic driving. This shows that fleet management system is the most central measure for economic driving. The evaluated studies show that such systems have an effect when they are used to give regular and/or immediate feedback to the drivers on their driving style, so that the drivers can adjust their driving style to a more economic one. The systems especially measure speed, acceleration, braking and idling. The evaluated studies show that these are measurable aspects of driving style that are closely linked to fuel consumption, and that when drivers change their driving style on these aspects, their consumption decreases.

3.2.3.2 Feedback

Feedback to drivers is the second most common element in the studies' economic driving interventions. Feedback is fundamental because it is a prerequisite for drivers to be able to learn from the system. This is perhaps the most important element in facilitating economic driving, because the purpose of the fleet management system is to provide a basis for feedback. It is the feedback on one's own driving style, which the drivers learn from, not the recording itself. The fleet management systems often give an overall grade/score for the drivers' economic driving style, partial scores for the various parameters for economic driving, and information on what the drivers should do more or less of to get a better score (Ayyildiz et al., 2017; Diaz-Ramirez et al., 2017; Nævestad et al., 2020). This information is provided on screens in the vehicles, and/or on the telephone application with colour illustrations (red, yellow, green) for good and bad scores, encouraging messages and/or comparison and competition with others.

This is in line with the principles of "Gamification," which involves including elements from games and play to motivate people to participate in various activities. This is done, for example, by using displays or websites that are reminiscent of games with visual feedback with colours or "emoticons," scoring, etc. (Magana and Munoz-Organero, 2015). The feedback must come relatively regularly and preferably right after driving, so that the drivers remember the trip (Ayyildiz et al., 2017; Sanguinetti et al., 2020). Some systems also have sound signals that are activated in case of uneconomic driving (Duarte et al., 2013; Rolim et al., 2014).

3.2.3.3 Training

Driver training is the third most common element in the studies' schemes for economic driving. The fact that most studies combine both training and fleet management feedback makes it difficult to conclude which of these measures that have the greatest effect. This may indicate that precisely the combination of measures, i.e., fleet management systems combined with other measures, is most effective.

The studies of training rarely provide supplementary information about what the training entails in practice. This applies, for example, to how practical it is, how much the drivers are involved, how adapted it is to the drivers' everyday life, the mixture between practical and theoretical training, how feedback is given, etc. how the fleet management system is used in the training. The lack of information about this can make systematic comparisons and learning from the measures difficult. Given the mixed effects of the studies, it seems important to get answers to these questions in future research, in order to develop such training in an optimal way. The research on training in economic driving describes the training to some extent as a "black box," which is not described in detail.

The studies we have evaluated indicate that we should not ask whether training has an effect in itself. Rather, we should focus on identifying the characteristics of the training that has the best effects. Feedback from the fleet management system is also a type of training. Through this feedback, drivers get information they can use to change their driving style (and thus learn).

3.2.3.4 Competitions and bonuses

Different types of incentives, such as bonuses for good scores or goal achievement and competitions between drivers for good scores are described in the studies of Liimitainen (2011), Lai (2015); Nævestad et al. (2020), Diaz-Ramirez et al. (2017) and Ayyildiz et al. (2017). Bonuses and reward systems are mentioned as crucial to maintain driver motivation and beneficial results of economic driving (Liimitainen, 2011; Lai, 2015). A key challenge is, however, that it is difficult to establish fair criteria for assessment of performance, as several factors influence fuel consumption (Liimitaininen, 2011). Nævestad et al. (2020) describe formal and informal competitions between drivers as a motivating element. In the companies studied by Nævestad et al. (2020), managers regularly published anonymous or non-anonymous lists of different scores to the drivers, so that they could compete with themselves or others. Diaz-Ramirez et al. (2017) also emphasize that social recognition among colleagues within the company can be an important motivation for improving one's own driving style. This applies, as mentioned, especially when they are part of a «gamification» scheme, which involves competition, social belonging, and identity (Magana and Munoz-Organero, 2015).

In several of the companies studied by Nævestad et al. (2020), the managers also motivated drivers with bonuses if they reached certain goals, both related to economic driving and traffic safety. Similar measures are described by Diaz-Ramirez et al. (2017); Ayyildiz et al. (2017). We can also relate this to the point above, that drivers' motivation is a fundamental factor that promotes economic driving. As this often is one of several measures in studies, it is difficult to estimate the isolated effects of competitions and bonuses for economic driving. Competitions and bonuses can also be demotivating if the goals are unrealistic (cf. Strømberg and Karlsson, 2013).

3.2.3.5 Organization of transport

The studies from truck transport show the importance of traffic management and organization of transport, i.e., planning and optimization of routes, coordination of loading and assignments, etc. Foytik and Robinson (2015) study the potential gains of route choice considerations. Walnum and Simonsen's (2015), Diaz-Ramirez et al. (2017) and Ayyildiz et al. (2017) find, as mentioned, that infrastructure and road characteristics (e.g., road gradient) are crucial for fuel consumption. The mentioned studies also mention the importance of the weight of the load, and to make sure to organize transport so you have as full vehicle as possible. Knowing where the vehicles are at all times is also important, so that you avoid unnecessary driving, if you already have a vehicle nearby to pick up goods.

3.2.3.6 Continuous analysis of key figures

Several of the studies indicate that continuous analysis of key figures is an important factor in successful organizational work with economic driving and energy management. Walnum and Simonsen (2015) indicate, for example, the importance of regular (daily) systematic analysis of data and KPIs, combined with strong management commitment. Ayyildiz et al. (2017) argue in the same way that working systematically with economic driving requires continuous work with the sub-aspects of economic driving style and it requires a good overview of the key figures related to the parameters of driving style. This involves analysis of large amounts of data. They mention as an example that a trip of 1 h generates 3,600 datasets (Ayyildiz et al., 2017: 107).

3.2.3.7 Optimization of vehicles

Another measure is the optimization of vehicles. Studies from heavy goods transport show that engine effect (in kW) is a factor that has a significant impact on fuel consumption, which can be influenced through optimization of vehicles (Ayyildiz et al., 2017;

Diaz-Ramirez et al., 2017). Walnum and Simonsen (2015) examine this systematically in their study, and therefore conclude that when trucking companies are to replace old vehicles, they should consider whether extra power is necessary, or whether a vehicle with smaller effect is sufficient. Here, car owners must consider road conditions (topography), the weight of the goods, etc. against economy, and remember that an undersized engine will go with too high rpm and be uneconomical. Such considerations are also emphasized in the other studies of economic driving in truck transport (Ayyildiz et al., 2017; Diaz-Ramirez et al., 2017). Optimisation of the vehicle fleet could also involve optimising the composition of vehicles using different types of energy, e.g., hydrogen, electricity (see also Figenbaum et al., 2019). Although there are few real-world data studies of this now, this is an important future research topic.

3.2.3.8 Energy and environmental management systems

Management systems aiming to reduce the environmental impact of organizational activities are referred to as environmental-, emission- or energy management systems (EMS). There are several different EMS available, which can also be used in transportation. 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. The ISO 50001 standard is seen as complementary to ISO 9001 for quality management and ISO 14001 for environmental management. There is a particularly clear connection between ISO 50001 and ISO 14001, and it is also emphasized that if energy is an organization's most important environmental impact, then ISO 50001 may be more appropriate than ISO 14001. The difference between these two standards is that ISO 50001 is quantitative and focuses on reduced energy consumption, while ISO 14001 provides a more qualitative look at all important environmental impacts in organizations (for example,: use of raw materials, emissions to the external environment).

Implementation of the ISO 50001 standard involves creating 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). In addition, the management system as a whole is reviewed regularly. The key element in EMS is the continuous improvement, achieved through the "Plan-Do-Check-Act" (PDCA) (Comoglio and Serena, 2011). ISO 50001 was created in 2011, and the second edition of this standard came in 2018. Even though the standard has existed for 11 years, we find very few scientific studies of it, for example, through searches in scientific journal databases, but we find several so-called "Business cases," which present main results, such as energy savings and costs, in various sectors.[1]

We have included one of these business cases in Table 2: FCC Environment 50001 Business Case (2020), published by the BSI (British Standards Institution). Although this is only a "business case", it is relevant to also report results from such sources of information in the absence of other empirical studies. The included study is from the waste management company «FCC Environment». This company is also involved in transport with heavy and light cars. Although the "business case" does not report specifically on results for fuel consumption, this is one of the main areas where the company has saved energy.

3.3 Factors influencing implementation of economic driving

3.3.1 Commitment of managers and employees

Commitment to economic driving among managers and employees is a prerequisite for the introduction of organizational measures aimed at economic driving (Strömberg and Karlsson, 2013; Ayyildiz et al., 2017; Diaz-Ramirez, 2017; Nævestad et al., 2020) and System for Energy and Environmental Management (Nawrocka et al., 2009; FCC Environment, 50001 Business Case (2020).

3.3.2 Type of driving

The type of driving that drivers are involved in is a fundamental factor that influences how successful measures aimed at economic driving are (Strömberg and Karlson et al., 2014; Walnum and Simonsen, 2015; Ayyildiz et al., 2017; Ayyildiz et al., 2017). These considerations is the reason that Liimitainen (2011) asserts that the main challenge with incentive system as a key measure to motivate economic driving is that it is difficult to establish fair criteria for assessment of performance, as several factors influence fuel consumption.

3.3.3 Work-related conditions, stress, and pressure

Work-related conditions, stress, and time pressure, etc. Influence drivers' opportunities to drive economically (Ayyildiz et al. (2017); (Strømberg and Karlsson, 2013).

3.3.4 The companies' facilitation of economic driving

Few of the studies focus on how the studied transport companies can facilitate economic driving among the drivers, but Diaz-Ramirez et al. (2017) emphasize this as a decisive factor. The evaluated studies generally look at some selected drivers, and usually not effects at the company level, or make evaluations of companies' work with measures. The analyses performed in the evaluated studies are therefore primarily at the driver level.

3.3.5 Anonymity and misuse

Strömberg and Karlsson (2013) report that some of the drivers in the company they studied were probably sceptical of the fleet management system and saw it as a way for management to monitor their behaviour.

3.4 Development of a model for economic driving

The third goal of the study is to create an analytical model that describes different levels of organizational facilitation of economic driving and energy management in trucking companies.

1 https://www.bsigroup.com/en-GB/iso-50001-energy-management/case-studies/

3.4.1 The background of the model

In almost all EU countries from which relevant data are available, the proportion of trucking companies with less than 10 employees is about 80% or more, while the proportion with more than 50 employees is usually around one percent (European Commission 2022: 27). It is natural to think that the small trucking companies have fewer resources (time, economy, expertise) than larger companies, and that this can constitute a significant barrier to introducing a system for energy management and economic driving at an organizational level.

The starting point for our model is therefore that we create a «ladder model», which describes the gradual introduction of measures, where companies must start with what has the greatest effect and which is easiest to implement, before moving on to the next level. This will probably be easier and more motivating than going straight to implementing an energy management system of the type ISO:50001, or ISO:14001. In addition, it will probably lead to more companies starting with measures aimed at economic driving and energy management.

3.4.2 The eco ladder for energy management

We have developed a model we call the Eco Ladder for energy management, based on an analysis of the research literature that we review in Table 2. This literature has been evaluated based on five criteria. The measures must:

1) Have been shown to have an effect on (or to be closely related to) (reductions in) energy consumption in general and fuel consumption in specific in previous research (based on good methods).
2) Be associated with relatively low costs, both in terms of economic and human resources, even for small companies.
3) Not be too complicated, context-dependent, or extensive.
4) Complement existing energy management standards in such a way that they can serve as an introduction to the formal standards, but they must also be effective in cases where they do not eventually lead to full certification (e.g., ISO: 50001, ISO: 14001).
5) Do not conflict with other considerations, such as safety considerations.

Through an evaluation of measures, based on these five criteria and an assessment of which factors are most basic, and easiest to start with, we have created a step-by-step ladder model. Each level denotes management practices and a specific cultural attitude ("environmental culture").[2]

3.4.3 Level 0: traditional approach to fuel consumption

In contrast to the other levels, we have included a "level 0" in the model, which denotes a traditional approach to fuel consumption. This is based on expert interviews we have conducted on economic driving (Nævestad and Hagman, 2020). Some of the interviewed experts contrasted the attitudes and culture of companies that work systematically with economic driving with a "traditional culture", or traditional attitude to energy use in transport companies. Several of the interviewed experts believed that this "traditional" attitude was the norm before, and that it still exists in several transport companies today. These "traditional" attitudes means that managers and drivers believe that "the vehicle uses the fuel it must use", and that this is something you have little influence over as a driver.

3.4.4 Level 1: managers' and employees' commitment to economic driving

The evaluated studies show that commitment to economic driving among managers and employees is the most basic level, and a prerequisite for the introduction of organizational measures aimed at economic driving and the system for energy management (Strømberg and Karlsson, 2013; Walnum and Simonsen, 2015; Ayyildiz et al., 2017; Diaz-Ramirez, 2017; Nævestad et al., 2020). (cf. criterion 1). This is also associated with low costs (criterion 2), is not complicated (criterion 3), it complements existing standards (criterion 4) and does not in principle conflict with other considerations (criterion 5). There is little research on the effects of specific management practices, and the evaluated studies are not very specific about how managers most effectively show commitment to, and reward drivers' economic driving.

Based on Schein's (2004) research on culture in organizations, however, we know that managers in organizations signal fundamental values through the things they focus on in their daily work. Based on Schein's mechanisms that managers can use to influence culture, relevant management practices at level 1 can be, for example,: Management often emphasizes that drivers should have as low fuel consumption as possible. Drivers get praise and recognition for driving economically and for good scores in the fleet management system. More examples are provided in Table 3.

3.4.5 Level 2: organized and systematic use of fleet management system

The next step in the Eco Ladder is the implementation of a fleet management system to record and map drivers' driving style, and using it to systematically facilitate economic driving. This is the most fundamental element in companies' work with economic driving (Ayyildiz et al., 2017; Diaz-Ramirez et al., 2017; Sanguinetti et al., 2020). This means that companies have the technology in the vehicles, which gives individual feedback to the drivers, so that they can learn from it and change their driving style (Ayyildiz et al., 2017). Systematic use of the fleet management system also involves training in economic driving. This can be done based on the drivers' score in the fleet management system. Most of the evaluated studies contain a form of training of drivers in economic driving style (Rolim et al., 2014; Strömberg and Karlsson, 2013; Symmons et al., 2008; Zarkadoula et al., 2007; af Wåhlberg, 2007; Duarte et al., 2013; Liimitainen, 2011; Lai, 2015). Systematic use of the fleet management system also involves formal or informal competitions between the drivers in having the most economic driving style, and possibly also a bonus for economic driving. The evaluated studies indicate that driver motivation is important and that various incentives (competitions and bonuses) to change

2 The notion that the different levels of management practices also includes different types of cultural attitudes ("environmental culture") to environmental management is based on expert interviews in Nævestad and Hagman (2020).

TABLE 3 Good management practices at each level in the Eco Ladder for energy management.

Level 1	1	Managers at all levels show a commitment to economic driving and energy management
	2	Management often emphasizes that drivers should have as low fuel consumption as possible
	3	Drivers are involved in and informed about measures for economic driving and energy management
	4	Drivers receive praise and recognition for driving economically and for good scores in the fleet management system
	5	Managers regularly talk about measures that can save fuel and energy
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, weekly), 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 examines 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

driving style and get high scores seem to be important measures (Liimitaininen, 2011; Lai, 2015; Magana and Munoz-Organero, 2015; Ayyildiz et al., 2017; Diaz-Ramirez et al., 2017; Sanguinetti et al., 2017; Nævestad et al., 2020).

Systematic use of a fleet management system seems to be a prerequisite for reductions in fuel consumption (cf. criterion 1). This entails significant costs (cf. criterion 2), but given that it is basic, this is a measure that must be introduced if one is to work efficiently with economic driving. Additionally, results indicate that the economic benefits outweigh the costs. This measure does not seem to be very complicated to use (cf. criterion 3): such systems are complicated, but they usually provide relatively simple feedback. In addition, they complement existing energy management standards (cf. criterion 4), and they also contribute to promoting other considerations, e.g., safety (cf. criterion 5). Finally, it should be mentioned that a bonus for economic driving hypothetically can lead to driving styles that are negative to safety, e.g., keeping little distance to vehicles in front to roll out as much as possible (Dekhordi et al., 2019). This probably indicates that such bonuses should be given for both economical and safe driving, and not economic driving.

3.4.6 Level 3: energy management system

The highest level of the Eco Ladder for energy management refers to an energy management system like ISO: 50001 or similar, or an environmental management system like ISO: 14001 or similar. Implementation of an energy management system is in line with a continuous improvement approach (Johnson 2013). The following management practices are important in such an approach: Explicit goal for reduced energy use (FCC Environment, Business case 2020; Nawrocka et al., 2009), A good and continuous overview of all key figures (KPIs) and factors influencing the success of this goal, such as diesel consumption, driver fleet management scores on specific parameters of driving style, vehicle fuel consumption under road different conditions, the fuel consumption of different engine types under different types of driving (Johnson et al., 2013; BSI, ISO: 50001 implementation guide). It also involves optimization of vehicles and equipment, (Walnum and Simonsen, 2015), optimization of driving routes and organization of transport (Walnum and Simonsen, 2015; Diaz -Ramirez et al., 2017), and optimization of other factors influencing energy use in the company (FCC Environment, Business case 2020). Replacing diesel engines with new technologies might also be an example of optimization of vehicles and equipment, e.g., hybrid solution, batteries, electric motors, hydrogen and fuel cells.

Having a systematic plan to reduce all energy consumption in the company is the main element in a system for energy management (BSI ISO: 50001 Implementation guide). It seems that such comprehensive energy management systems have a greater effect than just focusing on driving style, as previous studies indicate that focusing on vehicle and transport route optimization has more impact on fuel consumption than just focusing on driving style (Walnum and Simonsen, 2015; Diaz -Ramirez et al., 2017). Accordingly, the case study companies that report figures for reduced energy consumption following from ISO50001, often report about 20% reduction (FCC Environment, Business case 2020).

Thus, an energy management system is important, because it is related to the factors that have the greatest significance for fuel consumption in trucking companies (for example: road and infrastructure, optimising load, optimization of vehicles) (cf. criterion 1). While level 2 of the Eco Ladder is about driving style, and how to motivate drivers to use less fuel, we have seen that, for example, road characteristics and infrastructure have 10–12 times greater effect than driving style on fuel consumption

(Walnum and Simonsen, 2015). At the same time, the system level is the most demanding to work with, because it requires systematic analyses of large data sets, and continuous follow-up and improvement. This is therefore related to a considerable use of resources, both in terms of time, economy, and competence (cf. criterion 2), and it can also be complicated (cf. criterion 3). That is why this is the highest and most resource-intensive level in the Eco Ladder. This measure can also complement energy management standards (cf. criterion 4), because it contains all the elements of such standards. The measure may also be beneficial for other important concerns (cf. criterion 5), such as safety management, as driving style aspects related to safety, such as sudden decelerations, acceleration, and other incidents may be some of the parameters that are monitored.

3.4.7 Good management practices at each level

The fourth goal of the study is to define specific measures and practices at each level in the Eco Ladder for energy management. Table 3 summarizes good management practices at each level in the Eco Ladder, based on the review of effective measures at each level in the Eco Ladder above. The practices are suggestions, based on the reviewed research, and need to be validated further in future research. The practices can also be used as criteria for classifying the companies' level on the Eco Ladder.

4 Concluding discussion

4.1 Methodological weaknesses and strengths

1) Potential bias in the search. After conducting the literature search and analysing the results, we identified a potential subjective bias in selecting studies to include in the review, which might be related to the types of search words we apply (cf. Table 1). These focus on driving style and technologies to record this (e.g., IVDR and fleet management systems). This is due to our original focus on economic driving at the driver level. We have less search words related to the optimization of transport, e.g., organizing transport routes, coordinating drivers and planning transport in ways that minimize "unnecessary" kilometres to pick up goods, choosing routes that involves lower consumption etc. We also have few search words related to optimization of vehicles and equipment, e.g., replacing vehicles with large diesel engines with smaller and efficient engines and choosing the right types of engines to the right types of transport (e.g., long distance versus distribution), or replacing diesel engines with other types of energy. We have, nevertheless, identified studies focusing on these strategies. Moreover, we used more general search terms to identify such studies. These were search terms focusing on energy management system etc. (cf. Table 1).
2) Nevertheless, we identified few studies of energy management systems. The lack of studies of energy management system is a weakness of the study. Our literature review does not show empirical studies that specifically examine how much fuel can be saved by implementing a comprehensive system for energy management, for example, of the type ISO: 50001 or ISO: 14001 in transport companies. This is a significant shortcoming in the research literature, and concrete indications of possible effects and good practice could be a significant motivating factor for companies. We have only been able to discuss this indirectly, based on information about certain management practices at level 3. The only study of a comprehensive program for energy management is a so-called "business case" (FCC environment 50001 business case 2000).
3) Broad definition of economic driving. A main strength of the study is that we use a broad definition of economic driving. This means that we do not just focus on economic driving at the driver level (driving style), as most studies of this do, i.e., economic driving at an operational level (Alam and McNabola, 2014). We also focus on economic driving at the organizational level, i.e., how companies can facilitate an economic driving style among their own drivers. The implication of this is that we also lean from studies of systems for energy management and environmental management. This involves a more holistic and systematic approach to energy consumption in transport companies, and subsequently larger reductions in energy use than one can obtain by only focusing on driving style.
4) Framework for organisational facilitation. Another main strength of the study is that it provides a framework for organisational facilitation of economic driving and energy management. Our review indicates that there is a lack of such tools, that are based on systematic reviews on existing research, like the present study. An additional strength of the Eco Ladder is that it provides concrete management practices and expected gains, based on previous research.
5) Tool for small companies. Finally, the Eco Ladder that is developed in the study focuses on the situation of small companies with few resources. This is important as most trucking companies are small. Thus, the Eco Ladder may provide a simplified and more realistic way of starting with economic driving and energy management. This may increase the uptake of such management practices with subsequent positive effects for fuel use, emissions and economy.

4.2 Questions for future research

1) *We need more studies of heavy vehicles and transport companies.* The literature review shows that there are relatively few studies of economic driving with heavy vehicles, and in future research we need more studies of economic driving in transport companies with heavy vehicles.
2) *We need more studies of energy management systems, the various elements they comprise and the continuous improvement approach that they involve.* Our literature review shows no systematic empirical studies of energy management systems. It should also be mentioned that some of the management practices at level 3 in the Eco Ladder that we provide in Table 3 (i.e., energy management systems) might seem abstract and general. More concrete examples of what it means that the company has a "systematic (analytical/mapping) focus on saving fuel through optimising vehicles and equipment" (management practice 3 at level 3) (based on e.g., Nævestad and Hagman, 2020) could e.g.

be replacing vehicles with large diesel engines with smaller and more efficient engines, choosing the right types of engines to the right types of transport (e.g., long distance versus distribution), replacing equipment, e.g., changing to trailers with less rolling resistance, removing unnecessary objects on the vehicle that increase drag, calibrate axles, tire pressure etc. More concrete examples of what it means that the "company maps transport and works actively to optimise routes and organise transport (transport the most goods for the fewest km)" (management practice 4 at level 3) are e.g., that the company has GPS-based overview of where all vehicles are at all times, which might facilitate the use of the "closest vehicle" in all transport operations. More concrete examples of what it means that the "company conducts comprehensive analysis and takes measures aimed at all energy use in the company," could e.g., be that the company also analyses energy use in other company operations than transport, e.g., related to garages, parking facilities, washing equipment etc. It is difficult to conclude about the importance of the different management practices at Level 3 in the Eco Ladder, and this is an important area for future research.

3) *Need to validate the Eco Ladder for energy management in empirical studies*. Although the management practices in the Eco Ladder describe measures that have support in previous research, the approach itself and the gradual introduction of measures have not been validated in previous research. There is therefore a need to conduct empirical studies that examine the extent to which trucking companies have implemented the measures in the Eco Ladder for energy management, and whether it is the case that those who have introduced the most measures have had the largest reductions in fuel and energy consumption (or the lowest level of fuel consumption per km). A basic assumption behind the Eco Ladder is that the combination of the measures at level 2 and level 3 has the greatest effect. It is important to test this hypothesis, and if possible, also examine the effects of the specific management practices.
4) *Need to investigate additional effects of economic driving.* Previous research provides indications that trucking companies' measures for economic driving can have a number of positive additional effects. This applies, for example, working environment (e.g., drivers' perceived stress and time pressure) to traffic safety.
5) *Few studies of the content of training.* Several of the studies show that training in economic driving has an effect, and that the effects depend on the type of training provided. However, the studies often contain little specific information about the specific content of the training that is given and how it is given.
6) *Need for more robust studies (i.e., with pre and post measures, test and control groups).* The literature review generally shows a need for more robust studies of economic driving and energy management in trucking companies (cf. Sullman et al., 2015). The evaluated studies generally have few participants and often no control groups.
7) Need to develop an overview of baseline energy use. It might seem promising to motivate transport company owners to implement measures for economic driving and energy management, as this is related to energy savings and reduced costs. Their motivation could be fostered even more by providing e.g., an online "calculator" where they could provide key numbers related to their number of vehicles, annual kilometers driven, fuel costs etc. This could be based on a national/continental level of baseline energy use database, including different types of transport, sectors etc. Based on this, companies can set realistic targets in their energy saving, reductions in costs, emissions etc. This seems especially important for small companies with few resources. Thus, future research could aim to make such an overview of baseline energy use, and the suggested "calculator." The effects of such measures should be evaluated. Moreover, at organizational level, some type of shared platforms could be important to help small logistics companies share resources and reduce the costs and energy
8) *Need to test and adapt the Eco Ladder in different contexts*. The point of departure in the paper is to develop a simple, research-based model for how trucking companies can work with economic driving at the organizational level. The background for this is that most trucking companies are small, both in a European and in a Norwegian context. As it is likely that comprehensive energy management systems like e.g., ISO: 50001 might be too resource demanding for these companies, when it comes to time, competence and economy, these companies would probably benefit from a list of concrete research-based management practices. However, as there is not an abundance of studies of economic driving in trucking companies, we have also included studies of other heavy vehicles (i.e., bus) in the literature review. This means that the Eco Ladder approach also is relevant to other sectors than truck transport, and probably also to other companies than small companies, although it originally was meant as an aide to small companies. The application of the management practices to many different contexts, e.g., bus transport, transport with passenger car and van fleets etc. Is an important area for future research.
9) *Need for more real-life studies of economic driving and energy management systems.* We identified mostly studies with experimental designs or small test groups in the literature review, involving limited groups of drivers (sometimes only a handful). A real-life study the context of economic driving would mean a trial with an implementation of an economic driving scheme or energy management scheme in the whole company among all drivers. Such studies are useful, as they apply to the realistic application of the measures that we study. Facilitating economic driving among all drivers in a company, with different backgrounds (age, sex, nationality, experience etc.), different types of driving etc. might be different from facilitating economic driving for e.g., five drivers in an experiment, involving a given short route. Thus, real-life studies might provide more realistic results at the company level and also more knowledge about impeding and facilitating factors, as they involve more variation among the "test subjects", and also more realistic test settings. Some of the reviewed studies can perhaps be labeled real-life studies, as they involve companies in general and/or large fleets, e.g., FCC Environment (2020) and Nævestad et al. (2020) Lai et al. (2015) Duarte et al. (2013). More such studies are needed to shed light on the practical implementation of the Eco Ladder in real companies, including expected results.

5 Conclusion

We have developed a research-based model for how trucking companies can work with economic driving and energy management at the organizational level. The model is referred to as the Eco Ladder for energy management, and describes an approach with gradual introduction of specific measures. Based on existing research, we have discuss expected effects for economy, emissions, traffic safety and working environment.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

T-ON wrote the first draft and conducted literature review. ISH performed the literature search and also conducted literature review and provided text about the studies. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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