

Summary

Mini scenario: Safety ladder. Introduce measures for organisational safety management in goods transport companies

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An average of 688 people are injured in accidents involving heavy goods vehicles (HGVs) each year (most of them are other road users). A total of 138 of these people are severely injured or killed in the accidents. Based on our estimates, we assume that 58 % of the HGV accidents involve drivers employed by transport companies, which can be addressed by means of organizational safety management. The aim of the study is to examine possible consequences for the number of killed and severely injured in traffic if goods transport companies in Norway introduce the organizational safety management measures in the stepwise approach that we call the "Safety ladder". Previous research indicates that such organizational safety management measures are relatively uncommon in Norway, despite the fact that the two only robust studies of this found indicate that such measures can reduce the incidence of traffic accidents by between 20 and 60 %. We use two approaches to discuss the potential consequences that organizational safety management in Norwegian goods transport companies may have for the number of killed and severely injured. Additionally, we investigate the potential both retrospectively (previous accidents that could have been avoided) and prospectively (future accidents that can be avoided). A review of fatal accidents in the period 2005-2013 indicates a potential to avoid 62 fatalities/severely injured per year in the period. An analysis of personal traffic injuries in the period 2007-2016 shows a potential to avoid 66 fatalities/severely injured per year in the period. A linear projection of fatalities, with 80 traffic fatalities in total in 2020, shows a potential for avoiding 26 fatalities/severely injured in 2020. If we include transport for own account, the potentials are respectively 102, 96 and 40. The potentials indicate the numbers of accidents and injuries that we can take action against; they do not take already existing measures into account, or the fact that new measures do not have 100 % effect. We have provided some examples of calculations, where we take this into account, illustrating how these potentials can be realized through measures at the various levels of the Safety ladder. The estimates in the example calculations vary between 7 and 56 fatalities/severely injured that potentially can be avoided (retrospectively), depending on the conditions we apply regarding prevalence and effect, and whether we include transport for own account or not. The estimates for lighter personal injuries vary between 27 and 221. None of these estimates provide, however, a satisfactory picture of possible effects of introducing the Safety ladder for goods transport companies Norway, because of methodological weaknesses, and because we lack robust data on the prevalence and effect of organizational safety management measures. The approaches provide, however, examples that we probably can expect a certain decrease in the number of killed and severely injured in Norwegian goods transport companies if measures are taken in line with the safety ladder. We list seven reasons to explain why these estimates are conservative.

Background and aims

An analysis of the composition and development of the Norwegian goods transport market shows that heavy goods vehicles (HGV) represent the dominant means of transport. HGVs make up the largest total transported tons and ton kilometres, compared with maritime transport and rail transport. However, the considerable HGV transport on roads

of varying quality throughout the country throughout the year affects the numbers and types of accidents on Norwegian roads. Norway has about 35 % more killed per capita in HGV accidents than the average for Europe. These are often serious accidents with significant proportions of severely injured and killed due to heavy vehicle weight and mass. On average, about 1.500 people in Norway are injured in accidents involving drivers at work, and most (81 %) of the people injured in these accidents are other road users.

Although there are relatively few systematic studies in this area, research indicates that increased focus on organizational safety management can lead to increased road safety. The two only robust studies found of this indicate that such measures may reduce the prevalence of traffic accidents by between 20 and 60 %. In addition, previous studies show that hauliers transporting dangerous goods (road tanker) by road have a 75 % lower risk of accidents than other goods transport companies. This indicates what can be achieved through systematic organizational safety management (and special framework conditions).

However, it seems that neither transport companies, nor authorities focus sufficiently well on the importance of work-related risk factors for transport safety. We have previously suggested an approach that we term the Safety ladder for goods transport, which consists of four measures. This is suggested on the basis of a systematic literature study of organizational safety measures, an analysis of studies of accidents with drivers at work, and industry characteristics (86 % of companies have fewer than five employees).

The aim of the study is to examine possible consequences for the number of killed and severely injured in traffic if road goods transport companies in Norway introduce the organizational safety management measures in the Safety ladder.

The Safety ladder for road transport of goods

We define organizational safety management as the combination of informal and formal organizational measures aiming to increase the safety in organizations. We may refer to the formal organizational measures as safety structure, and the informal as safety culture.

Based on previous research in Norway and internationally, we concluded that four main measures aimed at organizational safety management have the greatest transport safety potential and are most realistic for regular goods transport companies.

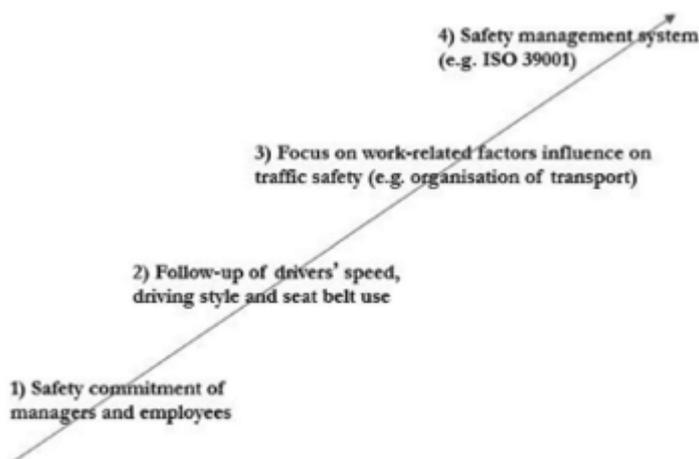


Figure S.1 Safety ladder for safety management in goods transport.

These four measures can be arranged on a ladder, starting at the lowest level, before proceeding to the next step. The idea behind the Safety ladder is that companies start at the bottom of the ladder if they have no measures aimed at work-related risk factors in the company. Based on previous research, we assume that the lowest levels are easiest to do something about and that they have the greatest effect. The first step in the ladder, “Managers’ commitment to safety, is the

most basic step in the Safety ladder, because research shows that this is usually a

prerequisite for the company's safety work to be successful. The second step in the safety ladder is "Follow-up of driver speed, driving style and seat belt usage". This is aimed at the main risk factors associated with drivers identified in the analysis of fatalities involving drivers in work. The third step in the Safety ladder is "Focus on work-related factors influence on transport safety". Given little focus on organizational safety management in goods transport companies, it is important that managers and employees in these companies develop an awareness the importance of work-related factors in transport safety. This applies, for example, to the organization of transport, with the consequences for drivers' experience of stress, time pressure, fatigue, etc. The fourth step in the Safety ladder is to implement a "Safety Management System", such as ISO 39001, or other similar alternatives.

Data sources and methods

The study is based on eight data sources. The data has been collected and analysed in connection with the present project (with the exception of point 3, 6 and partly 8).

- 1) Data on kilometres driven in Norway for Norwegian registered HGVs during the period 2003-2016, based on Statistics Norway's lorry survey.
- 2) Statistics Norway's structure statistics for transport and storage in the period 2007-2015, employed to estimate the proportion of kilometres driven (and accidents) by drivers employed by Norwegian goods transport companies.
- 3) Data from the National Road Administration's Accident Analysis Groups (AAG) on the characteristics of fatal accidents triggered by HGV drivers in the period 2005-2013, which we collected and analysed in connection with a previous project.
- 4) Statistics Norway data on personal injury accidents involving HGVs, in the period 2007-2016.
- 5) Data from TRAST, the insurance companies' database of property damage accidents involving HGVs, 2007-2016.
- 6) Additional information about 25 HGV crashes from reports from the Accident Investigation Board Norway (AIBN), which contains information on work-related risk factors, and which we analysed in connection with a previous project.
- 7) Survey to manager representatives (N = 62) and employee representatives (N = 59) to estimate the occurrence of organizational safety management measures in Norwegian road goods companies.
- 8) Systematic literature search and analysis of studies of organizational safety management in road transport, to estimate expected or possible effects of organizational safety management on accidents.

In this study, we use two approaches to examine possible consequences for the number of killed and severely injured in traffic if goods transport companies in Norway introduce the organizational safety management measures in the Safety ladder.

In the first approach, we use data on fatalities triggered by drivers at work, based on the AAG data, to assess the potential for the number of accidents and injuries that can be avoided through the various steps in the Safety ladder. In order to assess this, we identify, first, drivers that AAG defines as triggering for the accidents. Second, we identify key risk factors associated with the triggering drivers, which according to AAG were significant (= 2) or decisive (= 3) for the occurrence of the accident. Third, we assess whether these risk factors are relevant to any of the measures at the various levels of Safety ladder. If they are,

they are assigned a level at the Safety ladder. Fourth, we consider the importance of the risk factors for the accidents that are triggered by heavy goods drivers, by adding all the risk factors. By calculating the different risk factors' shares of the total number of risk factors, we obtain information about the given proportions for each risk factor, and thereby the shares of risk factors that can be addressed by the Safety ladder and those which cannot. Fifth, based on this we have estimated the proportion of the accidents and thus the number of killed and severely injured that could have been avoided if these risk factors had been dealt with in a perfect way.

In the second approach, we give example calculations of possible effects of measures operationalizing the various steps on the Safety ladder on the number of killed and severely injured in traffic accidents, based on Statistics Norway's data on police reported injuries in traffic. In order to develop examples of possible effects of implementing measures, we have provided an overview of kilometres driven by Norwegian registered HGVs in Norway. Second, we have estimated the proportion of kilometres driven by employed drivers in Norwegian goods transport companies. Third, we have provided information about how many accidents the Norwegian registered HGVs are involved in. Fourth, we have estimated the share of accidents involving employed drivers. We only have numbers for the kilometres driven by self-employed employed drivers. We lack an overview of the accident involvement of the two groups. Calculating the share of accidents involving employed drivers, we have therefore assigned employed drivers the same proportion of accidents as their share of the total number of kilometres driven each year. This means that we assume that the accident risk for the two groups is equal. This assumption is not necessarily true, and should therefore be investigated in future research. Based on the figures for kilometres driven and accidents, we have estimated the accident risk to the target group for the measures in the Safety ladder. Fifth, based on the numbers of accidents that employed drivers of Norwegian registered HGV have been involved in, we have identified the average number of personal injuries per year which are potentially preventable through measures directed at organizational safety management. Since the numbers of accidents of this type have been significantly reduced over the past ten years, we look at the average for two periods: the last 10 years and the last five years. We also calculated possible reduction in 2020, based on a linear projection. Sixth, we calculate the number of deaths and severely injured in these accidents. Seventh, we give examples of how many of these deaths and severely injured that could be avoided, given the results of the two studies from the literature study with high enough quality to be used for this purpose. Eighth, we also take into account the results of the survey of existing implementation of organizational safety management measures.

Accidents and risk

We assume that organizational safety management measures primarily can be introduced in Norwegian goods transport companies with employed drivers. We focus on Norwegian companies, because it is difficult for Norwegian authorities to demand organizational safety management measures from foreign transport companies, given EU-legislation in this field. We focus on employed drivers and not on self-employed drivers, since the latter is only one person, and because organizational safety management largely is about the relationship between managers and employees. Managers have a certain managerial prerogative (and duty) to intervene in employed drivers' work situations and introduce measures that can increase their safety (such as speed limiters, procedures prohibiting driving over speed limits, mobile use, etc., fleet management and measures to enhance safety culture). This

managerial prerogative exceeds the capabilities that the authorities have to regulate the driving of private drivers.

Figure S.2 shows the number of kilometres travelled and the number of HGVs driven by employed drivers who have been involved in personal injury accidents. We have used these two numbers to calculate the risk for each year.

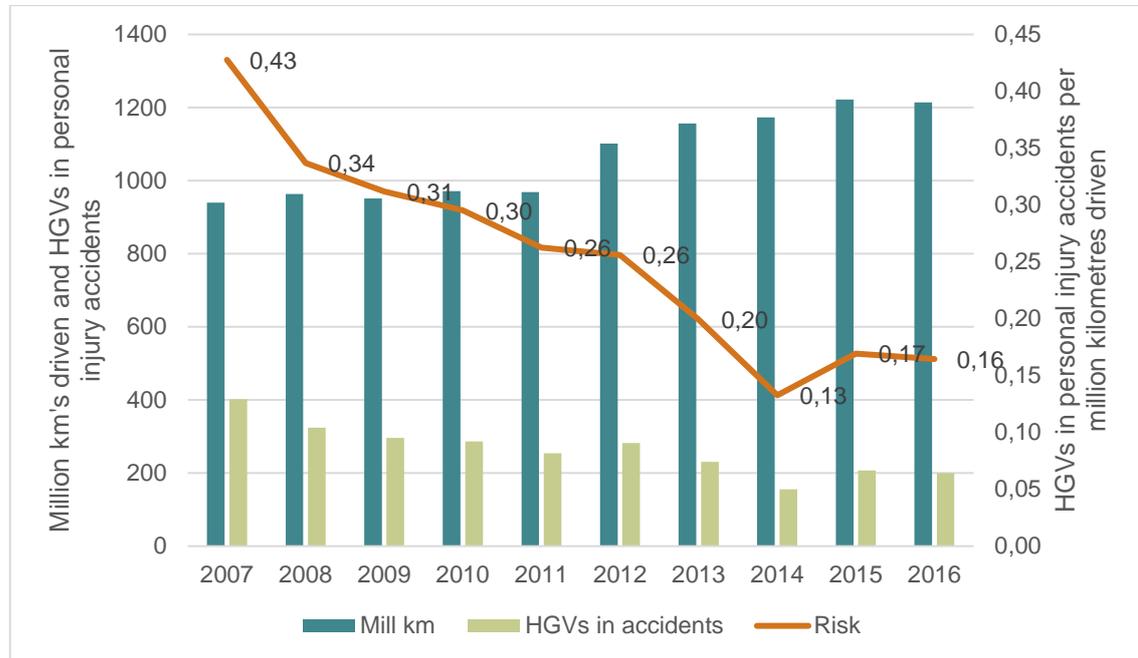


Figure S.2: Million km's driven and the number of Norwegian registered HGVs driven by employed drivers in goods transport companies (transport for hire or reward), involved in personal injury accidents per year 2007-2016 (left-hand scale), and risk per year (right-hand scale).

We have combined data on the kilometres driven for Norwegian registered HGVs in Norway in the period 2003-2016, based on Statistics Norway's lorry survey, with data from Statistics Norway's structural statistics for transport and storage. This is used to estimate the proportion of kilometres driven (and accidents) of employed drivers of Norwegian HGVs. These data indicate that drivers employed in goods transport companies are involved in 58 % of the kilometres driven with HGVs on Norwegian roads. We generally focus on drivers employed in transport companies (58 % of the kilometres), i.e. "transport for hire or reward", and only to a small extent (i.e. in some examples) "transport for own account", i.e. drivers employed in companies that are not primarily transport companies (31 % of the kilometres), but which also offers transport of the products they sell.

We do not have figures on the proportion of accidents involving employed drivers. We therefore assume that employed and self-employed drivers have equal risk, and attribute the same proportion of accidents as kilometres driven for the two groups. This assumption should be tested in future research.

Figure S.2 indicates that the risk of personal injury accidents for HGVs has been substantially reduced in recent years. The decline is interesting considering the low focus on organizational safety management in goods transport companies that our previous studies indicate. However, it must be mentioned that the general reduction in risk is in line with what we see for other road users, for example for passenger cars, and that it thus reflects a development in society involving higher road safety.

Prevalence of measures

We have conducted two surveys to assess the occurrence of measures focusing on organizational safety management in Norwegian goods transport companies.

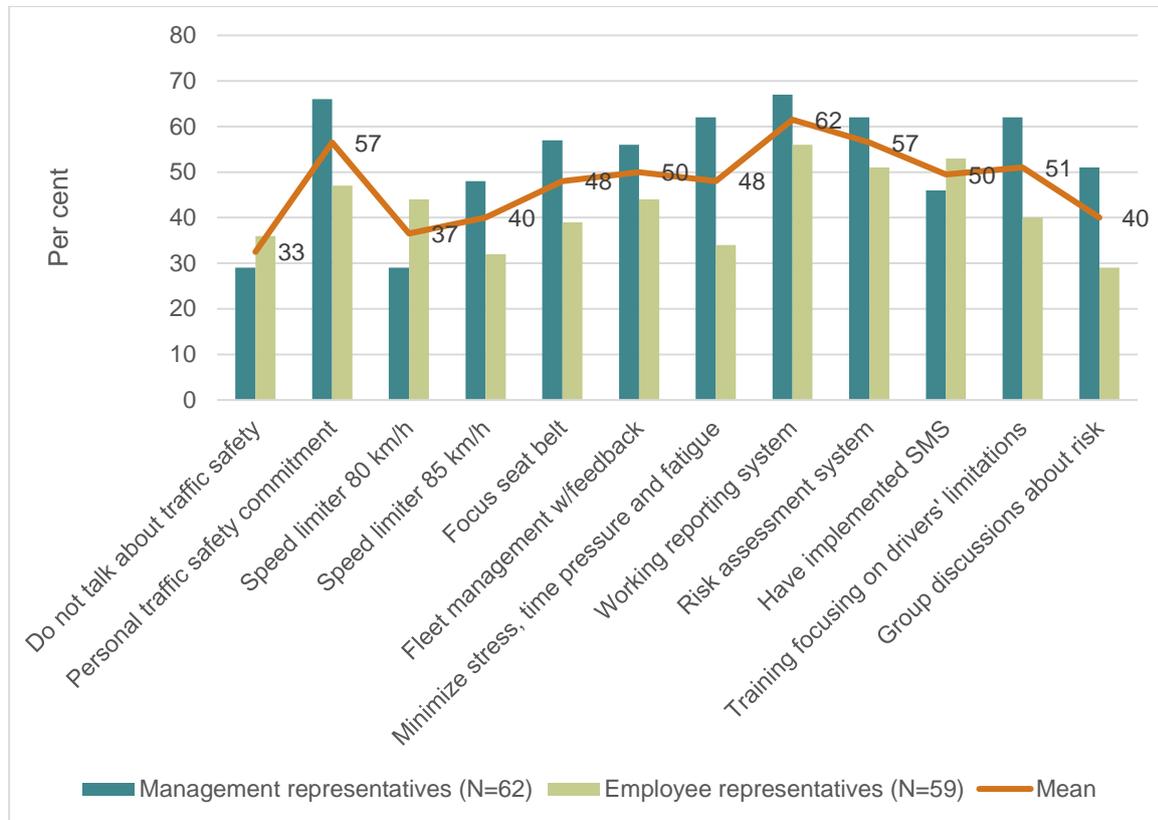


Figure S.3: Results from two surveys on the occurrence of 12 organizational safety management measures in Norwegian goods transport companies.

The first survey (N = 62) involved employers' representatives, while the other (N = 59) involved representatives on the employee side. The survey contained 12 questions about measures. Respondents were asked to give their answers as a percentage, and they received 10 response options (0-9%, 10-19%, etc.). Figure S.3 shows the average of their answers.

Our overall impression is that Figure S.3 seems to overestimate the occurrence of organizational safety management measures in road goods companies. This impression can be tested against measures we have information about the occurrence of. For example, we know that about 10 % of the members of the Norwegian Lorry-owner Association in 2016 made use of the safety management systems "Quality and Environment on the Road" and "HSE". At the same time, a handful of Norwegian road transport companies (bus and goods) had implemented ISO: 39001. Based on Figure S.3 above, we see that respondents estimate that 50 % of Norwegian goods transport companies have introduced safety management systems (cf. "The company has introduced a safety management system such as Quality and environment on the road, ISO9001, ISO39001 »). This estimate thus appears to be about five times as high as the real proportion. Possible reasons for this are discussed.

Consequences of measures

There are few studies of organizational safety management in road transport companies, which are published in peer-reviewed journals. We have conducted a systematic literature search and analysis of studies of measures aimed at organizational safety management in road transport to estimate expected or possible effects of organizational safety management on accidents. The search was carried out as part of a previous study, but the studies have been partially analysed again, among other things, to assess whether they estimate the impact (also focusing on how this is estimated) on accidents and which Safety Ladder level they address. We identified 24 studies, discussed which steps on the Safety Ladder they refer to, their main findings, strengths, and weaknesses. We also discussed challenges associated with using these studies to try to assess the effects of the various steps in the Safety ladder on killed and severely injured in traffic accidents. We concluded that only two of the studies have robust enough designs to allow us to use the results of them in our analyses. The first study found a major decline in accident risk among company drivers who participated in group discussions (59 %) or anticipatory driver training (41 %) and less effects among drivers who participated in incentive programs, or who received information from campaigns. The second study showed that the accident rate decreased by 20 % among drivers who received feedback on speed, acceleration, braking and fuel consumption (from a unit in the vehicles). Both studies focus on the impact on accidents in general, i.e. accidents involving property damage.

Estimating the potential for avoiding accidents and injuries

We estimate the potential of accidents and injuries that can be avoided through the various steps in the Safety ladder, based on data from AAG and Statistics Norway. Our estimates are conservative, for the following reasons: 1) We primarily focus on drivers employed in transport companies (58 % of the kilometres driven), i.e. “transport for hire or reward” and not “transport for own account” (31 % of the kilometres), which refers to drivers employed in companies which are not transport companies. 2) One may think of a “spillover” effect of company-based safety measures to private driving. 3) Fatalities with heavy vehicles constitute an increasing proportion of the decreasing number of fatal accidents occurring in Norwegian roads. 4) Some aspects of safety management will also have the potential to reduce accidents with heavy goods cars triggered by other road users. 5) We focus on Norwegian companies, because it is difficult for Norwegian authorities to demand organizational safety management measures from foreign transport companies. 6) Our estimates based on AAG data are conservative, as we only focus on accidents *triggered* by HGVs. 7) The estimates in the example calculations based on personal injury accidents data from Statistics Norway are conservative, because our two surveys seem to overestimate the occurrence of organizational safety management measures in road goods transport companies.

When we use the term potential, we refer to two types of estimates. We use the concept retrospectively, by making calculations based on the annual average for previous years, for example the period 2005-2013, and calculate an annual reduction in accidents and injuries per year in the period 2005-2013, if the measures had been implemented in 2005. Second, we use the term prospectively by making a linear projection of the number of accidents and injuries for one year, e.g. 2020, and assess how many of the accidents and injuries this which year could have been avoided, given the proportions of accidents and injuries that we estimated could be avoided in the retrospective calculations.

A previous study showed that the proportion of fatal accidents **triggered** by vehicles driven by professional drivers at work was 11 % (for the period 2005-2013). However, this whole proportion cannot be prevented by means of the Safety ladder. We have downgraded the proportion, excluding: 1) Accidents triggered by professional drivers who drive a different type of vehicle than HGVs (buses). 2) Accidents triggered by self-employed drivers (i.e., not employees). 3) Accidents triggered by drivers employed in foreign companies. Based on this, we estimate that 4 % of the fatal accidents were triggered by professional drivers of HGVs employed by a Norwegian company.

Based on this proportion, we have calculated the potential for the number of killed and severely injured per year, which can be avoided through the measures in the Safety ladder. Our analysis of the fatalities in the period 2005-2013 shows a potential to avoid 62 fatalities/severely injured per year. A linear projection of fatalities, with 80 fatalities in 2020 shows a potential to avoid 26 fatalities/severely injured in 2020.

We also do the same calculations, including drivers employed by non-transport companies (“transport for own account”) (31% of the kilometres). When included, we assume that a total of 90 % of the kilometres are driven by employed drivers.

Table S.1: Annual average: potential for avoiding fatal accidents triggered by Norwegian registered HGVs driven by employed drivers (“transport for hire or reward”) in the period 2005-2013, and in 2020, based on a linear projection of the annual number of fatal accidents. We also show calculations including transport for own account.

Time period	Fatal accidents per year	Triggered fatal accidents	Killed	Severely injured
2005-2013	191	7	8	53
2005-2013 including transport for own account	191	11	13	83
2020	80	3	3	22
2020 including transport for own account	80	5	5	35

The potential to avoid 62 killed/severely injured per year is a conservative estimate, based on the seven reasons we mentioned above.

We have made comparable calculations based on Statistics Norway’s data on police reported injuries in traffic to identify the average number of personal injuries per year which are potentially preventable through measures directed at organizational safety management. Since the number of accidents of this type has been considerably reduced over the past ten years, we look at the average for two periods: the last 10 years and the last five years. The review of personal injuries in the period 2007-2016 indicates a potential to avoid 66 dead/ severely injured per year.

Table S.2: Average for Norwegian registered, employee-driven HGVs in accidents involving personal injuries per year in the period 2007-2016 and 2012-2016, the average number of accidents and personal injuries in the accidents. We also include calculations including transport for own account.

Time period	HGVs	Accidents	Personal injuries	Killed	Severely injured	Minor injuries
2007-2016	264	257	360	29	43	288
2012-2016	222	216	302	24	36	242
2007-2016 including transport for own account	412	401	561	45	67	449
2012-2016 including transport for own account	334	326	456	37	55	365
2020	60	58	82	7	10	65
2020 including transport for own account	93	91	127	10	15	101

It is important to remember that the figures in Table S.1 and S.2 only show the potential for the number of injuries and deaths that can be prevented through measures focusing on organizational safety management. The two only robust studies of this indicate that such measures can reduce the incidence of traffic accidents by between 20 and 60 %. This applies to all traffic accidents.

The actual numbers of injuries and deaths that can be avoided through organizational safety management of the kind we describe in the Safety ladder are therefore far lower than the potential indicated in Table S.1 and S.2. This is among other things due to the fact that the numbers in Table S.1 and S.2 do not take already existing measures into account, or the fact that new measures do not have 100 % effect. We have provided some examples of calculations, where we take this into account, illustrating how these potentials can be realized through measures at the various levels of the Safety ladder. The estimates in the example calculations vary between 7 and 56 fatalities/severely injured that potentially can be avoided (retrospectively), depending on the conditions we apply regarding prevalence and effect, and whether we include transport for own account or not. None of these provide, however, a satisfactory picture of possible effects of introducing the Safety ladder for goods transport companies Norway, because of methodological weaknesses, and because we lack robust data on the effect of organizational safety management measures. This is why we focus on the numbers in Table S.1 and S.2. The approaches provide, however, examples that we probably can expect a certain decrease in the number of killed and severely injured in Norwegian goods transport companies if measures are taken in line with the safety ladder.

Methodological weaknesses

It should also be noted that neither of the two approaches we have used to estimate the possible consequences of the Safety ladder for the number of killed and severely injured in traffic accidents provide a sufficient picture of possible effects of introducing the Safety ladder for goods transport in Norwegian companies. Both approaches have too many methodological weaknesses. The example calculations are based on a number of assumptions, which must be investigated in future research. As mentioned above, we do not have numbers for employed drivers' and self-employed drivers' accident involvement, but assume that they have equal risk in our calculations. The same applies to drivers employed in companies where transportation is an auxiliary function to the primary business. These assumptions must be tested in future research, which can compare risk, measures, etc. for the three groups. In addition, we conclude that our estimates of existing implementation of measures, based on our surveys, are likely to overestimate the occurrence of measures (and thereby underestimate potential effects). The occurrence may also vary greatly between counties. The same applies to the presence of transport companies and employees drivers in counties. We have not taken this into account in the example calculations. Nor do we take into account other external influences in these calculations, for example related to increased transport safety brought forth by automation, effects of increased proportions of foreign HGVs and drivers, improved roads and new requirements from transport buyers.

Another weakness of our study is that there are only two studies of measures that have a high enough quality for us to use them. In addition, we discuss 9 methodological weaknesses associated with using data from available studies to estimate possible consequences of organizational safety management on the number of killed and severely injured in traffic:

- 1) Quality of studies; few before /after measurements with control groups, etc.
- 2) Few studies include data on the effects on accidents.
- 3) It may be challenging to generalize about experiences from measures addressing drivers at work at general to measures aimed at HGV drivers
- 4) It may be challenging to transfer experiences from measures in groups and/or organizations to the community level
- 5) It is not unproblematic to generalize about experiences from measures in other countries to Norway
- 6) Some of the studies only look at one measure, and they do not necessarily control for other measures additional to the described measure (although they may be important).
- 7) Some of the studies look at larger “packages of measures” in companies, which makes it difficult to point out the effect of individual measures.
- 8) Several of the studies are looking at effects on property damage accidents, and it is not necessarily feasible to assume equivalent effect on personal injury accidents.
- 9) All studies show effects of the measures, but this may be due to publication bias.

Lacking knowledge and questions for future research

It is important to remember that the approach in our step-by-step Safety ladder (i.e. starting with a specific step before the next) is not validated, neither by us, nor in previous research. This is an important area for future research. The Safety ladder, however, is based on a systematic literature study of measures aimed at organizational safety management, and analysis of traffic accidents involving drivers at work. As our literature review suggests, the lack of robust data on the impact of organizational safety management measures is a challenge for road traffic in general. This probably reflects the limited implementation of such measures in the road sector. We have pointed to a number of factors that should be investigated in future research. Our literature study shows that a main problem with the research on organizational safety management is that lacks a robust empirical basis for pointing out the relationship between different, specific management measures and practices and safety outcomes.

There are no sufficiently good studies evaluating the effects of specific management practices at Level 2 in Safety ladder; i.e. studies evaluating the effects of transport companies' follow up of drivers' speed, driving style and seat belt use. Two studies show a good effect of so-called anticipatory driver training, while another study does not show effect. This also requires more research.

The third step in the Safety ladder is “Focus on the importance of work-related factors for transport safety”. This particularly refers to the organization of transport, with the consequences it has for drivers' experienced stress, time pressure, fatigue etc. There is little research on this, with a few exceptions. Work related factors are also not registered in the accident statistics of Statistics Norway or the AAG (but they are discussed in the AIBN reports). We need more systematic registration of such factors, in order to be able to properly address them. We know a little about correlations between organization of transport and drivers' experienced stress, but we lack robust studies investigating the effects of such measures. This shows an important area for future research. It is difficult to draw general conclusions about the importance of work-related factors for transport safety, since different companies in different subsectors, with different characteristics, etc., will

have different challenges that may have to be addressed through various organizational means. These issues should be followed up in future research.

The fourth step in the Safety ladder is the implementation of safety management systems. The absence of (high quality) studies examining the effect of safety management systems on killed and severely injured in traffic accidents indicates a significant knowledge gap and need for future research. Previous research indicates that there seems to be a connection between SMS and objective safety outcomes (such as behaviour and accidents). However, this research also concludes that there is no consensus about which components of safety management systems that contribute most to safety outcomes.