CHALMERS

User scenarios

Field study on the usage of help functions for truck driving in rough road conditions

Bachelor of Science Thesis in the Bachelor Degree Programme, Product Design Engineering

Simon Isakson
Tomas Lindström

Examiner: Pontus Engelbrektsson
Department of Product and Production Development
Division of Design & Human Factors
CHALMERS UNIVERSITY OF TECHNOLOGY
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FOREWORD

This report accounts for our thesis project in the Bachelor of Science Programme Product Design Engineering at Chalmers University of Technology.

We would like to thank Marjukka Sagesjö and Emma Nilsson at Volvo 3P for their help and support during the project and Pontus Engelbrektsson at Chalmers for his good advice.

We would especially like to thank all the drivers who let us into their trucks and took the time to answer our questions, as well as those we didn't meet in person but helped us make contacts.

Simon Isakson
Tomas Lindström

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ABSTRACT

Volvo’s trucks can be equipped with a number of functions that are helpful when driving on rough road conditions, such as TCS-terrain (Traction Control System), differential locks, axle load distribution, axle lift, Robson-drive and sanding. In order to further the interaction between the driver and the functions as well as the functions themselves, Volvo 3P, a company within the Volvo Group, needs to know how and in what situations the functions are used. The purpose of this project is therefore to identify and map out the usage of the above mentioned functions.

A field study consisting of interviews and observations of 13 drivers, mainly in the timber transportation and construction segments, is carried out. The gathered data is compiled and presented in the form of user scenarios. A user scenario template, newly created by Volvo 3P, is evaluated and modified to give a better representation of actual usage of the functions.

The study shows that the drivers mostly try to use the functions in a preventive way. How each function is used is not dictated by driver characteristics but depends on the segment, situation and the truck’s axle configuration.

SAMMANFATTNING

Lastbilar tillverkade av Volvo Trucks kan vara utrustade med ett antal funktioner som underlättar körningen vid sämre väglag. Bland dessa finns terräng-TCS (Traction Control System), differentialspärrar, viktfördelare, boggilyft, Robson-drive och sandspridare. För att Volvo 3P, ett företag inom Volvo Group, ska kunna vidareutveckla interaktionen mellan föraren och funktionerna liksom funktionerna i sig behöver de kunskap om hur och i vilka situationer de används. Syftet med detta projekt är därför att identifiera och kartlägga användningen av dessa funktioner.

En fältstudie bestående av intervjuer och observationer med 13 lastbilsförare, inom främst timmertransport- och anläggningssegmenten, genomförs. Den insamlade informationen sammanställs och presenteras i form av användarscenarion. Till detta används en av Volvo 3P nyligen utformad mall som samtidigt utvärderas och modifieras för att ge en rättvisare bild av funktionernas användning.

Studien visar att förarna till stor del försöker använda funktionerna i förebyggande syfte för att minimera störningar i körningen och slitaget på lastbilen. Hur varje funktion används påverkas inte av förarens egenskaper utan beror istället på vilket segment föraren tillhör, hur situationen ser ut och lastbilens axelkonfiguration.

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1 INTRODUCTION

1.1 Background

Volvo 3P is a company within the Volvo Group. Part of the company's mission is to develop technologies that are used by the group's different truck brands: Volvo, Mack, Renault and UD. CAB division interior is in charge of developing cab interiors for the different models. Within this division, there is a unit called Driver Interface Feature whose role is more specifically to develop the driver environment with respect to the interfaces between the driver and the truck's different functions.

Volvo's trucks can be equipped with a number of functions that are helpful when driving in rough road conditions. Among these are TCS-terrain (Traction Control System), ESP (Electronic Stability Program), differential locks, axle load distribution, axle lift, Robson-drive, sanding and Onspot. What functions are installed depends on what kind of transportation the truck will be used for, the model, axle configuration etc. All functions are not found on all trucks.

In order to develop the truck cab with respect to these functions, that is the interface between the driver and the functions, controls, signals and instrument cluster, Volvo 3P needs to study how and in what situations these functions are used.

Volvo 3P wants to create a database containing descriptions of different functions available to the driver and their usage. These documents are meant to serve as a reference during future development processes. To this aim a template has newly been created. The goal is to have a working template that can be applied to any type of function. While this study deals with a specific category of functions used to help driving in rough road conditions, it is used as an opportunity to test and evaluate the newly created template.

1.2 Aim and purpose

The purpose of this project is to conduct a field study and to identify and map out the usage of the above mentioned functions. Interviews with drivers and field observations are conducted in order to get a complete picture of what needs these functions fulfill and how the drivers interact with them.

The central question is thus: how and in what situations are the different help functions used? The study will also seek to answer the following questions: what causes the usage of a specific function? Are some functions used in combination with others? How does planned and actual usage differ? What functions are used most frequently and what functions are most important to develop? How can the interface to the functions be improved?

The results are presented in the form of function description documents including user scenarios. To this aim, the current template is evaluated and modified to give a better representation of actual usage.

1.3 Delimitations

This project is limited to the study of the following functions: TCS-terrain (Traction Control System), ESP (Electronic Stability Program), differential locks, axle load distribution, axle lift, Robson-drive, sanding and Onspot. Which of these functions will be studied in detail is decided by what information can be gathered from the field study i.e. what functions the drivers currently use or have previous experience of. The studied drivers work mainly in two different sectors: the timber transport segment and the construction segment.

2 FRAME OF REFERENCE

To better understand the context within which this study was made, a description of the truck drivers' working conditions is given. The characteristics of the trucks encountered in the study are then presented, followed by a description of the studied functions. The use of scenarios in design is also explained.

2.1 Description of the truck drivers' working conditions

The results in this report are based on interviews with and observations of truck drivers from mainly two different segments: the timber transport segment and the construction segment.

Drivers in the timber segment load timber (Figure 2-1) in the forests and transport it to saw mills or paper mills to be processed. A large portion of their driving is done on forest roads that can be very narrow. One tour, including driving to the forest to collect timber, transporting it to the mill and unloading can take anywhere between 1 and 2 hours. They often work long hours and can do 5 - 10 tours in one working day.

Figure 2-1: using the crane to load timber

The conditions on forest roads are not always optimal. During the summer, roads are mostly good but from autumn to spring conditions can be quite severe. Rain and mud can make roads both slippery and uneven. Snow and ice in the winter can have the same effect and it is often the worst season. In severe conditions, trucks sometimes get stuck. Drivers in the timber segment work alone most of the time and there might not be any other drivers in the same area. Without any help and with the roads being so narrow, it can be quite difficult and time-consuming to get loose.

Most of the time, however, they drive in known areas and are aware of which sections of the roads can be problematic. Drivers also have good communication between them and can warn each other of risky places.

Because the consequences of getting stuck can be so serious, with time loss and possible damage to the truck, drivers try to be as cautious and foreseeing as possible. They use help functions in a preventive way. Conditions on main roads are not as often as bad, although during the winter, roads can sometimes be a little slippery because of ice and snow.

The main task for drivers working in the construction segment is to transport for example soil, dirt and gravel between landfills (Figure 2-2) and construction sites. They drive back and forth many times per day and one tour can take between 30 minutes and 1 hour, which adds up to 10 to 20 tours per day. The landfills and construction sites are not especially big and loading and unloading is done rather quickly. Therefore, only a small portion of the time is spent at these sites while most time is spent driving on paved roads. The terrain on landfills and construction sites is often quite bad, regardless of season. The surface can for example consist of gravel of different size, soil, mud, snow or ice. Sometimes it is firm and dense and easy to drive on but most of the time it is slippery or soft, which can be made even worse by rain. In either case the surface can be more or less uneven. These conditions can make driving difficult and there is a risk of getting stuck or damaging the surface, which makes driving even more difficult at the next passing. That is why drivers usually try to be cautious and use help functions more often than actually necessary, to be on the safe side. Fortunately there are often other drivers driving back and forth to the same place and bulldozers that can help if needed. On main roads, where they spend most of their time, conditions are usually good and only snow or ice can make the situation a little more difficult.

Figure 2-2: dumping dirt at a landfill

2.2 Description of truck characteristics

This section describes the relevant characteristics of the different types of trucks mentioned in this report, as well as the design of the function controls and the dashboard.

2.2.1 Tractor trucks and rigid trucks

There are two main types of trucks: tractor trucks and rigid trucks. Tractor trucks are common in long-haul road transports and are used to haul semi-trailers. Semi-trailers do not have a front axle and their front-end weight has to be supported by the tractor unit. Rigid trucks have longer bodies and take load directly on the truck bed. In this study, only rigid trucks have been observed. The trucks can be configured to carry different kinds of loads such as timber or gravel (Figure 2-3). Rigid trucks can also pull trailers that are supported by both front and rear axles. All timber transporters have a trailer and it is sometimes also used in the construction segment.

Figure 2-3: a truck for timber transportation and a dump truck

2.2.2 Axle configuration

Trucks can vary in several ways in their axle configuration. Both the total number of axles and the number of drive axles can vary. There may also be a difference in how many axles are steered and whether an axle can be lifted.

The common notation to describe the axle configuration is AxB, where A is the total number of wheels and B is the number of drive wheels. For example, a 6x4 truck has a total of 6 wheels (3 axles) and 4 of those are drive wheels (2 drive axles).

Figure 2-4 shows the common configurations that are mentioned in this report. A 6x4 configuration is commonly called “tandem” and an 8x4 configuration is commonly called “tridem”.

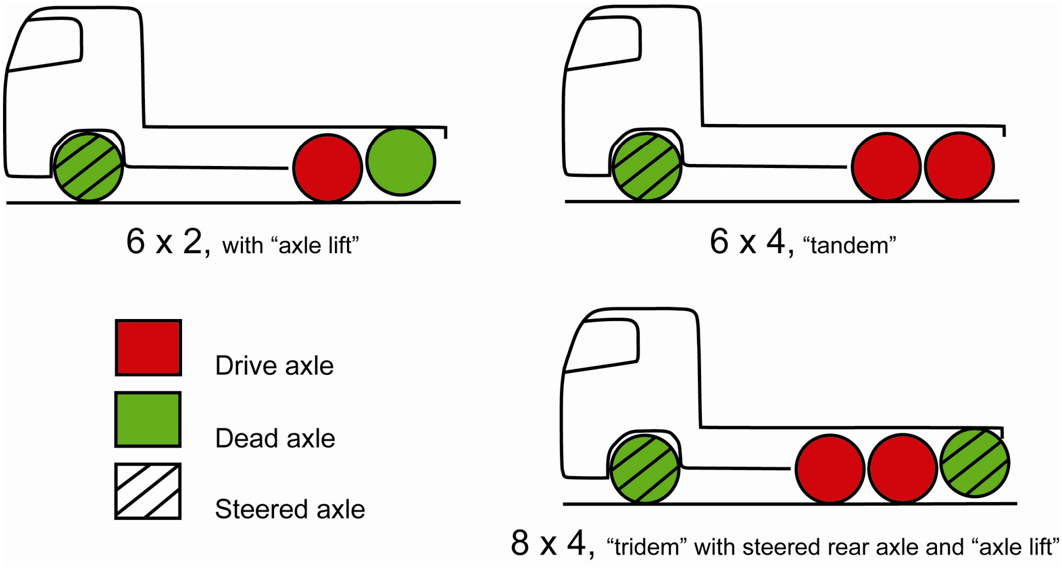


Figure 2-4: different axle configurations

2.2.3 Dashboard design

The controls for the different functions and the visual information describing function states are located on the dashboard. Although some information is also conveyed with auditory signals, most of the information is visual and presented in the instrument cluster which is placed in front of the driver behind the steering wheel (Figure 2-5, above). The visual information consists mostly of symbols of different kinds and colors. The controls for the observed functions do not have fixed positions but can be placed freely within certain areas. They are most commonly found in two areas on the right hand side of the dashboard (Figure 2-5, below).

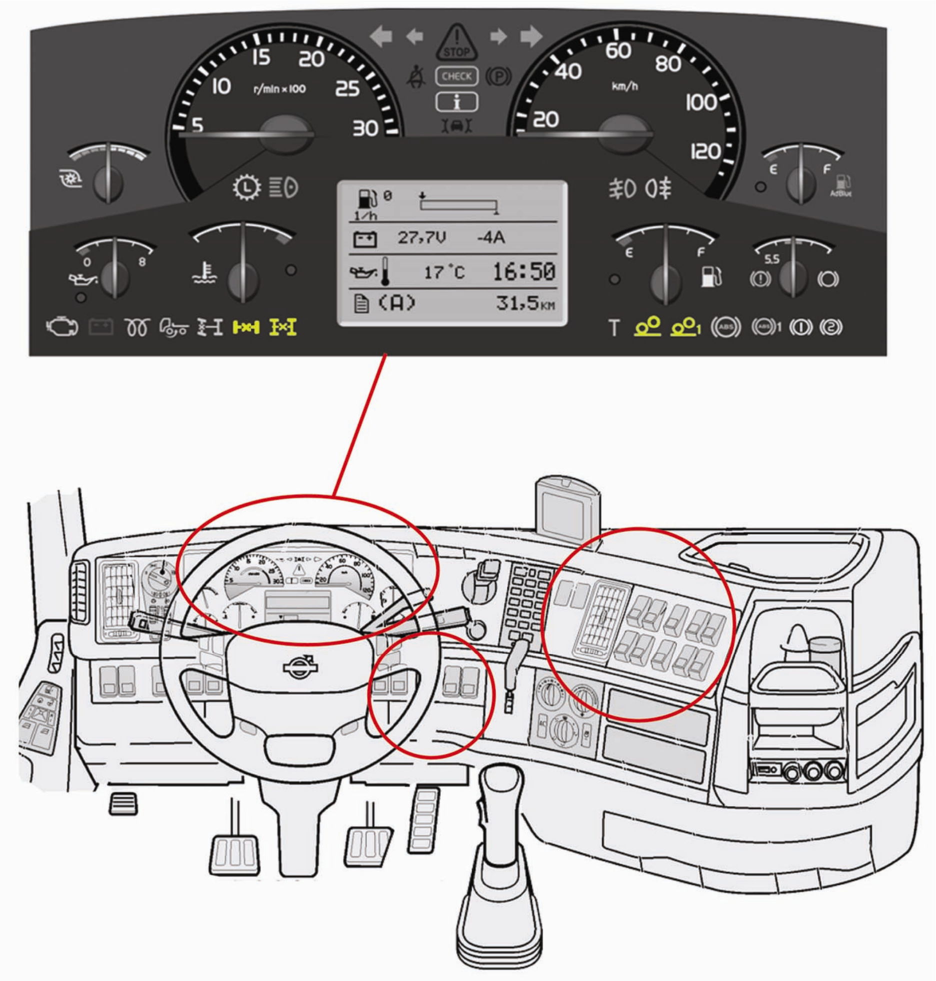


Figure 2-5: instrument cluster (above) and dashboard (below). Adapted from Driver's Manual FM/FH (Volvo Trucks 1998).

2.2.4 Controls

The controls take the form of buttons of different kinds with symbols that are usually designed to resemble the function they belong to. There are three different types of buttons. One is constructed so that it can be put in two or three fixed positions (Figure 2-6, left). Another is designed with a spring so that if you push it to its lower position and release the button it will go back to its higher position (Figure 2-6, middle). The third button is constructed so that it can be put in three fixed positions. It also has a safety lock and requires two fingers to be pushed down to its lower position (Figure 2-6, right).

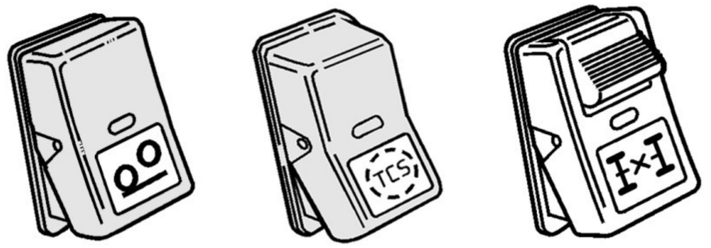


Figure 2-6: three different kinds of buttons for controlling the functions. Adapted from Driver's Manual FM/FH (Volvo Trucks 1998).

2.3 Description of the studied help functions

This section gives an overview of the different functions that are studied in this report. The function descriptions are also found in section 5 where the usage of each function is described in detail.

2.3.1 TCS-terrain (Traction Control System)

The Traction Control System or anti spin system distributes traction among the drive wheels. Whenever spin occurs the engine’s torque is decreased. At speeds below 40 km/h TCS also functions as an automatic differential brake (Volvo Trucks, 1998). If a drive wheel on one side starts spinning, the brake on this wheel is engaged and traction is distributed to the other drive wheels.

The driver can activate the TCS-terrain function which allows for more wheel spin when driving on difficult terrain.

2.3.2 Differential locks

A differential unit is a mechanism that compensates for the difference in rotation speed between the drive wheels (Bosch, 1996). Torque is distributed equally among the drive wheels, in effect limiting the effective torque to the greatest amount that will not cause one of the wheels to spin. When excess torque is applied after a wheel has started to spin, this wheel just spins faster while the other wheel on the same axle does not rotate at all.

There is a differential between the two wheels of a driving axle. A differential lock allows the two wheels on one axle to behave as if they were on a single shaft by restricting them to the same speed of rotation. This may increase traction as one wheel will not start spinning as long as the other wheel still has grip.

If there are two drive axles, there is also a central differential that distributes torque between the two axles. With the central differential locked, the same amount of power is transmitted to the front and rear axles regardless of traction conditions. Figure 2-7 shows the principle layout of differential locks on different axle configurations.

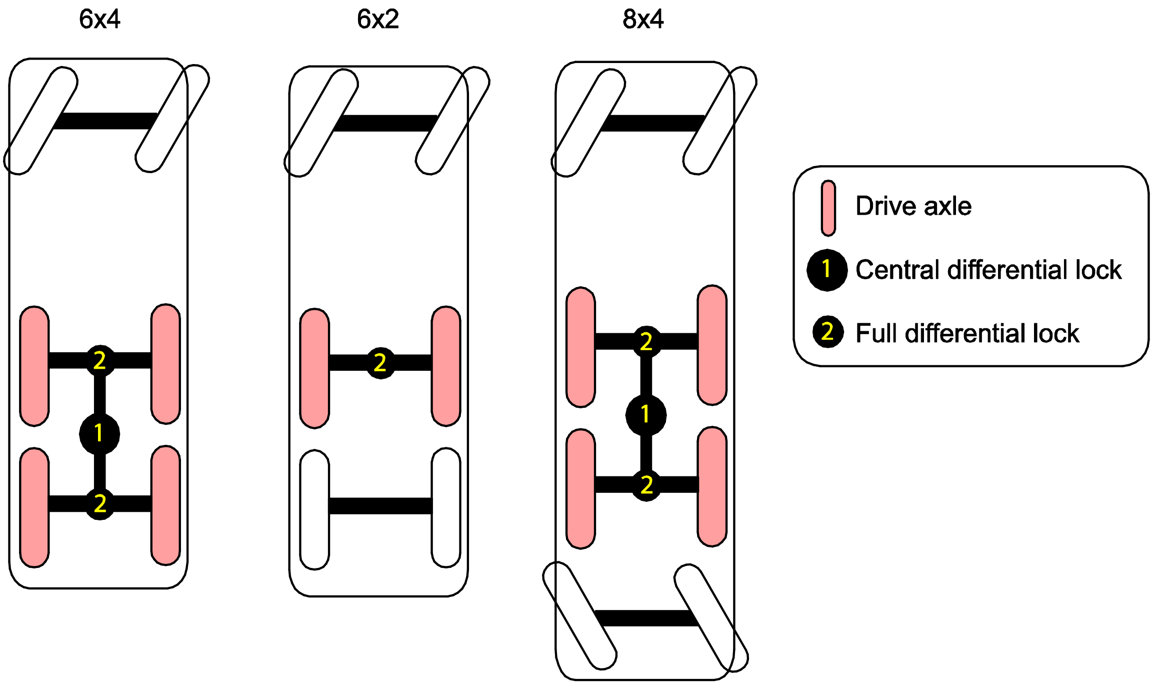


Figure 2-7: differential locks on different axle configurations

2.3.3 Axle load distribution

Axle load distribution is a function that enables the driver to control how the load is distributed between the rear axles. When the function is activated some of the load is transferred so that the drive axle (the front drive axle if there are two drive axles) carries most of the weight. The function is controlled by the air suspension (Electronically Controlled Suspension). Upon activation, the pressure in the air bellows of the rear axle is decreased while that of the front axle is increased.

2.3.4 Axle lift

Depending on a truck's axle configuration, one of the axles may be a "dead axle" which is free-rotating and thus not part of the driveline. For example in a 6x2 configuration there are two axles at the rear of the truck. Only one of these is driven and delivers traction. The other is a dead axle.

If the truck is equipped with an axle lift, the dead axle can be lifted from the ground on command as long as this does not result in axle load limits being exceeded.

2.3.5 Robson-drive

Robson drive is a function that makes it possible to temporarily give a 6x2 vehicle driving characteristics similar to those of a 6x4 vehicle. The system is comprised of a set of cog-wheels that can be lowered between the drive wheels and the wheels of a dead axle. This way traction power is transferred between the drive axle and the dead axle.

2.3.6 Sanding

When a truck is equipped with a sanding system, sand-filled boxes are mounted next to drive wheels on both sides of the vehicle. The system is activated on command whereby sand is spread onto or in front of the tires. Depending on the configuration, a single button activates sand spreaders on both sides or the spreaders can be activated independently using two separate buttons.

2.4 Using scenarios in design

Using scenarios in design is one way to make the design and development processes more user-oriented. A scenario is a description of typical and significant user activities (Carroll, 2000). The scenario typically contains a description of the user(s), what task they perform or want to perform, assumptions about the environment and the sequence of actions and events relevant to the scenario (Stanton, 2005).

Scenarios can be used at all stages of the development process and have been applied to a number of domains ranging from systems design to traditional products (Stanton, 2005; Cross, 2008).

Scenarios are normally based on observation of similar scenarios if the product or design concept already exists; in other cases they can be "made-up" using creative methods. Potential scenarios can also be created using other forms of data gathering such as interviews and questionnaires.

They are used to model the "needs and preferences, wishes and requirements" of users so as to provide guidelines for the design process (Cross, 2008). Beyond this, scenario analysis is a very flexible method as, once enough information has been gathered, any number of scenarios can be created and evaluated. Putting new design concepts into a scenario is a quick way to evaluate that concept. The scenario can also be used as a communication tool between designers or development teams (Stanton, 2005)

Scenarios may be presented in the form of narrative text or in a number of other ways, including story-boards of annotated pictures or drawings, video-mock-ups etc. They can also include different levels of detail, from high-level descriptions of overall motives to precise descriptions of the system's functionality (Carroll, 1997).

3 METHODS

In this section, the methods used to collect data during the course of the project, namely interviews and observation, are described. The method used to analyze collected data is also presented.

3.1 Interviews

To gather information about a person's opinions and what she thinks about various subjects, an interview is the most basic method. With an interview it is possible to gain understanding of how the person reasons as well as knowledge of her feelings, values and experiences. An interview is conducted with two or more people meeting and the interviewer (or the interviewers) stimulates the interviewee to talk or answer questions. The gathered data is mostly subjective. (Osvalder and Ulfvengren, 2008)

An interview can greatly vary in length, from 5 to 20 minutes for shorter interviews to 60 minutes or more for longer interviews. During shorter interviews, only facts about a specific topic can be covered and the depth is limited. With a longer interview, more topics can be covered and both the interviewer and the respondent can chose what area to expand on. (Kylén, 2004)

There are three types of interviews: structured, semi-structured and unstructured interviews. Structured interviews are best if the goal is to gather quantitative data. Conversely, an unstructured interview is best when qualitative data is sought. The choice of interview type is dictated by what kind of information is meaningful in the context.

An unstructured interview is useful in studies where the interviewer has limited knowledge of the topic. The interviewer prepares a number of broad areas to be covered. The interviewee is first asked to talk freely before the conversation is geared towards what the respondent feels is most important. As there are no fixed sets of answers but only open questions, it is possible to gain in-depth knowledge of what the respondent thinks. The drawback is that it can be difficult to compile the data and compare responses.

A structured interview has the advantage that it gives mostly quantitative data which is easier to analyze. However, a good knowledge of the subject is required to formulate the right questions. The interviewer has a preset list of questions that are asked in a specific order and have a set of fixed answer alternatives. This is suitable for shorter interviews with many respondents

A semi-structured interview is a compromise between the structured and the unstructured interview. The interviewer has a list of topics to cover but can freely choose in which order to ask questions. There are both open-ended and close-ended questions, so that the responses can be systematically analyzed while still giving the respondent ways to influence the course of the interview. It gives both qualitative and quantitative data.

It is important to test interview templates and questions early on to make sure they give the right kind of information. Both the situation in which the interview is conducted and the interviewer's characteristic can influence the results. For example, responses might be different depending on the interviewer’s level of education and experience, whether it is a man or a woman, his or her age, personality etc.

Interviews offer the advantage that it is possible to choose a representative population sample to interview. On the other hand it is often difficult to draw definitive conclusions about a target group’s attitudes. (Osvalder and Ulfvengren, 2008 and Kylén, 2004)

The gathered data can be documented either by taking notes or by recording the interview. If the interview is recorded, it has to be transcribed. The advantage of recording is that it is possible to go back to the record and check what the respondent really is saying. (Kylén, 2004)

3.2 Observations

Observation is the basic method to get a description of actual events. It can be used to gather information about user situations. Both the way the user handles a product or machine and the problems that might arise are of interest.

An observation can be done either in a real-life setting or in an artificial setting. Observations can provide information about things the user is not aware of and are therefore hard to identify in an interview. Feelings, desires and attitudes are not shown in observations. The underlying reasons that lead to the observed behavior can be hard to establish, which makes interpretation of the gathered data difficult. Cognitive processes are not shown. For these reasons it is recommended that observations be done in the early stages of a study, to be later complemented by interviews or questionnaires. (Osvalder and Ulfvengren, 2008)

An observation can be either systematic or unsystematic. An unsystematic observation means that no specific information is sought and everything is of interest. This kind of observation is used in the early stages of a study to gather information. A systematic observation is conducted when it is known in advance what events and behaviors are of interest.

Observations can also be either direct or indirect. In the former case, the observer is included in the situation and registers events with her own sense. It is important to try to minimize the observer’s influence on the situation. In indirect observations, the situation is recorded with a video camera and the observer is not physically present.

The information gathered can be both qualitative and quantitative. An example of quantitative data is the number of times a specific task is carried out in a certain period of time. Most information is qualitative and provides an understanding and explanation for how users act in a certain way.

According to Kylén (2004), when interpreting the results of an observation, it is important to take into account that the mere fact of being observed can influence a person’s behavior.

3.3 Analysis of data

Kylén (2004) presents one way to process and analyze gathered data. The data can be placed in a matrix which is usually created with respondents in columns, each question being a row.

The data is summarized in the matrix cells with text or images. The matrix can be scaled up on a large sheet of paper to make it easier to get an overview. If the number of cells is too large it becomes hard to get a good grasp of the information. Information from each row and column can be summarized. To do this, the number of cells should be limited to a maximum of 50-70. If clear links and relationships are to be established then the number of cells should be even smaller, around 20. If needed, a large matrix can be broken down into several smaller parts.

For example, if four respondents give answers to five different questions, the data can be compiled in a matrix like in Table 3-1. For each question, the answers from the different respondents can be compared and analyzed, resulting in a summary of the answers in the last column. A summary of the answers to all questions from one respondent can be written in the last row.

Table 3-1: matrix for analyzing gathered data

	Respondent A	Respondent B	Respondent C	Respondent D	
Question 1	xxxxx	xxxxx	xxxxx	xxxxx	Summary question 1
Question 2	xxxxx	xxxxx	xxxxx	xxxxx	Summary question 2
Question 3	xxxxx	xxxxx	xxxxx	xxxxx	Summary question 3
Question 4	xxxxx	xxxxx	xxxxx	xxxxx	Summary question 4
Question 5	xxxxx	xxxxx	xxxxx	xxxxx	Summary question 5
	Summary respondent A	Summary respondent B	Summary respondent C	Summary respondent D	

4 FIELD STUDY

The results presented in this report are based on information gathered in a field study consisting of interviews with truck drivers carried out in the truck cab while driving and observation of their work. The process, from the creation of interview questions to the analysis of gathered data, is here described.

4.1 Interview template

To prepare for the interviews the first step was to create the questions. As a base for this Volvo 3P's current user scenario template (appendix A) was used. During this process it was established that the information considered necessary to be gathered could be divided into a number of categories. These were:

- Background information on the driver and the truck
- Functions frequency of use and how they work
- Situations the functions were used in
- Handling of the functions
- Controls and symbols design and communication

The information sought after was mostly qualitative. The semi structured type of interview was chosen. In each category broader questions were supplemented with questions that little by little focused on more specific and detailed information.

The complete set of questions that was prepared prior to the first interview can be found in appendix C.

4.2 Interview participants

The results of this study are based on 13 interviews with drivers in different segments with trucks of varying types. The interviews were carried out between 25 March 2010 and 23 April 2010, that is to say at the end of winter and in the early spring. The weather conditions during the period ranged from sunshine to rain.

The number of interviews to hold and the specific drivers to interview were not set in advance, although a goal was set at around 20 interviews. Contacts were first taken with timber transporters who had previously taken part in studies made by Volvo 3P. The first interviews were made with a couple of these drivers. Based on the information gathered from those interviews it was established that timber transport and heavy-duty trucks for construction work would be the primary target segments of the study, simply because the functions of interest were most widely used in these segments. Contacts were thereafter primarily sought with transportation companies operating in those two segments.

The final composition of the group of interviewed drivers was in part the result of chance. Most of the contacted transportation companies were accommodating and had a positive view of the study. They responded that they would consider taking part but it was not always possible to meet the drivers due to scheduling difficulties. Another aspect was that they often did not know what route they were going to take on a particular day since routes could often be decided at the last minute. That made planning of the research more difficult. Additionally, because of thawing, trucks were not allowed to drive on some forest roads in certain periods and were therefore not possible to follow.

The 13 interviewed truck drivers that this study is based on all differ in many ways. Among the characteristics that could vary were: which segment they belonged to, what kind of truck they drove, how many years of experience they had and whether they were salaried drivers or operated their own company, owning their truck.

Table 4-1 shows how the different characteristics are distributed.

Table 4-1: Characteristics of interview participants

Interviewee	Segment	Axle configuration	Gear box	Experience	Owner / employee
IP 1	Timber	6x4	Manual	10	Owner
IP 2	Timber	6x4	Manual	50	Owner
IP 3	Timber	6x4	Manual	14	Employee
IP 4	Timber	6x4	iShift	5	Employee
IP 5	Tank	6x2	iShift	15	Employee
IP 6	Construction	6x4	Manual	8	Owner
IP 7	Construction	8x4	Manual	25	Owner
IP 8	Construction	6x2	Manual	36	Owner
IP 9	Construction	8x4	iShift	12	Employee
IP 10	Construction	6x4	iShift	10	Owner
IP 11	Construction	8x4	Manual	27	Employee
IP 12	Construction	6x2	iShift	20	Employee
IP 13	Construction	8x4	Manual	36	Owner

To summarize, when it comes to segments there were:

- 4 timber transportation trucks
- 1 tank truck
- 8 construction trucks

Looking at the axle configuration shows that:

- 3 trucks were 6x2
- 6 trucks were 6x4 (tandem)
- 4 trucks were 8x4 (tridem)

Difference in gearbox configuration shows that:

- 8 had manual
- 5 had iShift

The experience ranged between 5 – 50 years.

The average experience was: 20.62 years.

The following functions were to be studied: ESP, TCS, differential locks, axle load distribution, axle lift, sanding and onspot. All trucks were equipped with TCS, differential locks and either axle load distribution or axle lift (or both) depending on their axle configuration. Five trucks had sanding installed and only one had Robson drive, although several others had previous experience with the function.

Onspot was dropped from the study because none of the drivers had the function installed on their current truck. ESP was similarly dropped because none of the drivers had anything to say about that function. In many cases they were unaware if their truck was equipped with ESP or not. Those who did know and had the function had no particular opinion to express since the function is active at all times and cannot be controlled by the driver.

4.3 Carrying out the interviews

All prepared questions were not asked to all drivers and the questions were not always asked in the exact same order. The semi-structured form of interview meant that the interviewee’s thoughts and current mind set dictated the interview process to a great extent. As all interviews were carried out inside the truck cab while driving, the situations that arose on the road also greatly influenced the order of the topics covered.

There were two factors that mainly contributed to the amount of information that could be extracted from the interviews: what functions the driver’s truck was equipped with as well as the driver’s experience in using them and the length of the interview itself which varied from 30 to 150 minutes.

To make documentation of the interview easier the conversations were recorded, with the interviewee’s permission, on a portable sound recorder.

4.4 Observations

At the beginning of the project, knowledge of the truck drivers’ real working situation was limited. Therefore the observations were done with an open mind with the purpose to gather as much information as possible. The main reason was to gain an understanding of their work and the causes of their actions. Therefore mostly qualitative information was of interest.

Since the interviews took place inside the truck cab while driving, observations and interviews were carried out concurrently. To be able to go back and analyze actions in more detail at a later stage, a video camera was also used to record the drivers’ actions and handling of different functions in specific situations that arose during the course of the interviews.

As much as circumstances allowed, the situations were also documented by taking pictures of the terrain.

4.5 Analysis of data

The interviews were recorded using a portable sound recorder and each interview was later transcribed, which resulted in a large amount of data. This data was compiled using matrices. For each of the studied functions, a matrix was created. Each interviewed driver made up one column while the different categories linked to the user scenario template were placed in rows (goals, situation, time aspects, design, handling, other). The interview responses were broken down into single statements that were placed in the cell corresponding to the respondent and category.

Table 4-2: excerpt from a matrix containing interview data

Differential locks	Respondent 1	Respondent 2
Underlying reasons / goals	As a precaution. You don't want to fail at the first try, if you start spinning, you dig tracks and it's going to be even harder next time.	
Situation		I turn it on as soon as I drive in to a construction site if the terrain is uneven.
Time aspects	I use the diff locks a lot, very often. As a rule, it's the first thing I do, and 99% of times, it's enough.	I use them a lot, whenever there's a little risk. Several times every day. Why would you take a chance?
Design		
Handling	I usually keep the central diff lock on until I'm out on the road. It can be engaged while driving, but if your wheels are spinning it's bad for the axle. That's why you need to turn it on before it starts spinning.	The central lock is enough in most situations.
Improvements		
Other		

Table 4-2 shows some responses concerning the central differential lock from two respondents. These responses, along with others in the same line, allowed us to come to the conclusion that the central differential lock is used as a precaution many times every day. For drivers in the construction segment, it's usually the first function to be used and most of the time, no other measures are needed.

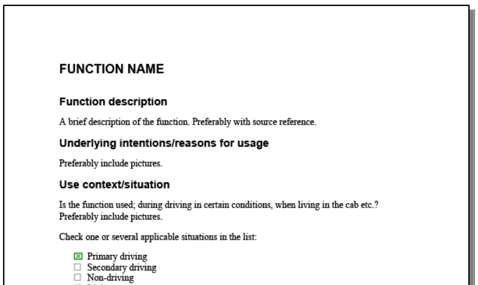
5 RESULTS

The results from the field study are presented here. First, the process that led to the modification of the user scenario template is explained. The usage of the different help functions are then introduced with two broad scenarios, before the usage of each function is described in detail.

5.1 Development of a user scenario template

Volvo 3P wants to be able to document the usage of different functions in a consistent way. The documents, which are meant to serve as reference during future development processes, should include a description of the function itself as well as descriptions of the key situations in which it is used, how it is handled and so on.

The results from the field study are here used to test and evaluate Volvo 3P's newly created template. The modifications that are proposed are based on the information that has been gathered on a specific category of functions. Their application on other types of functions should be further tested.



FUNCTION NAME

Function description

A brief description of the function. Preferably with source reference.

Underlying intentions/reasons for usage

Preferably include pictures.

Use context/situation

Is the function used; during driving in certain conditions, when living in the cab etc.?
Preferably include pictures.

Check one or several applicable situations in the list:

- ☒ Primary driving
- ☐ Secondary driving
- ☐ Non-driving
- ☐ Living: passenger seat
- ☐ Living: bunk area
- ☐ Working

Frequency of use:

- ☒ Many times a day
- ☐ Daily
- ☐ At certain conditions, e.g:

For how long time in average is the function enabled/activated?

Used in combination/sequence with other functions:

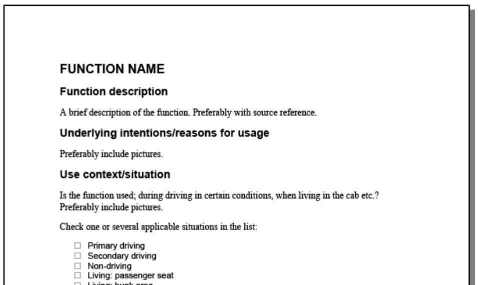
Vehicle type / segment / markets / variants / superstructures

Applicable to…

User scenarios (user action related to existing HMI)

In the User scenarios *user actions* and *vehicle actions* are identified and connected to usage situations. The vehicle actions are divided into *function actions* and *additional feedback* (vehicle actions that exists solely for the user's understanding).

Figure 5-1: current template



FUNCTION NAME

Function description

A brief description of the function. Preferably with source reference.

Underlying intentions/reasons for usage

Preferably include pictures.

Use context/situation

Is the function used; during driving in certain conditions, when living in the cab etc.?
Preferably include pictures.

Check one or several applicable situations in the list:

- ☐ Primary driving
- ☐ Secondary driving
- ☐ Non-driving
- ☐ Living: passenger seat
- ☐ Living: bunk area
- ☐ Working

Frequency of use:

- ☐ Many times a day (every day)
- ☐ Many time a day (some days)
- ☐ Daily
- ☐ Sometimes
- ☐ Rarely
- ☐ Never

Seasonal variation:

- ☐ Yes
- ☐ No

Duration of use:

- ☐ Seconds
- ☐ 1 – 5 minutes
- ☐ 5 – 30 minutes
- ☐ ≥ 30 minutes

Usage in combination or sequence with other functions:

Vehicle type / segment / markets / variants / superstructures

Applicable to…

Figure 5-2: proposed template

The current template (Figure 5-1) can be found in appendix A and the modified version (Figure 5-2) in appendix B.

The first step in the process was to attempt to fill out, for each of the studied functions, the template in its current form. The goal in mind was to see if the questions in the template could be answered and if there was relevant data from the field study that did not fit into it.

It was quickly established that giving general answers was a difficult task. Although the information provided by the interviewed truck drivers was generally consistent, there was often a need to categorize answers by segment, domain of application or axle configuration. The result is that it can seem like the function description documents are a collection of special cases, rather than an analysis. However, this is a fair representation of the conditions encountered in the field.

When categorization was needed, the clearest and most legible way to compile the answers was to create tables. Many times only two categories were necessary, making for a simple table. In some cases, two dimensions had to be taken into account. For instance, there are two main domains of application of the axle load distribution function: it can be used to gain traction or it can be used to make the truck more maneuverable. The frequency at which the function is used also depends on the truck's axle configuration. This resulted in a 2x3 matrix.

Some of the questions in the template were modified. In the case of close-ended questions with fixed answers, different answer alternatives were provided to better cover the situations encountered.

5.1.1 Frequency of use

Data gathered during interviews and observations suggested that if a function is needed on a particular day, odds are that this function will be used many times during the course of that day. This is explained by the fact that drivers encounter the same situations over and over. In the case of construction sites, they drive back and forth between the site and landfills or gravel pits and quarries. Timber transporters might not drive on the same spot twice in a day but they do load timbers several times and always need to drive on forest roads. Their routes are concentrated within a limited geographic area where weather and road conditions are likely to be similar throughout the day. Of course the need to use a particular function can vary from day to day according to weather.

It was noted that in some cases the use of a function was more or less constant throughout the year while in others usage could vary greatly from season to season. For example, a function might be used many times a day in the winter, but only occasionally during the summer months.

The current and proposed alternatives for frequency of use are as follows:

Current alternative

Frequency of use:
- ☐ Many times a day
- ☐ Daily
- ☐ At certain conditions, e.g:

Proposed alternative

Frequency of use:
- ☐ Many times a day (every day)
- ☐ Many time a day (some days)
- ☐ Daily
- ☐ Sometimes
- ☐ Rarely
- ☐ Never

Seasonal variation:
- ☐ Yes
- ☐ No

The alternative “daily” was not used for the functions studied in this report but it could be useful when studying other types of functions. The distinction between “sometimes” and “rarely” is not clear because it is difficult to get accurate statistics on how often a function is used. The two alternatives are here used to distinguish between cases when a driver uses a function from time to time, say every week, every other week or so, and cases when the driver says there are situations in which he has used the function but doesn’t necessarily recall the last time it occurred.

5.1.2 Duration of use

To get a good overview fixed alternatives were provided for the question of duration of use as well. The time intervals: “seconds”, “1-5 minutes”, “5-30 minutes” and “≥ 30 minutes” are approximate and the limits should not be interpreted as absolute. Naturally drivers did not provide absolute values for how long a function was used. The function is used in a specific situation, for however long the situation requires. However durations could be compared and it was clear that some functions can be used for very short lapses of time in some situations whereas in other situations a function might be used for an extended period of time. By providing numerical alternatives, a quicker assessment can be made and this gives a general idea of how long the function can be used.

An example of the proposed alternatives with two different situation categories follows:

Empty load	**Full load**
☐ Seconds ☐ 1 – 5 minutes ☒ 5 – 30 minutes ☒ ≥ 30 minutes	☒ Seconds ☐ 1 – 5 minutes ☐ 5 – 30 minutes ☐ ≥ 30 minutes

5.1.3 Usage in combination or sequence with other functions

Most of the functions studied in this report could conceivably be used in combination with every other function. At first a matrix was made trying to detail in what situations the different combinations could be used. The matrix was too big however, and did not provide a good overview. Instead, only key situations with likely combinations are described.

5.1.4 User scenarios

For every function there are a number of different use cases and the different situations have to be described to give a complete picture of how the function is used. A requirement from Volvo 3P was that “user actions” and “vehicle actions”, including “function actions” and “additional feedback” were to be included in the user scenarios. After a short background description of the scenario, actions and handling were compiled in table form, inspired by tabulated hierarchical task analysis (Stanton, 2005). Activities related to the functions are written in bold and all actions related to such an activity are placed in chronological order in subsequent rows at a lower level of indentation. Every action is marked with:

- U - user actions
- F - function actions
- A - additional feedback

Other activities that are relevant to the scenario but not linked to the functions are written in normal font.

Table 5-1 is an example from a user scenario describing the use of the TCS-terrain function.

Table 5-1: example of a table used to describe a user scenario

The driver decides to activate TCS-terrain as a precaution		
	The driver presses the TCS-terrain button	U
	The indicator lamp in the TCS-terrain button is lit	A
	TCS-terrain is activated	F
The driver accelerates		
The hill is climbed without TCS intervening		
The driver deactivates TCS-terrain		
	The driver presses the TCS-terrain button	U
	The indicator lamp in the TCS-terrain button is turned off	A
	TCS-terrain is deactivated	F

5.1.5 Risks

Where appropriate, a general description of the risks related to a specific function was included. The questions from the original template were kept with the distinction that questions related to activation and deactivation of the functions were separated. The same applies to the question of time-criticality. The responses could be very different for activation and deactivation.

5.2 General results

It was clear from the data gathered during interviews and observations that the truck drivers take very good care of their trucks and are cautious to avoid any risk of damages. Imprudent driving can lead to damages which can be very costly to repair. Getting stuck can also cause lower income because of time loss. Timber transporters are especially sensitive to this since they are most often working in more isolated environments and the need to use a tow truck is very time consuming. Therefore help functions are, as a rule, activated in advance and used as a preventive measure. “There’s no sense in taking a chance”, “you want to be sure you’re going to make it”, “it’s a safety” were common comments. In most cases, they can see on the terrain ahead what function or functions that is necessary so use.

While still exercising precaution, timber transporters sometimes have to drive in very bad conditions. There are often no alternative routes and no other vehicles nearby to help. By contrast, drivers on construction sites know that if they will get stuck, there is almost always the possibility of getting towed by another truck or bulldozer or even having an excavation machine give a little push on the truck.

Within the pool of interviewed drivers, no significant differences in attitudes were discovered based on differences in age, years of experience or ownership of the truck. Instead, the use of the different help functions was mainly decided by segment (timber or construction) and axle configuration.

Most drivers also agree that no matter how much help these functions can give when driving in rough conditions, the quality of their tires is a very important factor. When they use functions to avoid spinning or lift an axle for example, the wear on tires is reduced and thereby they last longer.

A common trait was that drivers value a sense of control and want to feel like they are in charge over the vehicle and the situation. For this reason, automatically activated functions are generally not popular. “Make it simple” was a recurring comment. The general conclusion from the field study is however that drivers are, on the whole, happy with both the functions themselves and the design of the controls. TCS was the only function that was clearly unpopular with many, if not most, drivers. Especially timber transporters do not see the point in having TCS since it can easily lead to them not being able to climb a hill. They feel it would be better for them if it was not installed at all, even though they recognize that the function might be useful for drivers who exclusively drive on paved roads.

Since the drivers activate the functions deliberately for a specific purpose and most often as a preventive measure they are usually aware of what state the functions are in. However there are times when the driver may be distracted or for some other reason not sure of what functions are active at the moment. In these situations in particular, they believe it is very important to have good and quickly legible information as to the state of the functions. Having ready access to this information is an important safety feature.

The design of the buttons received positive reviews. It should be noted that a majority of the interviewed drivers had driven Volvo trucks for many years and thereby were accustomed to the layout. The size of the buttons is appropriate and they give good feedback with a distinctive click when pressed.

The fact that buttons can be placed freely on the dashboard is popular. Similar functions that are often used together can be placed next to each other. An advantage is that the owner of a transportation company can make sure that all trucks in the company have the same function layout, so that if needed, drivers can easily switch trucks and not have to think about where the functions are placed.

5.3 Two broad scenarios including the use of all functions

Two broad scenarios including the use of all functions studied in this report have been created. These serve as an introduction and place the functions in a context. The two scenarios, one set in the timber segment and the other in the construction segment, give a general picture of how the functions can be used. The tables used in these scenarios to describe actions are a simpler variation of those described in section 5.1.4 where actions are not broken down to user actions and vehicle actions.

5.3.1 Scenario 1: timber segment

This scenario takes place during the winter. A timber transporter with a 6x4 truck is driving with an empty load and turns onto a forest road to load timber. The road is plowed but the snow cover is a few centimeters deep. A few hundred meters in comes a sharp turn, closely followed by a steep downward slope. The stack of timber to load is located at the foot of the hill. However the driver keeps going forward until he finds an appropriate spot to make a u-turn. (Figure 5-3)

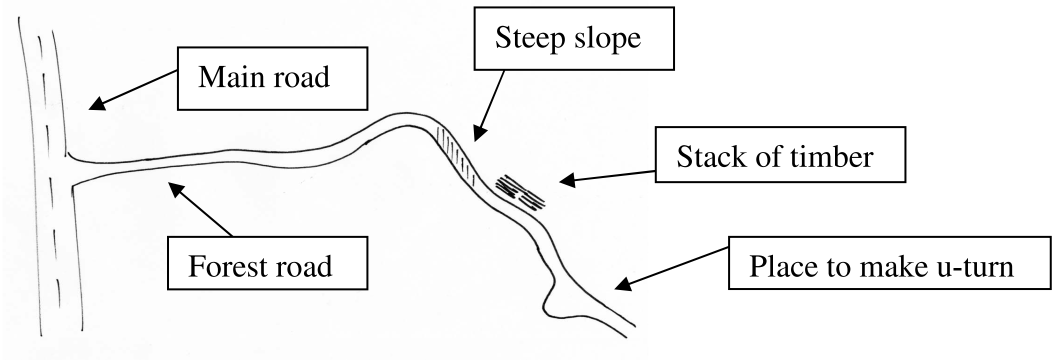


Figure 5-3: an illustration of scenario 1

Figure 5-4: Driving on the forest road

Figure 5-5: finding a place to make a u-turn

The driver turns in to the forest road (Figure 5-4)	
The driver activates the central differential lock	
	As a precaution to minimize spinning
The driver keeps going and reaches the downward slope	
The driver activates the sanding function for 100 m	
	To ensure good traction on the way back up
The driver keeps going until he finds a place to make a u-turn (Figure 5-5)	
The driver activates the axle load distribution function **The driver activates the axle lift on the trailer**	
	To improve maneuverability
The driver makes a u-turn and drives back towards the hill	
The driver activates the full differential locks	

	To make sure the locks are engaged later when driving up the hill
The driver activates the sanding function	
	To ensure that the truck doesn't glide while loading and improve traction at start
The driver stops the truck next to the stack of timber	
The driver deactivates the sanding function	
The driver loads the truck and trailer with timber (Figure 5-6)	
The driver activates the TCS-terrain function	
	To allow for more wheel-spin and avoid loss of engine power on the slope
The driver starts and drives up the hill (Figure 5-7)	
At the crest of the hill and just before turning, the driver deactivates the full differential locks	
	To improve steering and avoid harming axles in sharp turn
The driver turns and keeps driving toward the main road	
The driver drives out on the main road	
The driver deactivates TCS-terrain **The driver deactivates the central differential lock**	
	The functions are not needed when driving on a level paved road

Figure 5-6: loading timber

Figure 5-7: driving up a snowy hill

5.3.2 Scenario 2: construction segment

This scenario takes place in early spring on a construction site. The weather is nice but the terrain is still soft and humid. The 6x2 truck is equipped with Robson-drive. At the start of the scenario the truck is fully loaded with gravel and is about to drive in to the construction site.

The driver turns in to the construction site	
The driver activates Robson-drive	
	To improve traction on the soft terrain and minimize spinning

<table>
<tr><td colspan="2">The driver makes a u-turn and reverses to the unloading site</td></tr>
<tr><td colspan="2">The driver lifts the truck bed and unloads the gravel</td></tr>
<tr><td colspan="2">**The driver activates the full differential lock**</td></tr>
<tr><td></td><td>To improve traction as starting help</td></tr>
<tr><td colspan="2">The driver starts going forward</td></tr>
<tr><td colspan="2">The driver lowers the truck bed</td></tr>
<tr><td colspan="2">The driver drives away from the soft terrain</td></tr>
<tr><td colspan="2">**The driver deactivates the full differential lock**
The drive deactivates Robson-drive</td></tr>
<tr><td></td><td>The functions are not needed when driving on hard terrain</td></tr>
<tr><td colspan="2">**The driver activates the axle lift**</td></tr>
<tr><td></td><td>To improve traction with empty load and minimize wear on tires on paved road</td></tr>
<tr><td colspan="2">The driver drives out of the construction site</td></tr>
</table>

5.4 TCS-terrain (Traction Control System)

5.4.1 Function description

Traction Control System or anti spin system distributes traction among the drive wheels. Whenever spin occurs the engine's torque is decreased. At speeds below 40 km/h TCS also functions as an automatic differential brake. If a drive wheel on one side starts spinning, the brake on this wheel is engaged and traction is distributed to the other drive wheels.

The driver can activate the TCS-terrain function which allows for more wheel-spin when driving on difficult terrain. The control button (Figure 5-8) has a spring and comes back to its default position after having been pressed. A second press on the button deactivates the function.

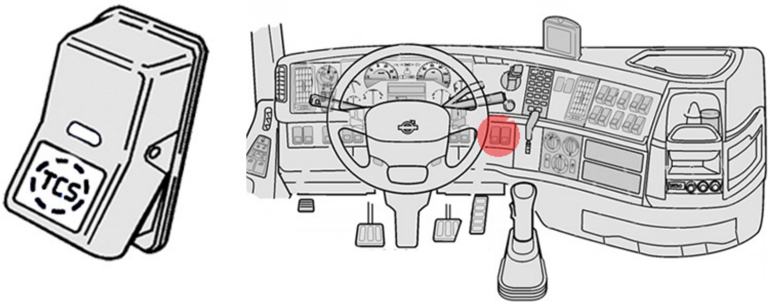


Figure 5-8: TCS-terrain control and location on dashboard. Adapted from Driver's Manual FM/FH (Volvo Trucks 1998).

5.4.2 Underlying intentions/reasons for usage

In order to drive on an upward slope with a fully loaded truck, all available engine power might be needed. If for some reason the TCS intervenes there is a risk that the loss of power induced might be enough to prevent the truck from getting all the way up the slope. Having enough speed from the start can be a determining factor of success in climbing up steep slopes.

If the TCS-terrain function is active then the driving wheels are allowed to spin more and there is less risk of TCS intervening.

5.4.3 Use context/situation

Check one or several applicable situations in the list:

- ☐ Primary driving
- ☒ Secondary driving
- ☐ Non-driving
- ☐ Living: passenger seat
- ☐ Living: bunk area
- ☐ Working

TCS-terrain is mainly used to drive on upward slopes when there is a risk for wheels to start spinning. Most commonly it is used on forest roads during the winter months when roads are snowy or icy and conditions are generally slippery. On steep slopes and in very slippery conditions TCS-terrain might also be used on regular paved roads, especially with a fully loaded truck.

Problems might also arise in other seasons on damp and soft soil or muddy terrain if the truck is sinking.

On construction sites it can be used both if there is a need to reverse for a long distance towards a dumping site and as a starting help after the truck has been unloaded. This would be a last resort where the terrain is very soft because of deep mud or soaked gravel and there is a risk of getting stuck.

Frequency of use

Timber segment	**Construction segment**
☒ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☐ Sometimes ☐ Rarely ☐ Never Seasonal variation ☒ Yes (applies mostly in winter) ☐ No	☐ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☒ Sometimes ☐ Rarely ☐ Never Seasonal variation ☐ Yes ☒ No

Duration of use

Timber segment	**Construction segment**
☐ Seconds ☐ 1 – 5 minutes ☒ 5 – 30 minutes ☐ ≥ 30 minutes	☒ Seconds ☐ 1 – 5 minutes ☐ 5 – 30 minutes ☐ ≥ 30 minutes

Drivers on construction sites are not confronted to situations where TCS-terrain is needed as often as timber transporters. This is reflected in differences in attitudes when using the function. Drivers in the timber segment are more likely to activate TCS-terrain at an early stage in a preventive way. On construction sites however, drivers are more likely to wait until there is no other alternative. Another reason for this is that if wheels are allowed to spin, the terrain is damaged and it becomes even more difficult to drive on at the next passing.

Usage in combination or sequence with other functions

It is very likely that whenever TCS-terrain is activated, the central differential lock is already engaged. For timber transporters, both TCS-terrain and the central differential lock are used in a preventive way. On construction sites, TCS-terrain is used more as a last resort in situations where the central differential lock would have already been engaged.

> *”As a rule, the differential lock is on before [TCS-terrain] so it’s usually used in combination with the differential lock.”*

If the road conditions are even more severe, the driver might have to use other functions as well, such as the full differential lock or sanding or even both.

5.4.4 Vehicle type / segment / markets / variants / superstructures

In the course of this study, the TCS-terrain function has been observed on:

- FM, FH, FH16 with 400 hp – 660 hp, model year 2001 – 2008
- Timber transport and construction segments
- Swedish market
- 6x4 and 8x4 configuration

The TCS-terrain function was also present on trucks with a 6x2 configuration. However, none of those drivers ever used the function.

5.4.5 User scenarios (user action related to existing HMI)

Scenario 1: upward slope on forest road

A timber transporter driving a 6x4 truck has just loaded his truck and trailer with timber and is heading towards a sawmill. He is driving on a forest road. It is fall and it has been raining. The road is soaked and muddy. The driver sees a steep hill ahead. The central differential lock is engaged.

The driver decides to activate TCS-terrain as a precaution		
	The driver presses the TCS-terrain button	U
	The indicator lamp in the TCS-terrain button is lit	A
	TCS-terrain is activated	F
The driver accelerates		
The hill is climbed without TCS intervening		
The driver deactivates TCS-terrain		
	The driver presses the TCS-terrain button	U
	The indicator lamp in the TCS-terrain button is turned off	A
	TCS-terrain is deactivated	F

Scenario 2: activation after TCS intervention

A partially loaded timber transporter (6x4, loaded truck but empty trailer) is driving on a gravel road. It has been raining earlier in the week but today the sun is shining. There are fields on both sides of the road and the road is dry. There is a long upward slope ahead. As usual on gravel roads and out of habit, the central differential lock is engaged. The driver is aware of the slope but the road is dry and in good condition and he thinks the differential lock will be enough. The driver reaches the slope and keeps driving. As the slope becomes steeper, the road goes into a forest. Because the trees are high, the sun does not reach the ground on this portion of the road and as a result the road is still wet.

Upon driving on a pool of mud, one of the drive wheel starts spinning		
TCS intervenes and the engine’s torque is decreased. The truck loses speed.		
The driver quickly activates TCS-terrain		
	The driver very quickly presses the TCS-terrain button	U
	The indicator light on the TCS-terrain button is lit	A
	TCS-terrain is activated	F
The driver accelerates		
The truck regains speed		

The terrain is wet for the rest of the slope. Some wheels spin at times but with TCS-terrain activated, TCS does not intervene. The driver reaches the top of the hill. Once the driver reaches the main asphalt road he deactivates TCS-terrain.

The driver deactivates TCS-terrain		
	The driver presses the TCS-terrain button	U
	The indicator lamp in the TCS-terrain button is turned off	A
	TCS-terrain is deactivated	F

Scenario 3: TCS-terrain as starting help

This scenario takes place on a construction site. The truck is a dump truck with axle configuration 8x4. The truck is fully loaded with gravel that has to be dumped far out on the site. The terrain is very soft and wet due to recent rain. The driver reverses and drives toward the dumping place where a bulldozer is waiting. With the truck fully loaded and the central differential lock engaged, the truck has enough traction to reach the bulldozer. The driver is a little distracted and does not notice that the truck has created deep tracks in the ground (Figure 5-9). When he reaches the bulldozer, he raises the truck bed and starts dumping the gravel.

The driver raises the truck bed		
The driver activates the full differential lock		
	The driver presses on the differential lock control and pushes it to its downward position	U
	The full differential lock is activated	F
	The warning signal for full differential lock flashes	A
The driver raises the rear axle		
	The driver pushes the axle lift button to its upward position	U
	The indicator light on the axle lift button is lit	A
	The axle lift indicator in the instrument cluster is lit	A
	The rear axle is lifted	F
The driver starts driving forward		
The drive wheels start spinning		
TCS intervenes and the engine’s torque is decreased. There is not enough power to move forward		

The driver activates TCS-terrain		
	The driver presses the TCS-terrain button	U
	The indicator lamp in the TCS-terrain button is lit	A
	TCS-terrain is activated	F
The driver tries driving forward again and the truck is able to move.		
When the driver reaches more stable terrain, he deactivates TCS-terrain		
	The driver presses the TCS-terrain button	U
	The indicator lamp in the TCS-terrain button is turned off	A
	TCS-terrain is deactivated	F
The driver deactivates the full differential lock and drives away from the construction site		

Figure 5-9: deep tracks on construction site

5.4.6 Different driver types

No difference in usage was observed based on driver characteristics. Usage depends on situation and context and varies only across segments.

5.4.7 Start up behavior

Drivers who use the function frequently generally think that driving would be easier if TCS was not installed at all or TCS-terrain was active from start up.

> *"TCS is a useless function that only creates problems. In the real world it only creates problems. It would be better if it didn't exist."*
>
> *"I don't know a single timber transporter that hasn't cursed because of [TCS]. I'd like to get rid of it."*
>
> *"If I feel a wheel spinning then I let go of the gas pedal, I don't need anything doing it for me."*

Drivers who do not use the function frequently have not expressed an opinion on the issue.

5.4.8 Multiple controls

Is there a need to control the function from multiple locations?

☐ Yes
☒ No

If yes, from where?

5.4.9 Possible risks

What are the consequences if:

1. **The driver does not find the control in time**
   TCS-terrain should be activated before TCS has intervened. If the control is not found in time there is a risk that the truck will lack the necessary power to climb a slope or drive away from muddy terrain and get stuck.

2. **The driver does not find the control at all**
   Same risks as in 1.

3. **The driver is not aware that the function is activated**
   No major risks. The consequence could be more spinning.

4. **The driver is not aware that the function is deactivated**
   Same risks as in 1.

5. **The function is activated by mistake**
   Same risks as in 3.

Time criticality to activate

- ☒ High
- ☐ Medium
- ☐ Low
- ☐ None

TCS-terrain should be activated in advance, before TCS has a chance to intervene. If TCS has intervened then TCS-terrain has to be activated very quickly, before too much power has been lost.

Time criticality to deactivate function

- ☐ High
- ☐ Medium
- ☐ Low
- ☒ None

There are no risks associated with driving with the function needlessly activated. Wheels might spin more easily but driving isn't affected much.

5.4.10 Vehicle modes

The functions are to be operational in the following vehicle modes:

- ☐ Crank
- ☒ Running
- ☐ Pre-running
- ☐ Accessory
- ☐ Living
- ☐ Parked

5.4.11 Possible improvements

TCS-terrain could be activated automatically whenever the central differential lock is engaged. This idea is somewhat controversial. Most drivers are not in favour of combining functions or automation.

Let TCS-terrain be active on start up by default.

Let the function be controlled by a regular button with two fixed positions so that the function remains in the same state after having turned off and started up the engine again.

5.5 Differential locks

5.5.1 Function description

A differential unit is a mechanism that compensates for the difference in rotation speed between the drive wheels (Bosch, 1996). Torque is distributed equally among the drive wheels, in effect limiting the effective torque to the greatest amount that will not cause one of the wheels to spin. When excess torque is applied after a wheel has started to spin, this wheel just spins faster while the other wheel on the same axle does not rotate at all.

There is a differential between the two wheels of a driving axle. A differential lock allows the two wheels on one axle to behave as if they were on a single shaft by restricting them to the same speed of rotation. This may increase traction as one wheel will not start spinning as long as the other wheel still has grip.

If there are two drive axles, there is also a central differential that distributes torque between the two axles. With the center differential locked, the same amount of power is transmitted to the front and rear axles regardless of traction conditions. Figure 5-10 shows the principle layout of differential locks on different axle configurations.

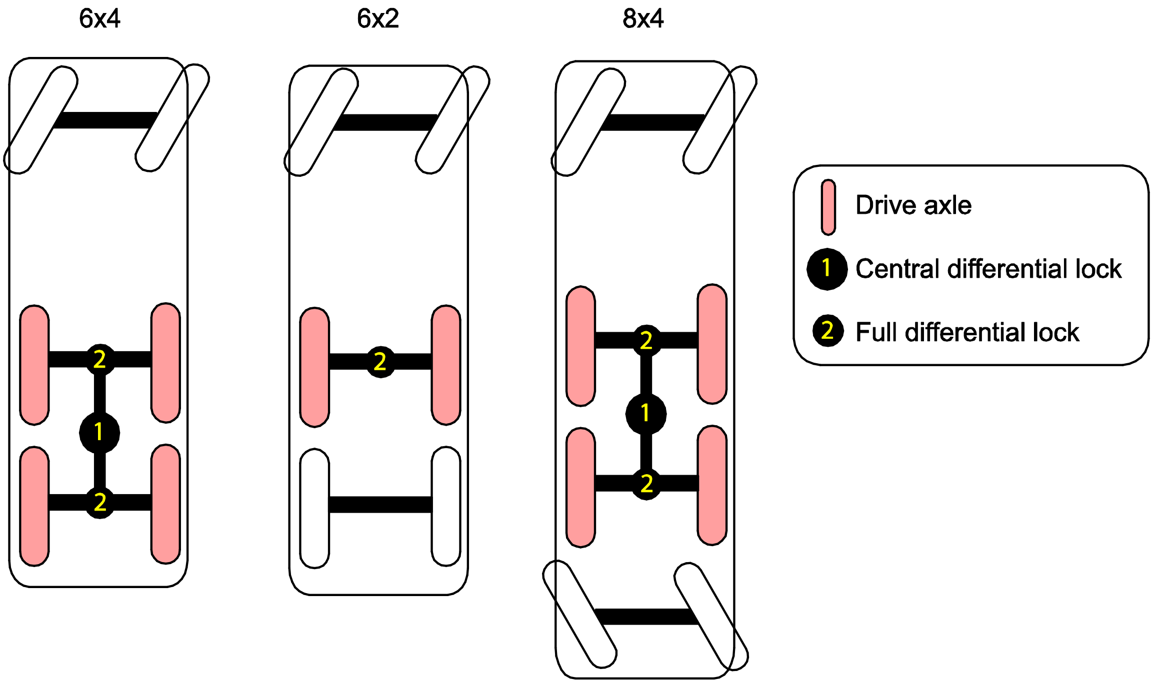


Figure 5-10: differential locks on different axle configurations

The differential locks are operated by one single 3-position button (Figure 5-11):

- In the upper position, all locks are disengaged.
- In the middle position, the central differential is locked and the same amount of power is transmitted to the front and rear drive axles regardless of traction conditions. (On trucks with a single drive axle, pushing the differential lock button to this position has no effect.) If a wheel starts spinning and the other wheel on the same axle stops, the

second drive axle still receives the same amount of power and keeps moving the truck forward as long as those wheels have traction.

- In the lower position, the full differential lock is engaged, meaning that all differentials are locked.

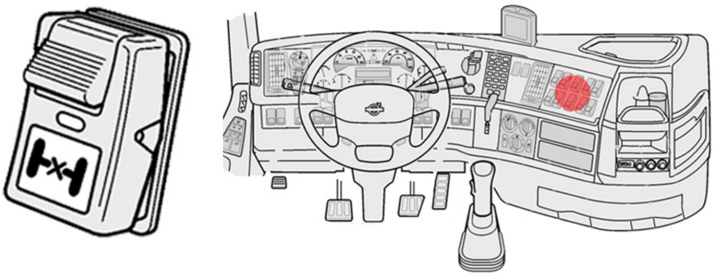


Figure 5-11: differential locks control and location on dashboard. Adapted from Driver's Manual FM/FH (Volvo Trucks 1998).

5.5.2 Underlying intentions/reasons for usage

The goal when activating differential locks is to gain traction and minimize the effect of wheel-spinning. With the differentials unlocked, a spinning wheel means that the overall torque transmitted to the drive wheels is decreased, in the worst case, to the point where the truck is unable to move. When the differentials are locked, this unwanted effect is removed.

5.5.3 Use context/situation

Check one or several applicable situations in the list:

☐ Primary driving
☒ Secondary driving
☐ Non-driving
☐ Living: passenger seat
☐ Living: bunk area
☐ Working

Central differential lock

In the construction segment, drivers often engage the central differential lock as a precaution when they drive off an asphalt road and in to a construction site or a landfill where they are to load or dump dirt or gravel. The terrain can often be soft or muddy (Figure 5-12), especially when it has rained. It can also be loose gravel or gravel with sharp rocks.

Figure 5-12: soft and muddy terrain on a construction site

The function is used in all seasons. During the winter it can be helpful when driving on a slope and the road is slippery due to the presence of ice patches or slush.

Timber transporters use the central differential lock mainly when driving on forest roads (Figure 5-13, Figure 5-14). Most commonly it is used during the winter months when just having some snow on the road is reason enough to engage it. In other seasons it is used if the terrain is muddy, especially if forest machines have drawn mud out from the forest onto the road. The function is also helpful if the terrain is uneven and there is a risk that a wheel might lift off the ground.


Figure 5-13: terrain on a forest road


Figure 5-14: terrain on a forest road

Full differential lock

In the construction segment drivers usually don't use the full differential lock other than as a last resort. When a dump truck is fully loaded there is a lot of weight on the drive axles and traction is good.

> *"When you have a load, traction is really good, it almost drives like a tank."*

Conversely, after the load has been dumped, there is much less weight on the drive axles and traction is diminished. For this reason, drivers don't want to use all available help functions when reversing out to the dump site, for fear of coming too far and not being able to drive away. They would rather not use the full differential lock and save it in case they are stuck after having dumped. They might engage the full differential lock before stopping if they fear getting stuck.

The function can also be used as a precaution when driving on particularly steep slopes on construction sites or icy or slushy hills in the winter.

Using the full differential lock is also a way to prevent harming more fragile terrain such as lawns or grass over soft material. With the locks engaged, wheels are less likely to spin and dig deep tracks.

Timber transporters mainly use the full differential lock on icy or slushy slopes. The lock is engaged as a precaution beforehand to make sure that the truck won't get stuck. It is also typically used before stopping in the middle of a slope (e.g. to load) to avoid spinning and gliding backwards when driving away. Figure 5-15 shows how deep mud can form after heavy rain on a forest road, a situation where the full differential lock also had to be used.

Figure 5-15: deep mud after heavy rain on forest road

Frequency of use

	Timber segment	**Construction segment**
Central differential lock	☒ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☐ Sometimes ☐ Rarely ☐ Never Seasonal variation ☐ Yes ☒ No	☒ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☐ Sometimes ☐ Rarely ☐ Never Seasonal variation ☐ Yes ☒ No
Full differential lock	☐ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☒ Sometimes ☐ Rarely ☐ Never Seasonal variation ☒ Yes (Mostly winter) ☐ No	☐ Many times a day (every day) ☒ Many time a day (some days) ☐ Daily ☐ Sometimes ☐ Rarely ☐ Never Seasonal variation ☐ Yes ☒ No

Duration of use

	Timber segment	**Construction segment**
Central differential lock	☐ Seconds ☐ 1 – 5 minutes ☒ 5 – 30 minutes ☒ ≥ 30 minutes	☒ Seconds ☒ 1 – 5 minutes ☐ 5 – 30 minutes ☐ ≥ 30 minutes
Full differential lock	☒ Seconds ☒ 1 – 5 minutes ☐ 5 – 30 minutes ☐ ≥ 30 minutes	☒ Seconds ☐ 1 – 5 minutes ☐ 5 – 30 minutes ☐ ≥ 30 minutes

On construction sites the central differential lock is generally used for short periods, until the rough terrain is passed or until the truck has left the construction site. Timber transporters commonly engage the central differential lock as soon as they drive off asphalt.

The full differential lock is never used longer than necessary and drivers are keen to disengage the lock as quickly as possible.

Usage in combination or sequence with other functions

The central differential lock is often used by timber transporters in combinations with TCS-terrain when driving on slippery slopes. On construction sites, the same combination is sometimes used when driving out of rough terrain.

The central differential lock needs to be engaged before using axle load distribution.

The full differential lock makes sanding more effective, as sand can be spread alternately on both sides of the truck. If the situation is critical like a steep, icy hill, it can be used in combination with both sanding and TCS-terrain.

When fully loaded and using Robson-drive, the full differential lock is the next step to gain more traction.

5.5.4 Vehicle type / segment / markets / variants / superstructures

In the course of this study, the full differential lock function has been observed on:

- FM, FH, FH16 with 400 hp – 660 hp, model year 2001 – 2008
- Timber transport and construction segments
- Swedish market
- 6x2, 6x4 and 8x4 configuration

The central differential lock function has been observed on all the same categories of trucks except 6x2 configurations.

5.5.5 User scenarios (user action related to existing HMI)

Scenario 1: driving onto a forest road to load timber

A timber transporter is driving on a main road on his way to get a new load of timber. He is about to drive off the main road onto a forest road. The terrain on the forest road is somewhat uneven with pot holes (Figure 5-16) and the road is soft and wet because of recent rain.

The driver drives off the main road onto the forest road		
The driver activates the central differential lock		
	The driver presses the differential lock button and pushes it to its middle position	U
	The indicator lamp on the differential lock button is lit	A
	The central differential lock is engaged	F
	The warning lamp for the central differential lock is lit in the instrument cluster	A
The driver keeps driving until he reaches the timber to load		

Figure 5-16: uneven forest road

Scenario 2: driving away from a landfill after having unloaded dirt

A dump truck has just unloaded dirt at a landfill and is going back to a construction site to get another load. The terrain is mostly dirt and mud and is very soft. The central differential lock is engaged but when the driver reverses to the dumping site one wheel starts spinning and the truck sinks a little bit. He needs some extra help to drive away.

The driver activates the full differential lock		
	The driver presses the differential lock button and pushes it to its lower position	U
	The full differential lock is activated	F
	The warning light for the full differential lock in the instrument cluster is lit and flashes	A
The driver drives away from the soft terrain		
The driver deactivates the full differential lock		
	The driver presses the differential lock button and pushes it to its middle position	U
	The full differential lock is deactivated	F
	The warning light for the full differential lock is turned off	A
The driver keeps driving toward the main road		
The driver deactivates the central differential lock		
	The driver presses the differential lock button and pushes it to its upper position	U

	The indicator light on the differential lock button is turned off	A
	The central differential lock is deactivated	F
	The warning light for the central differential lock in the instrument cluster is turned off	A

Figure 5-17: soft mud on landfill

Scenario 3: reversing on a construction site to get a new load

A dump truck is going to load muddy dirt that is being excavated on a construction site where a new road is being built. The loading site is at the end of a steep downward slope (Figure 5-18). To be able to drive away when fully loaded the driver needs some extra help.

Figure 5-18: steep slope on construction site

<table>
<tr><td colspan="3">The driver reverses and drives down the slope</td></tr>
<tr><td colspan="3">The driver activates the full differential lock</td></tr>
<tr><td rowspan="3"></td><td>The driver presses the differential lock button and pushes it to its lower position</td><td>U</td></tr>
<tr><td>The full differential lock is activated</td><td>F</td></tr>
<tr><td>The warning light for the full differential lock in the instrument cluster is lit and flashes</td><td>A</td></tr>
<tr><td colspan="3">The driver stops at the loading site and the truck is loaded</td></tr>
<tr><td colspan="3">The driver drives up the slope until he reaches level ground</td></tr>
<tr><td colspan="3">The driver deactivated the full differential lock</td></tr>
<tr><td rowspan="3"></td><td>The driver presses the differential lock button and pushes it to its middle position</td><td>U</td></tr>
<tr><td>The full differential lock is deactivated</td><td>F</td></tr>
<tr><td>The warning lamp for the full differential lock in the instrument cluster stops flashing and is turned off</td><td>A</td></tr>
<tr><td colspan="3">The driver drives away</td></tr>
</table>

Scenario 4: driving on an icy upward slope on a main road
A fully loaded timber truck is driving on a main road, on his way to a saw mill. It is winter and the road is icy. The central differential lock is engaged. He sees an upward slope ahead.

The driver is driving towards the slope		
The driver activates TCS-terrain		
	The driver presses the TCS-terrain button	U
	The indicator light on the TCS-terrain button is lit	A
	TCS-terrain is activated	F
The driver drives up the slope		
A wheel starts spinning. TCS intervenes despite TCS-terrain being active. The truck loses speed.		
The driver activates the full differential lock		
	The driver presses the differential lock button and pushes it to its lower position	U
	The full differential lock is engaged	F
	The warning lamp for the full differential lock in the instrument cluster is lit and flashes	A
The truck regains traction and is able to reach the crest		
The driver deactivates the full differential lock		
	The driver presses the differential lock button and pushes it to its middle position	U
	The full differential lock is disengaged	F
	The warning lamp for the full differential lock in the instrument cluster stops flashing and is turned off.	A

5.5.6 Different driver types

No difference in usage has been observed based on driver characteristics.

5.5.7 Start up behavior

Differential locks should not be automatically engaged or disengaged on startup but remain in the same state as they were when the engine was turned off. Drivers want to have control over the function's state: if the differential locks are engaged when the engine is turned off, the driver has most likely planned that they would be needed when starting. On the other hand, if they are disengaged when the engine is turned off, automatically engaging them on startup could lead to negative consequences.

5.5.8 Multiple controls

Is there a need to control the function from multiple locations?

☐ Yes
☒ No

If yes, from where?

5.5.9 Possible risks

Central differential lock

What are the consequences if:

1. **The driver does not find the control in time**
   Risk of a wheel spinning and getting stuck.

   Risk of harming axles if function is activated when wheels are already spinning.

2. **The driver does not find the control at all**
   Risk of a wheel spinning and getting stuck.

3. **The driver is not aware that the function is activated**
   No major risk. Slightly more wear on tires. Somewhat stiffer direction, barely noticeable.

4. **The driver is not aware that the function is deactivated**
   Risk of a wheel spinning and getting stuck.

5. **The function is activated by mistake**
   No major risk. Slightly more wear on tires. Somewhat stiffer steering, barely noticeable.

Full differential lock

What are the consequences if:

1. **The driver does not find the control in time**
   Steering is stiff. If not deactivated in time, risk of not being able to turn if road curbs or comes to an intersection.

   Risk of wheels spinning and getting stuck.

   Risk of harming axles if function is activated when wheels are already spinning.

2. **The driver does not find the control at all**
   Risk of wheels spinning and getting stuck.

3. **The driver is not aware that the function is activated**
   Major risk because of stiff steering, especially on dry asphalt. Wear on axles and tires.

4. **The driver is not aware that the function is deactivated**
   Risk of wheels spinning and getting stuck.

5. **The function is activated by mistake**
   Major risk because of stiff steering, especially on dry asphalt. Wear on axles and tires.

If the road is leaning sideways and the full differential lock is engaged, there is a risk of losing grip on all wheels simultaneously and gliding toward the ditch.

Time criticality to activate

Central differential lock	Full differential lock
☐ High ☐ Medium ☒ Low ☐ None	☐ High ☒ Medium ☐ Low ☒ None (if stopping before activation)

The central differential lock is mostly used as a precaution and thus usually not activated in time-critical situations. If the lock is not engaged and wheels start spinning on soft terrain however, the driver needs to let go of the gas pedal, activate the function and accelerate again fairly quickly.

Drivers mostly feel the function is activated quickly after having pressed the button.

Drivers have expressed two opinions regarding when they can activate the full differential lock. Some say they have to come to a full stop before engaging the lock while others say it can be done while driving, as long as the wheels are not spinning. In the former case, time-criticality is low. In the latter, time-criticality can be higher depending on the situation. It is mostly critical while driving up a slope where maintaining some speed is important.

Time criticality to deactivate function

Central differential lock	Full differential lock
☐ High ☐ Medium ☐ Low ☒ None	☒ High ☐ Medium ☐ Low ☐ None

The central differential lock is not time-critical to deactivate as it does not affect the truck's handling noticeably.

The full differential lock can be very time-critical to deactivate as it impairs steering. It should be deactivated as soon as it is no longer needed.

5.5.10 Vehicle modes

The functions are to be operational in the following vehicle modes:

- ☐ Crank
- ☒ Running
- ☐ Pre-running
- ☐ Accessory
- ☐ Living
- ☐ Parked

5.5.11 Possible improvements

Drivers believe it is important to know whether the functions are active or not. There have been suggestions that warning signals should be more visible (perhaps bigger, clearer and higher up in the cluster). Some have also suggested using auditory warnings for the full differential lock. The warning should not be too loud however, and many drivers do not like auditory warnings at all.

5.6 Axle lift

5.6.1 Function description

Depending on a truck’s axle configuration, one of the axles may be a “dead axle” which is free-rotating and thus not part of the driveline. For example in a 6x2 configuration there are two axles at the rear of the truck. Only one of these is driven and delivers traction. The other is a dead axle.

If the truck is equipped with an axle lift, the dead axle can be lifted from the ground on command from the cab (Figure 5-19) as long as this does not result in axle load limits being exceeded.

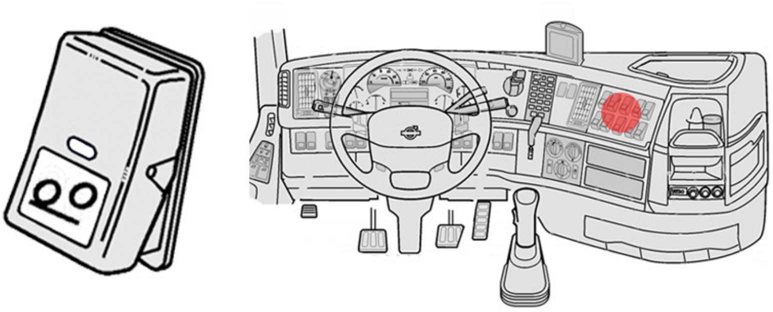


Figure 5-19: axle lift control and location on dashboard. Adapted from Driver's Manual FM/FH (Volvo Trucks 1998).

5.6.2 Underlying intentions/reasons for usage

There are many reasons to lift a dead axle. When the axle is lifted and the wheels are no longer in contact with the ground, friction is minimized. There is no wear on the dead axles’ tires and fuel consumption goes down. With the axle lifted, the truck’s wheel base is shorter. The turning radius is smaller and maneuvering becomes easier. Another reason to lift the dead axle is that the weight load is increased on the drive axle (or drive axles depending on configuration) which can increase traction.

5.6.3 Use context/situation

Check one or several applicable situations in the list:

- ☐ Primary driving
- ☒ Secondary driving
- ☐ Non-driving
- ☐ Living: passenger seat
- ☐ Living: bunk area
- ☐ Working

If this function is available, drivers lift the dead axle as soon as they have unloaded the truck. This is done regardless of road conditions.

The drivers are aware that the axle should not be lifted when the truck is loaded. Even so, it is mentioned that in some situations, they can try to lift the axle even when loaded in order to increase the load on the drive axle and gain traction.

Frequency of use:

- ☒ Many times a day (every day)
- ☐ Many time a day (some days)
- ☐ Daily
- ☐ Sometimes
- ☐ Rarely
- ☐ Never

Seasonal variation:

- ☐ Yes
- ☒ No

Duration of use:

Empty load	Full load
☐ Seconds ☐ 1 – 5 minutes ☒ 5 – 30 minutes ☒ ≥ 30 minutes	☒ Seconds ☐ 1 – 5 minutes ☐ 5 – 30 minutes ☐ ≥ 30 minutes

Since the axle is lifted every time the truck is unloaded, the function is in use about 50 % of the time.

If the function is used despite the truck being loaded then it is used only for a few seconds or minutes, long enough to drive through the rough terrain.

Usage in combination or sequence with other functions:
If the terrain is very soft or slippery and the load shift to the drive axle (or axles) when the dead axle is lifted is not enough, differential locks can be used.

If the axle load distribution function or air dump is used on a tridem to increase maneuverability then the dead axle is already lifted and the central differential lock is engaged.

5.6.4 Vehicle type / segment / markets / variants / superstructures

In the course of this study, the axle lift function has been observed on:

- FH, FH16 with 480 hp – 660 hp, model year 2001 – 2008
- Construction segment
- Swedish market
- 6x2 and 8x4 configuration

5.6.5 User scenarios (user action related to existing HMI)

Scenario 1: unloading dirt on a landfill.

A dump truck driver (8×4), with the truck fully loaded with dirt, is driving on a main road. The driver is heading for a landfill to unload (Figure 5-20). It is summer, the sun is shining and the terrain on the landfill is dry and a little bit uneven. The driver turns from the main road in to the landfill and further on to the unloading place. The central differential lock is engaged.

Figure 5-20: unloading dirt on a landfill

The driver makes a u-turn and reverses to the place to unload		
The driver unloads the dirt		
The driver activates the axle lift		
	The driver presses the axle lift button	U
	The indicator light on the axle load distribution button is lit	A
	The dead axle behind the two driving axles is lifted	F
	The warning lamp for axle lift is lit in the instrument cluster	A
The driver drives away from the unloading place and out on the road		

Scenario 2: driving up a slope on the main road in the spring

A dump truck driver (8×4) is driving on an asphalted main road with the truck loaded with dirt heading towards a landfill. The road is icy because it has been raining the latest days but during the night it has been below zero (Figure 5-21). The driver is getting closer to a long slope ahead.

Figure 5-21: Close to the crest on a long, steep, icy slope.

The driver activates the central differential lock		
	The driver presses the central differential lock button to its middle position	U
	The indicator light on the central differential lock button is lit	A
	The central differential lock is activated	F
	The warning lamp for differential lock is lit in the instrument cluster	A
The driver drives up the slope		
Closer to the crest the trucks traction is reduced		
The driver quickly activates the axle lift		
	The driver quickly presses the axle lift button	U
	The indicator light on the axle lift button is lit	A
	The dead axle behind the two drive axles is lifted	F
	The warning lamp for axle lift is lit in the instrument cluster	A
The driver continues driving up the slope and over the crest		

The driver deactivates the axle lift		
	The driver presses the axle lift button	U
	The indicator light on the axle lift button is turned off	A
	The dead axle behind the two drive axles is lowered	F
	The warning lamp for axle lift is turned off in the instrument cluster	A
The driver keeps on driving		

5.6.6 Different driver types

No difference in usage has been observed based on driver characteristics.

5.6.7 Start up behavior

The function should not be automatically activated or deactivated at start up.

5.6.8 Multiple controls

Is there a need to control the function from multiple locations?

☐ Yes
☒ No

If yes, from where?

5.6.9 Possible risks

Drivers are aware that the function cannot be used if axle loads become too high, meaning that the dead axle is not lifted if it would mean that axle load limits would be exceeded. However they still use the function cautiously and only use it when loaded if really needed.

Drive axles are subject to strain when the dead axle is lifted, especially if the terrain is uneven.

What are the consequences if:

1. **The driver does not find the control in time**
   It might be harder to drive away after the load has been dumped. There is a risk that wheels might spin and the truck might get stuck.

2. **The driver does not find the control at all**
   Same risks as in 1.

3. **The driver is not aware that the function is activated**
   If the driver is not aware that the dead axle is lifted, the drive axles risk damage if new load is put on the truck.

4. **The driver is not aware that the function is deactivated**
   No particular risk. Lower traction in slippery conditions.

5. **The function is activated by mistake**
   If the axle is accidentally lowered when driving at higher speeds, the axle will hit the road with some force which could induce damage on the axle.

Time criticality to activate function

- ☐ High
- ☐ Medium
- ☒ Low
- ☐ None

Time criticality to deactivate function

- ☐ High
- ☐ Medium
- ☒ Low
- ☐ None

The function needs to be activated or deactivate at the appropriate time. However it is not commonly used in situations where time-criticality is high.

5.6.10 Vehicle modes

The functions are to be operational in the following vehicle modes:

- ☐ Crank
- ☒ Running
- ☐ Pre-running
- ☐ Accessory
- ☐ Living
- ☐ Parked

5.6.11 Possible improvements

No suggestion regarding this function specifically.

5.7 Axle load distribution

5.7.1 Function description

Axle load distribution is a function that enables the driver to control how the load is distributed between the rear axles. When the function is activated some of the load is transferred so that the drive axle (the front drive axle if there are two drive axles) carries most of the weight. The function is controlled by the air suspension (Electronically Controlled Suspension). Upon activation, the pressure in the air bellows of the rear axle is decreased while that of the front axle is increased.

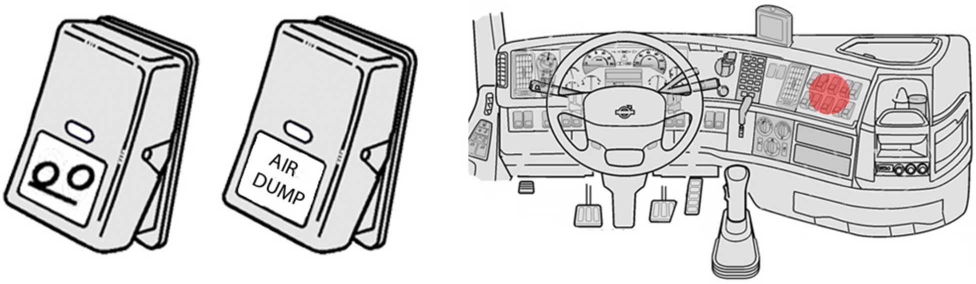


Figure 5-22: axle load distribution controls and location on dashboard. Adapted from Driver's Manual FM/FH (Volvo Trucks 1998).

On 6x2 and 6x4 trucks, the function is controlled by the same button as the axle lift. On 8x4 trucks the button is labeled “Air dump” (Figure 5-22).

5.7.2 Underlying intentions/reasons for usage

There are two main reasons to use axle load distribution. By increasing the load on one of the drive axles, it is possible to gain more traction. By minimizing the load on the rear-most axle, the truck’s wheel-base is in effect shortened. This is used to increase the truck’s maneuverability and decrease its turn radius, and to make reversing easier.

Distributing axle load can also decrease wear on tires.

5.7.3 Use context/situation

Check one or several applicable situations in the list:

- ☐ Primary driving
- ☒ Secondary driving
- ☐ Non-driving
- ☐ Living: passenger seat
- ☐ Living: bunk area
- ☐ Working

6x4 and 8x4

The axle load distribution function is almost always used on empty load.

When a tandem or tridem truck is unloaded, traction is decreased because there is so little weight on each drive axle. When activating the axle load distribution, a heavier load is transferred to the front drive axle and traction is improved. This is used on slippery road conditions, particularly when driving on slopes.

The function is most frequently used when the driver needs to make a sharp turn, u-turn or when reversing. Timber transporters use this function very often. They commonly have to drive away from a forest road the same way they are coming from. In that case, they always make a u-turn while still empty, before loading timber.

In extreme situations, drivers might try to use the axle load distribution function to gain traction even when driving with a load. However, they are aware that the function does not allow axle load limits to be exceeded and that this might not make much of a difference.

6x2

In a 6x2 configuration there is only one drive axle and there is no central differential lock. If the truck is equipped with Robson-drive, that function is used in the same way a central differential lock would. If there is no Robson-drive however, axle load distribution is frequently used to gain traction. When driving on an empty load the dead-axle is lifted, but when the truck is loaded, transferring only some of the load to the drive axle can improve traction. The drivers often use this in a preventive way.

Frequency of use:

Timber segment	
When used for traction	**When used for manoeuvrability**
☐ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☐ Sometimes ☒ Rarely ☐ Never Seasonal variation: ☐ Yes ☒ No	☒ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☐ Sometimes ☐ Rarely ☐ Never Seasonal variation: ☐ Yes ☒ No

Construction segment		
	When used for traction	**When used for manoeuvrability**
6x2	☒ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☐ Sometimes ☐ Rarely ☐ Never Seasonal variation: ☐ Yes ☒ No	☐ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☐ Sometimes ☐ Rarely ☒ Never Seasonal variation: ☐ Yes ☒ No

6x4	☐ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☒ Sometimes ☐ Rarely ☐ Never Seasonal variation: ☐ Yes ☒ No	☐ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☒ Sometimes ☐ Rarely ☐ Never Seasonal variation: ☐ Yes ☒ No
8x4	☐ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☐ Sometimes ☒ Rarely ☐ Never Seasonal variation: ☐ Yes ☒ No	☐ Many times a day (every day) ☐ Many time a day (some days) ☐ Daily ☐ Sometimes ☒ Rarely ☐ Never Seasonal variation: ☐ Yes ☒ No

Duration of use:

When used for traction	**When used for manoeuvrability**
☐ Seconds	☐ Seconds
☒ 1 – 5 minutes	☒ 1 – 5 minutes
☒ 5 – 30 minutes	☐ 5 – 30 minutes
☐ ≥ 30 minutes	☐ ≥ 30 minutes

The function is activated for short periods of time. Manoeuvres are done fairly quickly, in a matter of minutes. When the function is used to gain traction, it can be active for longer periods, but drivers are weary of harming the axles and mostly deactivate the function as soon as road conditions allow it.

Usage in combination or sequence with other functions:

In vehicles with more than one drive axle, the function can only be activated if the central differential lock is engaged.

Sanding is commonly used at the same time when manoeuvring on icy or snowy roads.

For 6x2 trucks that use it to gain traction, the full differential lock is the next step when driving on rough terrain.

5.7.4 Vehicle type / segment / markets / variants / superstructures

In the course of this study, the axle load distribution function has been observed on:

- FM, FH, FH16 with 400 hp – 660 hp, model year 2001 – 2008
- Timber transport and construction segments
- Swedish market
- 6x2, 6x4 and 8x4 configuration

5.7.5 User scenarios (user action related to existing HMI)

Scenario 1: making a u-turn on a forest road

A timber transporter is driving on a forest road with an empty load. It is early spring and the road is damp. The central differential lock is engaged. He passes the stack of timber he is supposed to load but keeps on driving until he finds a spot to make a u-turn (Figure 5-23). He has to drive away the same way he is coming from and knows it would be hard to make a u-turn while fully loaded.

Figure 5-23: a small space is enough to make a u-turn

The driver activates the axle load distribution function		
	The driver presses the axle load distribution button	U
	The indicator light on the axle load distribution button is lit	A
	The pressure in the air bellows is distributed so that most of the load is shifted to the front drive axle	F
	The warning lamp for axle lift is lit in the instrument cluster	A
The driver lifts the rear axle on the trailer		
	The driver presses the trailer axle lift button	U
	The indicator light on the trailer axle lift button is lit	A
	The warning lamp for the trailer axle lift is lit in the instrument cluster	A
	The rear axle on the trailer is lifted	F
The driver makes a u-turn and drives back towards the stack of timber		

The driver lowers the rear axle on the trailer		
	The driver presses the trailer axle lift button	U
	The indicator light on the trailer axle lift button is turned off	A
	The rear axle on the trailer is lowered	F
	The warning lamp for the trailer axle lift in the instrument cluster is turned off	A
The driver deactivates the axle load distribution function		
	The driver presses on the axle load distribution button	U
	The indicator lamp on the axle load distribution button is turned off	A
	The pressure in the air bellows is returned to its default levels and the load is distributed evenly between the two drive axles	F
	The warning lamp for the axle lift in the instrument cluster is turned off	A
The driver stops next to the stack of timber and prepares to load		

Scenario 2: driving on a muddy landfill.

A dump truck driver (6×4) is driving on a main road with empty load. The driver is going to load soil at a landfill for transport to a construction site. The terrain is muddy with deep tracks (Figure 5-24). The central differential lock is engaged. To be a little cautious the driver decides to use the axle load distribution.

Figure 5-24: two different views of a muddy landfill with deep tracks

The driver activates the axle load distribution function		
	The driver presses the axle load distribution button	U
	The indicator light on the axle load distribution button is lit	A
	The pressure in the air bellows is distributed so that most of the load is shifted to the front drive axle	F
	The warning lamp for axle lift is lit in the instrument cluster	A

The driver drives in to the landfill and towards the place where he is about to load		
The driver stops and makes a u-turn and reverses to the place to load		
The driver deactivates the axle load distribution function		
	The driver presses the axle load distribution button	U
	The indicator lamp on the axle load distribution button is turned off	A
	The pressure in the air bellows is returned to its default levels and the load is distributed evenly between the two drive axles	F
	The warning lamp for the axle lift in the instrument cluster is turned off	A

5.7.6 Different driver types

No difference in usage has been observed based on driver characteristics.

5.7.7 Start up behavior

The function should not be activated on startup. It is not likely that the engine would be turned off in the situations where the function is used. The function is mostly used for such a short period of time that it is deactivated before the truck comes to a stop. No driver has suggested that the function should be activated automatically at startup if it had been activate at engine stop.

5.7.8 Multiple controls

Is there a need to control the function from multiple locations?

☐ Yes
☒ No

If yes, from where?

5.7.9 Possible risks

To avoid putting too much strain on the axles, drivers use this function with caution depending on how heavy the load is, even though load is only distributed up to axle load limitations.

With axle load distribution activated, the truck is less stable at higher speed.

According to some drivers, the truck's ability to brake can be affected. The function should be deactivated before stopping on a steep slope if the road is slippery, so that all wheels have good grip on the road.

What are the consequences if:

1. **The driver does not find the control in time**
   There is a risk of not having enough traction in time to drive through rough or slippery terrain. If stopping on a steep slope, there is a risk of not having enough grip on all wheels to brake properly if not deactivated in time.

2. **The driver does not find the control at all**
   Same risks as in 1.

3. **The driver is not aware that the function is activated**
   Some loss of stability at high speed.

4. **The driver is not aware that the function is deactivated**
   The driver might try to drive on slippery terrain without the expected, sufficient traction.

5. **The function is activated by mistake**
   Some loss of stability at high speed.

Time criticality to activate function

When used to improve traction	When used to improve manoeuvrability
☐ High ☒ Medium ☐ Low ☐ None	☐ High ☐ Medium ☐ Low ☒ None

Time criticality to deactivate function

If stopping on a slope	In all other cases
☒ High ☐ Medium ☐ Low ☐ None	☐ High ☐ Medium ☐ Low ☒ None

5.7.10 Vehicle modes

The functions are to be operational in the following vehicle modes:

☐ Crank
☒ Running
☐ Pre-running
☐ Accessory
☐ Living
☐ Parked

5.7.11 Possible improvements

No suggestion regarding this function specifically.

5.8 Robson-drive

5.8.1 Function description

Robson drive is a function that makes it possible to temporarily give a 6x2 vehicle driving characteristics similar to those of a 6x4 vehicle. The system is comprised of a set of cog-wheels that can be lowered between the drive wheels and the wheels of a dead axle (Figure 5-25). This way traction power is transferred between the drive axle and the dead axle. The function is controlled by a two-position button (Figure 5-26).

Figure 5-25: Robson-drive on a dump truck

Figure 5-26: Robson-drive control and location on dashboard. Adapted from Driver's Manual FM/FH (Volvo Trucks 1998).

5.8.2 Underlying intentions/reasons for usage

The goal when using Robson-drive is the same as when using the central differential lock in a tandem truck. The aim is to have traction on as many wheels as possible. It can help reduce spinning.

5.8.3 Use context/situation

Check one or several applicable situations in the list:

- ☐ Primary driving
- ☒ Secondary driving
- ☐ Non-driving
- ☐ Living: passenger seat
- ☐ Living: bunk area
- ☐ Working

Activating Robson-drive is often the first measure when road conditions are not optimal. The terrain does not have to be particularly rough for this function to be used. A small slope with loose gravel for example is reason enough. Soft terrains like loose or wet dirt or snow are also reasons to activate Robson-drive. The function is often used when driving on steep slopes, especially when reversing. These situations are often encountered on construction sites.

The cog-wheels should not be lowered when the drive wheels are spinning or when the truck is at a complete stop. If they are, tires run the risk of being lacerated. Because of the function's design, it is used as a preventive measure to an even greater extent than other functions. It is used very often, even in situations that might not have required it.

Robson-drive can also be used as help when towing a heavy trailer. One driver also describes how the function is always activated when plowing snow in the winter.

The function is generally used at low speed. It is almost always used when the truck is loaded. (When driving on empty load, the dead-axle is invariably lifted and there is no reason to use Robson-drive.)

Frequency of use:

☒ Many times a day (every day)
☐ Many time a day (some days)
☐ Daily
☐ Sometimes
☐ Rarely
☐ Never

Seasonal variation:

☐ Yes
☒ No

Duration of use:

☒ Seconds
☒ 1 – 5 minutes
☐ 5 – 30 minutes
☐ ≥ 30 minutes

When driving on construction sites, the function is only active for a short moment, perhaps only a few seconds or a couple of minutes, until the truck is back on more solid terrain.

In special cases, such as when towing heavy trailers or plowing snow, the function can be active for extended periods of time, continuously while driving.

Usage in combination or sequence with other functions:

When Robson-drive is active, the next step to improve traction is to engage the full differential lock. Therefore the combination of Robson-drive and full differential lock is used in tough situations such as when the terrain is very soft or when there is loose soil on a steep slope.

5.8.4 Vehicle type / segment / markets / variants / superstructures

In the course of this study, Robson-drive has been observed on:

- FH 460 hp, model year 2005
- Construction segment
- Swedish market
- 6x2 configuration

Many drivers had previous experience with the function.

5.8.5 User scenarios (user action related to existing HMI)

Scenario 1: using Robson drive to gain traction on a construction site

This scenario takes place on a construction site. The driver is operating a dump truck with a 6x2 configuration equipped with Robson-drive. The truck is fully loaded with gravel, is coming from the main asphalt road and is turning in to the construction site. It is spring time and the sky is clear but the terrain on the site is still wet in some places (Figure 5-27).

Figure 5-27: wet terrain on construction site

The driver turns in to the construction site		
The drive activates Robson-drive		
	The driver presses the Robson-drive button	U
	The indicator light on the Robson-drive button is lit	A
	A warning signal sounds in the cab	A
	The Robson cog-wheels are lowered	F
	The warning signal stops	A
The driver reverses to the unloading site		
The driver raises the truck bed and unloads the gravel		
The driver slowly starts driving forward while the last of the load is gliding off the bed		
The driver lowers the truck bed		

The driver deactivates the Robson-drive function		
	The driver presses the Robson-drive button	U
	The indicator light on the Robson-drive button is lit	A
	A warning signal sounds in the cab	A
	The Robson cog-wheels are lifted	F
	The warning signal stops	A
The driver lifts the dead axle		
	The driver presses the axle lift button	U
	The indicator light on the axle lift button is lit	A
	A warning signal sounds in the cab	A
	The dead axle is lifted	F
	The warning lamp for the axle lift in the instrument cluster is lit	A
	The warning signal stops	A
The driver drives away onto the main asphalt road		

5.8.6 Different driver types

No difference in usage was observed based on driver characteristics.

5.8.7 Start up behavior

Robson-drive should not be activated or deactivated on start up.

5.8.8 Multiple controls

Is there a need to control the function from multiple locations?

☐ Yes
☒ No

If yes, from where?

5.8.9 Possible risks

Use of this function requires caution. The cog-wheels should not be lowered when the drive wheels are spinning or when the truck is at a complete stop. Otherwise tires can wear out or be lacerated. The strain on the cog-wheels can also be such that they risk getting warped.

What are the consequences if:

1. **The driver does not find the control in time**
   In many cases it will be too late. When a wheel has started spinning or if the truck already is stuck then it is very hard to activate the function.

   > *"If you start sinking, if you start getting stuck then it's too late, you can't lower the cog-wheels."*

2. **The driver does not find the control at all**
   Same risks as in 1.

3. **The driver is not aware that the function is activated**
   There is significant wear on the tires on all wheels. The higher the speed, the bigger the strain on tires and on the cog-wheels.

   > *"It shows very clearly if you have left them down and forgotten about them. There is a lot of noise when you come up to 30 km/h."*

4. **The driver is not aware that the function is deactivated**
   No major risk other than not having the expected traction.

5. **The function is activated by mistake**
   There is a risk of significant damage if the function is activated when wheels are spinning, when the truck is at a complete stop or at high speeds.

Time criticality to activate function

- ☐ High
- ☒ Medium
- ☐ Low
- ☐ None

Since the function shouldn't be activated when wheels are spinning or the truck is at a complete stop, there is a window of opportunity that shouldn't be missed. This is why time-criticality at activation is higher than the central differential lock which is used in the same situations.

Time criticality to deactivate function

- ☐ High
- ☐ Medium
- ☒ Low
- ☐ None

It is best to deactivate the function as early as possible because of possible strain on axles and tires. However there is no imminent danger in keeping it active a little longer as it doesn't impair the truck's handling.

5.8.10 Vehicle modes

The functions are to be operational in the following vehicle modes:

- ☐ Crank
- ☒ Running
- ☐ Pre-running
- ☐ Accessory
- ☐ Living
- ☐ Parked

5.8.11 Possible improvements

No suggestion regarding this function specifically.

5.9 Sanding

5.9.1 Function description

When a truck is equipped with a sanding system, sand-filled boxes are mounted next to drive wheels on both sides of the vehicle (Figure 5-28). The system is activated on command from the cab whereby sand is spread onto or in front of the tires. Depending on the configuration, a single button activates sand spreaders on both sides (Figure 5-29) or the spreaders can be activated independently using two separate buttons.

Figure 5-28: sand box mounted on timber truck

Figure 5-29: sanding control and location on dashboard. Adapted from Driver's Manual FM/FH (Volvo Trucks 1998).

5.9.2 Underlying intentions/reasons for usage

The goal when using the sanding function is to gain traction. A layer of sand under the wheels increases friction between the tires and the terrain.

5.9.3 Use context/situation

Check one or several applicable situations in the list:

- ☐ Primary driving
- ☒ Secondary driving
- ☐ Non-driving
- ☐ Living: passenger seat
- ☐ Living: bunk area
- ☐ Working

Sanding is almost exclusively used in winter conditions. It helps getting traction on snow-covered roads where there are icy patches, when there is freezing rain and more generally in slippery conditions.

Figure 5-30: a steep slope where sanding was needed but not enough traction was gained

The most common situation is driving on a slope. When driving upward, the goal is to have more traction, avoid spinning and getting all the way up to the crest. Figure 5-30 shows a situation where sanding was used but enough traction was not gained anyway. When driving downward, the goal is to improve the truck's ability to brake, which can be seriously impaired on slippery slopes.

While driving, the tires are warmed up. When the truck stops, the ice crust can melt and form a cavity under the wheel. It is then hard to drive away. By sanding just before coming to a stop, a layer of sand is left under the tire and more grip is available at start. For the same reason, sanding can be used before stopping to load the truck. This is especially true if stopping on a slope, but even on level ground the truck can glide while being loaded if the road is slippery.

Sanding could also be somewhat helpful in muddy conditions, depending on how coarse sand is used. However, the help is marginal and not enough to offset the cost of carrying the weight of two sandboxes. The boxes are commonly taken off the trucks come April.

Frequency of use:

- ☒ Many times a day (every day)
- ☐ Many time a day (some days)
- ☐ Daily
- ☐ Sometimes
- ☐ Rarely
- ☐ Never

Seasonal variation:

- ☒ Yes
- ☐ No

Timber transportation is where the function is most widely used. Drivers say they use it many times per day during the winter, for every load as a rule.

Duration of use:

- ☒ Seconds
- ☐ 1 – 5 minutes
- ☐ 5 – 30 minutes
- ☐ ≥ 30 minutes

The function is only activated for short moments. There is enough sand in the boxes to last for 100 m – 300 m depending on how coarse the sand is and speed. The quantity of sand used in a particular situation can vary depending on how easy it is to get hold of more sand. Timber transporter can usually fill their sandboxes at saw mills or paper mills where they unload. The boxes often need filling several times per day.

Some drivers have separate controls for the sandboxes on either side of the truck. This way they can sand alternately on each side and save sand.

Usage in combination or sequence with other functions:

While driving on upward slopes when conditions are slippery enough to warrant sanding, TCS-terrain is usually activated.

Drivers also say that sanding is more effective if the full differential lock is engaged. In that case, less sand is required and it is possible to sand alternately on each side.

5.9.4 Vehicle type / segment / markets / variants / superstructures

In the course of this study, the sanding function has been observed on:

- FH with 520 hp – 550 hp, model year 2001 – 2008
- Timber segment
- Swedish market
- 6x4 configuration

5.9.5 User scenarios (user action related to existing HMI)

Scenario 1: driving up a snowy hill with ice patches

A timber transporter with a tandem truck is driving on a forest road. The truck and trailer are fully loaded. It is the end of the winter, thawing has started. The snow cover is still a few centimeters thick, but the temperature is just around freezing point and ice patches are forming. The central differential lock is engaged. There driver comes to the foot of a hill.

The driver activates TCS-terrain		
	The driver presses the TCS-terrain button	U
	The indicator light in the TCS-terrain button is lit	A
	TCS-terrain is activated	F
The driver starts climbing up the hill, keeping as much speed as possible.		
The driver feels a wheel spinning. With TCS-terrain active, there is no loss of engine power.		
The driver decides to use sanding to improve traction		
The driver activates the full differential lock		
	The driver presses the differential lock button and pushes it to its lower position	U
	The full differential lock is engaged	F
	The warning lamp for the full differential lock in the instrument cluster is lit and flashes	A
The driver starts sanding alternately on the right and left side of the truck		
repeat	The driver presses the left sanding button for 3 seconds	U
	The indicator lamp in the left sanding button is lit	A
	Sand is spread in front of the left front drive wheel for 3 seconds	F
	The driver presses the right sanding button for 3 seconds	U
	The indicator light on the right sanding button is lit	A
	Sand is spread in front of the right front drive wheel for 3 seconds	F
The driver reaches the crest of the hill		
The driver deactivates the full differential lock		
	The driver presses the differential lock button and pushes it back to its middle position	U
	The full differential lock is disengaged	F
	The warning lamp for the full differential lock in the instrument cluster is stops flashing and is turned off	A

The driver keeps TCS-terrain and the central differential lock active until he drives off the forest road onto a main asphalt road.

Scenario 2: using sanding to avoid gliding while loading and facilitate start

A timber transporter is driving on a forest road with a slight slope and is on his way to load his last load of timber for the day. It has rained earlier in the day and the temperature is now falling to freezing point. There is a slight upward slope (Figure 5-31) where the stack of timber to load is located. The driver is worried that the road might become slippery.

Figure 5-31: slight slope on a forest road, ice forming as temperature falls

The driver approaches the stack of timber		
The driver activates sanding		
	The driver presses the sanding button	U
	The indicator light on the Sanding button is lit	A
	Sand is spread in front of the two front drive wheels	F
The driver brakes and the truck comes to a complete stop		
	Sand stops spreading	F
The driver deactivates sanding		
	The driver presses on the sanding button	U
	The indicator light on the sanding button is turned off	A
The driver loads the stack of timber. Thanks to the bed of sand under the wheels, the truck does not glide		
The driver has no problem starting and drives away with no wheel-spin.		

5.9.6 Different driver types

No difference in usage has been observed based on driver characteristics.

5.9.7 Start up behavior

The function should not be activated on start up

5.9.8 Multiple controls

Is there a need to control the function from multiple locations?

☐ Yes
☒ No

If yes, from where?

5.9.9 Possible risks

What are the consequences if:

1. **The driver does not find the control in time**
   While driving on a downward slope, there is a risk of not having enough grip to brake properly. While driving on an upward slope, there is a risk of wheels starting to spin and not being able to reach the crest. In the worst case, the truck could lose grip completely and risk gliding down. In this case it is hard to steer the truck.

2. **The driver does not find the control at all**
   Same risks as in 1. If the driver does not find the control it can be more difficult to drive away from a stop.

3. **The driver is not aware that the function is activated**
   No major risk other than running out of sand.

4. **The driver is not aware that the function is deactivated**
   No risk.

5. **The function is activated by mistake**
   No major risk other than running out of sand.

Time criticality to activate function

☒ High
☐ Medium
☐ Low
☐ None

On upward slopes when wheels start spinning or on downward slopes when in need of grip to brake, it can be vital to activate the function quickly.

In other cases it is not as critical, particularly not when used as starting help.

Time criticality to deactivate function

- ☐ High
- ☐ Medium
- ☐ Low
- ☒ None

5.9.10 Vehicle modes

The functions are to be operational in the following vehicle modes:

- ☐ Crank
- ☒ Running
- ☐ Pre-running
- ☐ Accessory
- ☐ Living
- ☐ Parked

5.9.11 Possible improvements

No suggestion regarding this function specifically.

6 DISCUSSION

In this section, the methods used for the field study and how they may have affected the results are discussed. Recommendations for further development are also given.

6.1 Methods used and how they may have affected the results

The composition of the group of interview participants was not set in advance and was formed little by little, depending on what drivers were available for interviews. In accordance, the distribution of both drivers' and trucks' characteristics is the result of chance more than careful planning. However, contacts were sought in the two segments that appeared to be the most frequent users of the functions at hand, and the group of interview participants still turned out to be quite diverse. A couple of additional drivers in the timber segment to really confirm the results would have been good. The information that could be gathered through observation was dependent on the current weather and road conditions. Had the field study been made earlier during the winter when the snow cover was still thick, results might have been different. All interviewed drivers were also men, which could be an issue. In any case, the purpose of the interviews was to gather qualitative data, not make a statistical analysis. Although different drivers may have had different examples to share, answers were similar and there was no “outlier”.

Conducting the interviews in the trucks while on the road proved to be an advantage. This allowed the driver to have direct access to the studied functions while answering questions about them. Many of the actions taken by the drivers are deeply rooted and almost automatic. Being able to touch the controls and point at them made for a much easier conversation. It also allowed the driver to come back to a previous question and expand on earlier responses if the situation made him think about things he had not mentioned at first. Finally, there was no real time constraints since most often the interview was continued until all questions had been covered, at which point the driver dropped the interviewers off at the next appropriate moment.

Using interviews and observations as data gathering methods gave good results. Other methods such as questionnaires and focus groups were also considered. Since most of the information sought was qualitative, using questionnaires would not have been a good choice. It would also have been difficult to formulate the questions in a satisfactory way, since knowledge of the functions and their use was so limited at the start of the project. A focus group where participants were free to talk to each other and expand on each other's comments might have given some additional insight. However, it would have been very difficult to organize.

6.2 Recommendations for future development

Based on the results of the field study, the following areas should be considered in future developments:

TCS can cause problems for many drivers, especially in the timber segments. The problem can be solved relatively easily by making the function optional, for example. A two-position button can also be used to choose whether TCS-terrain should be active or not. This way the status would remain the same even after turning off and starting up the engine, which is not possible with the current spring button (TCS-terrain is inactive by default).

Automation is widely used to make handling easier and improve the safety of vehicles. If automation is to be used to further develop and improve the functions studied in this report, care should be taken to satisfy the drivers' strong wish to have a sense of control.

It is very important that information about the current state of the functions is communicated to the driver efficiently, not least to ensure safety. For instance, if the driver for some reason is distracted and is not entirely sure about a function’s status, he should be able to read it rapidly and easily. A natural extension of this work would therefore be to analyze how the information system can be designed in an optimal way. To this end, careful attention should be paid to the facts that:

- Improper use of the functions can lead to negative consequences of varying degrees. Using the full differential locks the wrong way, for example, could cause severe damages. This should be taken into account in order to create an appropriate prioritization of the information from the different functions.
- External factors like speed, load, turning of steering wheels, degree of slope and terrain can influence this prioritization.

7 A NOTE ON SUSTAINABILITY

The big emissions of carbon dioxide in today's society and their negative effect on the environment are a subject that has been lively discussed during the latest years. Most scientists agree that this has started a global warming process that can have serious consequences for both the earth and our civilization if actions are not taken directly.

Contributing to these emissions is the transportation by land which is very important for today's society. A lot of this transport is made with trucks and therefore the truck driver's actions can have a big effect. Eco-driving, for example, is something that has been growing lately. The driver should avoid revving the engine when it is not necessary and try to roll in downward slopes. That will have the effect that less fuel will be used and thereby also less carbon dioxide will be emitted. In the long run less fuel will have to be extracted and less transportation of fuel is required, which both will have the same positive effect. Volvo trucks offers this kind of courses to Volvo truck drivers.

Drivers can also reduce their effect on the environment by preventing tire wear the best they can. The more tires on a truck that are touching the ground the more tire wear there will be. That leads to waste of material and it will also increase fuel consumption. Therefore it is important for drivers to lift their axles as soon as they are not necessary. If a driver turns sharply on a paved road with the full differential lock engaged the tire wear will also be great. The roads will at the same time be worn which leads to waste of material. Drivers can be influenced to behave in an environmentally positive way by designing information systems correctly.

8 CONCLUSION

The purpose of the project was to conduct a field study in order to identify and map out the current usage of a number of functions aimed at facilitating driving in rough road conditions.

Data was gathered by interviewing and observing 13 drivers mainly from the timber transportation and construction segments, where the use of the studied function is widespread. The data was compiled into documents containing detailed descriptions of the usage of each function, including user scenarios and possible combinations of functions.

A template for these description documents was provided by Volvo 3P. Part of the task was to evaluate the template and adapt it so it could be used to describe any function. It proved difficult to describe the usage of the different functions in a consistent way. Usage could vary between segments, situations or according to truck characteristics and answers had to be categorized for a complete picture to be given.

The main findings were that the drivers value most of the functions and value the help they offer. They are generally happy with the design of controls. Although usage varied across segments and different trucks, it was found that usage was independent of driver characteristics. No difference in usage was found based on differences in age, experience, attitudes.

No major discrepancies were found between the planned usage of the functions, as described in the user manual, and their actual usage in the field.

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APPENDIX A – CURRENT USER SCENARIO TEMPLATE

Function description

A brief description of the function. Preferably with source reference.

Underlying intentions/reasons for usage

Preferably include pictures.

Use context/situation

Is the function used; during driving in certain conditions, when living in the cab etc.?
Preferably include pictures.

Check one or several applicable situations in the list:

☒ Primary driving
☐ Secondary driving
☐ Non-driving
☐ Living: passenger seat
☐ Living: bunk area
☐ Working

Frequency of use:

☒ Many times a day
☐ Daily
☐ At certain conditions, e.g:

For how long time in average is the function enabled/activated?

Used in combination/sequence with other functions:

Vehicle type / segment / markets / variants / superstructures

Applicable to…

User scenarios (user action related to existing HMI)

In the User scenarios *user actions* and *vehicle actions* are identified and connected to usage situations. The vehicle actions are divided into *function actions* and *additional feedback* (vehicle actions that exists solely for the user's understanding).

- User action
- Function action } Vehicle action
- Additional feedback

For some usage situation the interaction will differ depending on control and/or function variants. When this is the case the different interaction variants are marked out as alternatives.

Describe some key usage situations and include the U, F and A bullets described above.

Different driver types

Do differences in driver characteristics result in different use of the function? Consider novice/expert, attitudes, way of driving and reason for driving.

Start up behavior

Is it needed to have the function automatically enabled/disabled at engine on?

Multiple controls

Is there a need to control the function from multiple locations?

☒ Yes
    - If yes, from where

☐ No

Possible risks

Describe possible risks.

What are the consequences if:

- The driver does not find the control in time
- The driver does not find the control at all
- The driver is not aware that the function is activated/deactivated
- The function is activated by mistake

Time criticality to activate/deactivate function:

☒ High
☐ Medium
☐ Low
☐ None

Vehicle modes

The functions are to be operational in the following vehicle modes:

☐ Crank
☒ Running
☐ Pre-running
☐ Accessory
☐ Living
☐ Parked

Possible improvements

Are there user needs that are not satisfied with the existing solution?

APPENDIX B – PROPOSED USER SCENARIO TEMPLATE

Function description

A brief description of the function. Preferably with source reference.
Include pictures of function or schematic sketch explaining the function if needed. Include pictures of controls and their location on dashboard.

Underlying intentions/reasons for usage

Preferably include pictures.

Use context/situation

Is the function used; during driving in certain conditions, when living in the cab etc.?
Preferably include pictures.

Check one or several applicable situations in the list:

- ☐ Primary driving
- ☐ Secondary driving
- ☐ Non-driving
- ☐ Living: passenger seat
- ☐ Living: bunk area
- ☐ Working

Frequency of use:

- ☐ Many times a day (every day)
- ☐ Many time a day (some days)
- ☐ Daily
- ☐ Sometimes
- ☐ Rarely
- ☐ Never

Seasonal variation:

- ☐ Yes
- ☐ No

Comments.

Duration of use:

- ☐ Seconds
- ☐ 1 – 5 minutes
- ☐ 5 – 30 minutes
- ☐ ≥ 30 minutes

Comments.

Usage in combination or sequence with other functions:

Vehicle type / segment / markets / variants / superstructures

Applicable to…

User scenarios (user action related to existing HMI)

In the User scenarios *user actions* and *vehicle actions* are identified and connected to usage situations. The vehicle actions are divided into *function actions* and *additional feedback* (vehicle actions that exists solely for the user’s understanding).

- User action
- Function action
- Additional feedback

} Vehicle action

For some usage situation the interaction will differ depending on control and/or function variants. When this is the case the different interaction variants are marked out as alternatives.

Describe some key usage situations and include the U, F and A bullets described above.

Actions can be presented in the form of a table with the following structure:

Activity related to function		
	Action 1	U
	Action 2	A
	Action 3	F
Activity needed for context		
Next activity related to function		
	Action 1	U
	Action 2	F

Use pictures to illustrate the scenario when possible.

Different driver types

Do differences in driver characteristics result in different use of the function? Consider novice/expert, attitudes, way of driving and reason for driving.

Start up behavior

Is it needed to have the function automatically enabled/disabled at engine on?

Multiple controls

Is there a need to control the function from multiple locations?

☐ Yes
☐ No

If yes, from where?

Possible risks

Description of general risks and important factors to consider.

What are the consequences if:

1. **The driver does not find the control in time**
2. **The driver does not find the control at all**
3. **The driver is not aware that the function is activated**
4. **The driver is not aware that the function is deactivated**
5. **The function is activated by mistake**

Time criticality to activate function

☐ High
☐ Medium
☐ Low
☐ None

Time criticality to deactivate function

☐ High
☐ Medium
☐ Low
☐ None

Vehicle modes

The functions are to be operational in the following vehicle modes:

☐ Crank
☐ Running
☐ Pre-running
☐ Accessory
☐ Living
☐ Parked

Possible improvements

Are there user needs that are not satisfied with the existing solution?

APPENDIX C – INTERVIEW TEMPLATE

FRÅGOR OM FÖRARE OCH LASTBIL

- Ålder?
- Antal års körerfarenhet?
- Vilken lastbilsmodell kör de?
- Vilka hjälpfunktioner har denna lastbil?
- Hur länge har de kört just denna lastbil?
- Är det deras egen lastbil?
- Har de själva valt vilka funktioner som den ska inneha?
- Vilken erfarenhet har du av användning av funktionen/funktionerna?

FUNKTION

- Kan du beskriva funktionen, hur den fungerar?
- Hur ofta används den?

SITUATION

- I vilken/vilka situation/er används den?
- Hur kan väglaget se ut och hur påverkar det?
- Hur påverkar vädret situationen?
- Hur/när märker du att situationen uppstår?
- Vid vilka hastigheter kan situationen uppstå?
- I vilken grad inverkar lutningen av underlaget?
- Vilken vikt/belastning kan lastbilen ha och hur påverkar det?
- Hur fort är det nödvändigt att agera?

HANTERING

- Ger situationen alltid upphov till samma handling/agerande?
- Hur ser handlingssekvensen ut när situationen uppstår?
- Behöver flera handlingar utföras samtidigt?
- Behöver flera funktioner användas samtidigt?
- Behöver flera funktioner kunna aktiveras på samma gång?
- Hur lätt/svårt är det att utföra nödvändiga handlingar?
- Hur tidskritiskt är det att aktivera/avaktivera funktionerna?
- Hur lång tid tar det att aktivera eller avaktivera funktionen innan den ger effekt. Kan det variera från situation till situation?
- Vad händer om funtionen in aktiveras? Har det hänt? Vilken situation? Hur ofta? Varför?
- Kan funktionen aktiveras från fler ställen? Är det önskvärt? Varifrån? Varför?
- Hur upplevs situationen?
- Finns det några störande saker utanför eller i hytten?

- Hur ofta uppkommer den speciella situationen?
- Hur länge vara situationen?
- Hur länge används funktionen?
- Vad händer om funktionen inte aktiveras? Har det hänt? Vilken situation? Hur ofta? Varför?
- Vad händer om funktionen aktiveras av misstag? Har det hänt? Vilken situation? Hur ofta? Varför?
- Är funktionen och eller situationen något som pratas om mellan förare?
- Bör funktionen slås på/av vid motorstart?

REGLAGE

- Hur märker man om funktionen är av eller på eller i vilket läge den är?
- Hur ser informationen ut? Vilken feedback? Ljud, ljus mm.?
- Vilken form av feedback är bäst?
- Är det någon speciell typ av reglage du trivs bäst med?
- Vilken typ av reglage är det på funktionen?
- Hur lätt eller svårt är det att komma åt funktionen?Var sitter reglagen mest optimalt?
- Rätt/fel kombination av reglage tillsammans?
- Vilken storlek av reglagen föredras?
- Sitter de för tätt/långt ifrån varandra?

- Har de erfarenhet av andra lastbilar med andra uppsättningar/kombinationer av funktioner?
- Om ja. Är det någon speciell uppsättning/kombination som de föredrar?