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SELMA

A method for identification of critical situations in automated trucks

Master of Science Thesis in the Master Degree Program Industrial Design Engineering
Master of Science Thesis in the Master Degree Program Product Development

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Abstract

While automated vehicle technology progresses, new situations in the traffic may occur that consequently can lead to new risks for the driver. These risks need to be identified to enable safe vehicle designs. To assure identification and assessment of risks in automated vehicles, new, complementary or adapted methods for analysis of these may be required. The thesis objective was to design a method for identification of critical situations in automated trucks, a method which can support engineers working with concept development of trucks. The thesis was made within Volvo Group Trucks Technology, in the first half of 2017.

The thesis consisted of two working blocks: 1) the system study and 2) the method development. The first working block aimed to explore underlying reasons for potential risks and established working procedures for risk analysis, and the second working block involved a design of a new method for identification of critical situations. The major part of the system study, consisted of literature studies, interviews and think-aloud sessions, were the aim was to collect information about both content and design of the new method. The study explored five factors which may lead to critical situations: driver, truck, organisation, traffic and infrastructure. It was concluded that the best way to identify critical situations was to use and combine these factors within the method. The method development was based on the implications found in the system study, and consisted of an iterative process of creation and evaluation. To assure that the method would lead to useful results and satisfaction, the definition of usability was continuously considered in the work.

The resulting method, SELMA is a method for identification of critical situations. It consists of two separate tools: guide words and guide cards. The guide words are open for interpretation, and meant to generate new, rare and unpredictable situations. The guide cards are more concrete and meant to guide the users in generating specific and combined situations. Both tools originate from the factors explored in the system study. In accordance to the result, the thesis concludes that any method used to analyse and evaluate driver risks in automated trucks, should consider the interaction between the defined factors. Automated trucks bring new challenges and demands within these areas and critical situations emerge from this interplay.

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1 Introduction

The following chapter introduces the master thesis by briefly describing its background, objectives and research questions.

1.1 Background

Advances in the development of automated technique have raised interests in a range of fields, including the vehicle industry. It is no longer a question of *if*, but *when* automated cars and trucks run regularly (IEEE Spectrum, 2017). Automation enables improvements in both experience and safety for the driver, and researchers around the world work hard to turn ideas into reality. Adaptive cruise control, lateral steering support, automatic emergency braking and parking assistance are some of the advanced driver-assistance systems which car, and to some extent truck manufacturers, offer today. It is claimed that both private and business transportation derive advantages from automated driving, since roads will be safer and traffic and fuel efficiency will be greatly improved (Thompson, 2016).

Another opportunity arises when the driver can focus on non-driving related tasks while the vehicle drives, either at times or continuously. With high automation – SAE driving automation level 4 – the vehicle is responsible for all driving tasks, even when the driver does not respond appropriately at request to intervene (Chapter 3.3). However, automation generates new challenges and demands. The traffic and the driver’s role will change, and new situations consequently lead to new risks for the driver. These risks need to be identified, so that safe equipment can be designed. Current methods for risk analysis are developed to manage currently known situations, but may not handle risks and situations associated with automated vehicles. To assure identification and assessment of risks and development of safety equipment which can protect the driver, new or complementary methods may be required. These methods must consider the intersection of automation, human factors and safety systems (Figure 1).

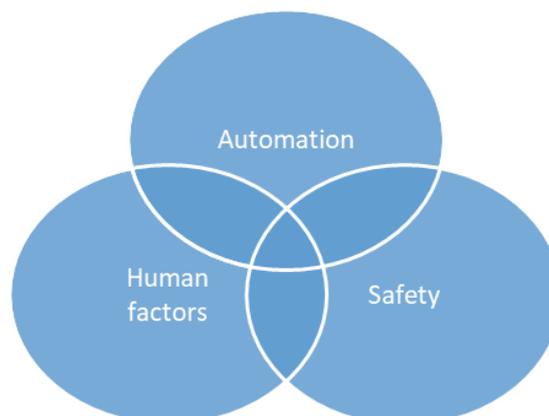


Figure 1: Intersection between automation, human factors and safety.

1.2 Objective

The objective of the master thesis was to design a new method for identification of critical situations. The method should consider situations in relation to SAE Level 4 and long-haul trucks driving on highways. The method should be used to support the engineers working with concept development of trucks, and the thesis consider both its content and design.

The thesis was made within Volvo Group Trucks Technology (Volvo GTT), at the department of Vehicle, Technology and Safety, in the first half of 2017.

1.3 Research questions

The thesis planned to answer and use the following research questions as a support throughout the process:

- What aspects and occasions may lead to critical situations for the driver of automated trucks?
- How should a new method, which aims to identify these situations be designed?

1.4 Report structure

The report consists of twelve chapters (Figure 2). To start, Chapter 1 presents the background and the objective of the thesis. Following this, comes Chapter 2 which presents the final result – the method that the thesis has developed. After that follows Chapter 3 as an introduction to subjects that have served as a foundation for the work in the thesis. Chapter 4 presents the procedure and methods used during the work.

The following four chapters are divided into two parts: The System study (Chapter 5 and 6) and the Method development (Chapter 7 and 8). These chapters correspond to the thesis two working blocks and presents the thesis' results. At last, Chapters 9 and 10 present discussions of the thesis work and results, and the conclusions drawn from the work.

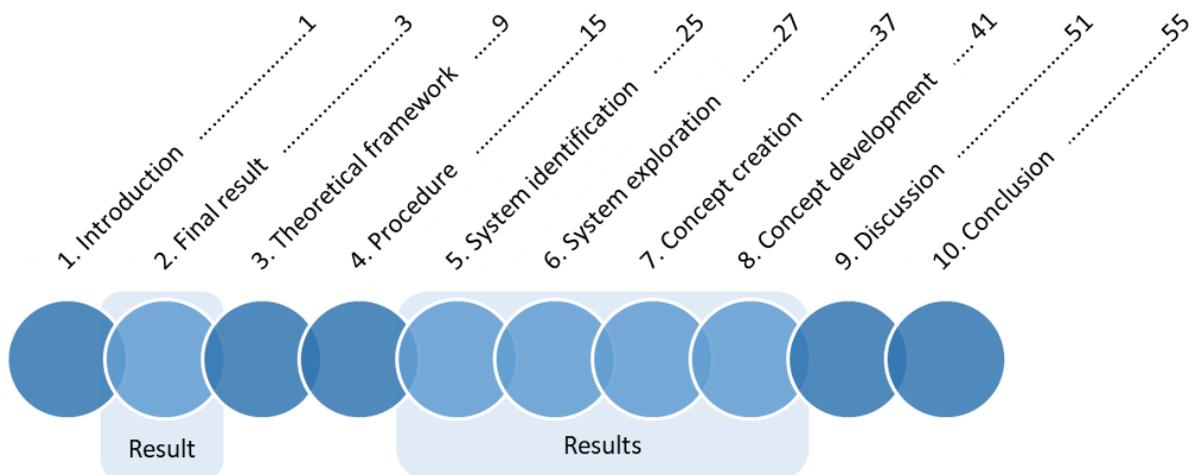


Figure 2: The report structure.

2 Final result

The result of the thesis is the method SELMA (Sofia and Emilia's Lorry Method Analysis). The method aims to: complement existing methods for risks analysis, such as the ones presented in the theoretical framework (Chapter 3.4); and support the concept development by providing tools for identification of situations which may occur in relation to automated trucks.

SELMA is meant to complement current risk analysis methods. It aims to come up with new and particularly future situations, which current risk analyses can evaluate. The method is not supposed to cover all potential risks, but is an inspirational tool with the objective to broaden the perspective of engineers who works with risk prevention.

SELMA consists of two tools: Guide cards and Guide words (Figure 3). The *Guide cards* aims to identify situations which occurs in the interaction between different risk factors, and the *Guide words* aims to identify more unpredictable and unexpected situations. The factors, as well as the content of SELMA originates from the study of aspects which affect the driving of automated trucks (Chapter 6.2). The cards present statements from the study, and the words present single words selected from the same.



Figure 3: SELMA Guide cards and Guide words.

The procedure of use is the same for both the Guide cards and the Guide words, and runs:

- 1) Selects cards from one or more categories, or form a sentence of a few or more words. These represent statements.
- 2) Question *what if* in relation to the statement.
- 3) Use the answers to brainstorm around new and potentially critical situations.
- 4) Write down the situations.

The method derives advantages from collaborative work. This, to broaden the perspective of the situations and bring out various view-points. Following this and the creative work approach, SELMA is

foremost suitable for work in groups, and preferably teams which represent different expertise or parts of an organisation. While working, the participants should welcome any idea, avoid criticism and focus on generating as many situations as possible. As a suggestion, a moderator can be appointed to check this and one other person responsible for the documentation.

As previously stated, both the Guide cards and the Guide words are meant to inspire the generation of new situations. This, by providing a creative and new work approach which corresponds to the innovation within automation. Moreover, the tools make use of the many speculations and opinions within the field, by recalling the participant's experiences and encouraging associations.

In comparison, the two tools provide different work approaches which may suit different personalities and preferences. The cards serve a one more structured approach which guarantee a set of situations, whereas the words are more explorative and potentially less certain.

2.1 Guide cards

SELMA Guide cards consists of 31 cards: 1 instruction cards and 30 guide cards (Figure 4). The guide cards present situations and aspects related to the driving of automated trucks, more precisely; re-formulated sentences from the list of guidelines (Chapter 6.3). The Guide cards aim to inspire the ideation of new situations by asking the user to combine cards and look for coincide events. The following chapter presents the content, the use and the design of the Guide cards.



Figure 4: SELMA Guide cards.

2.1.1 Content

The cards present various aspects which affects the driving of automated trucks. The content – aspects which affects the driving automated trucks – is categorised into the six groups: driver, truck, organisation, traffic, infrastructure and driver-truck interaction. These correspond to the five risk factors identified during the system exploration (Chapter 6.2) as well as the additional interaction between the driver and the truck.

Some cards are critical situations or events themselves, whereas some are without risk until they coincide with situations from other factors. The cards from the factor *driver* present tasks,

behaviours and positions of the driver. The ones related to the *truck*, considers potential failures of hardware and software, as well as challenges for and behaviours of the system. The factor *organisation* – meaning haulages and logistics firm – affects the driving via rules, regulations and incentives to make business, reduce costs and improve efficiency. The *traffic*, which is the interaction between the truck and other vehicles, brings out challenges that involve the driving of others, as well as sudden appearance of animals or other hindrance. In close relation to the traffic, comes the *infrastructure*. It considers the road environment in terms of road condition, quality of roads and road signs, country and weather. Lastly, the *interaction between the driver and the truck*, introduces situations that may occur due to ambiguous task allocation and in the transition between the system and the driver. The complete set of cards can be found in Appendix 1.

2.1.2 Use and work approach

SELMA Guide cards can be used one at a time or in combination with each other. In either case, the user asks *what if...* followed by the statement(s) of the cards, and uses the answers to form and brainstorm around potentially new situations. When combining the cards, the results are situations which occur in the interaction between the factors, besides coincide events. In any case, all situations should be written down. To find more and new situations, trigger the ideation and create discussion, cards can preferably be added and subtracted while working.

The picture below (Figure 5) shows one example of how the guide cards can be used. In this case, the answer of the question *what if* may lead to a critical situation where the driver unsafely turns or brakes to avoid a collision. This, because of stress from the organization and the sudden appearance of a hinder.



Figure 5: A combination of three SELMA Guide cards.

2.1.3 Design

The cards have the same basic design: a lower part, which presents the question *what if* and the factor, and an upper part where the actual statement is written. Besides, the cards are colour coded according to the categories (Figure 6). This aims to support and encourage the user to combine cards from the factors. The selections of the colours are inspired by the map of primary and secondary colours, where the primary colours red, blue and yellow, and the secondary colours green and purple are used in this case (Hutton-Jamieson, 1986). Cards considering the driver are red and meant to associate with the human body, the truck are blue as traditional working clothes and the organisation is yellow. Cards relating to the traffic and the infrastructure are dark green respectively

light green, and aims to bring the mind to the surrounding nature. Last, come the cards which relate to the interaction between the driver and the truck – the human-machine interaction. As the combination between driver and truck implies, this colour is the mix of blue and red: purple.



Figure 6: SELMA Guide cards and the colors of the factors.

2.2 Guide words

SELMA Guide words include some hundred words (Figure 7). The most are related to the driving of automated trucks, and some are words added to ease sentence structuring. The idea with the words is to use them as a base for brainstorming of unpredictable and unexpected situations. The following chapter tells about the content, the use and the design of the Guide words.



Figure 7: A selection of SELMA Guide words.

2.2.1 Content

The majority of the Guide words originates from a study of the factors which affect the driving. These are re-formulated sentences from the list of guidelines (Chapter 6.3). Besides, there are words inspired by the content of a word game, and another some selected by the authors (Magnet poetry, 2017). The last, are analogues and opposites added to achieve a balanced and complete set of words. A complete list of the guide words can be found in Appendix 2.

The words are of different parts of speech, most in primary form. There are nouns, adjectives, verbs and particles meant to ease the sentence structuring. The selection of words is limited, but since some have several meanings either in English or other languages, they can be interpreted also in other ways.

2.2.2 Use and work approach

SELMA Guide words are used to form sentences which can be used as a start when identifying critical situations. More precisely, the user takes words, form a sentence of these, asks *what if* in relation to the statement and uses the answers to brainstorm around potentially new situations.

The sentences can be made up of a few or more words, either deliberately selected or randomly chosen. The way depends on personal preference and can preferably be alternated to vary the method. Both approaches have advantages: selecting specific words may suit some personalities better, whereas using a more random approach may lead to more unpredictable and unexpected situations. Also, sentences can be studied in combination with or in relation to each other. This to improve the identification of consequences, parallel and subsequent events. The principle behind the work is inspired by the approach of brainstorming. Both when forming the sentences and answering the question, quantity should be preferred in front of quality, criticism be postponed and any idea met. This to emphasize creativity and generation of unpredictable situations.

The pictures below (Figure 8 and Figure 9) show two sentences formed by participants during a workshop where the Guide words were tested (Chapter 8.2). The first sentence, made up of the words *appearance*, *traffic* and *emergency* lead to a situation where another vehicle ends up in front the truck as a consequence of a previous accident. This is a situation which the truck cannot predict, and potentially neither prevent not mitigate. The other example started from the words *drive*, *sudden*, *huge*, *yellow* and *fast*. From this, the participants came up with a situation where a kangaroo runs in front of the truck and moreover, a discussion about handling of unpredictable events and behaviours in general.



Figure 8: A sentence formed by SELMA Guide words.

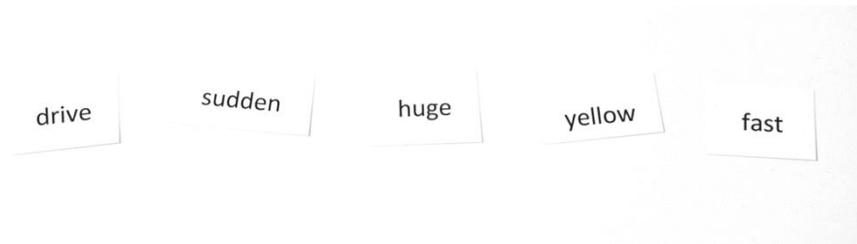


Figure 9: Another sentence formed by SELMA Guide words.

2.2.3 Design

All words have the same style and colour: black print on white papers. This simplicity is an advantage of the method. It enables for users to combine words without respect to their origin, opens-up for various sentence formations and interpretations. Moreover, it eases reviews and makes it possible for users to print words and use them whenever and wherever they like.

The Guide words can also potentially also be made as magnets. These should have the same style and size as the paper words. Using magnets will not support update and distribution, but potentially be more user-friendly thanks to its light load, easier grasp and long lasting. Not the least, this means the words can be used and stored on whiteboards.

2.3 Conclusion

The final result is the method SELMA meant to support identification of critical situations in automated trucks. It consists of two tools, Guide cards and Guide words, which apply two different approaches for idea generation. Guide cards uses a structured approach, based on pre-defined situations and is used to form a number of concrete situations. Guide words emphasize more explorative work and aim to form unpredictable situations.

In total, SELMA supports the concept development of automated trucks. It provides a creative and new approach to risk identification, which agrees with the innovative area of automated trucks. The method also derives advantages from promoting collaborative work, as it promotes generative work and enables users from various functions to contribute.

3 Theoretical framework

The following chapter introduces subjects which served as a foundation for the thesis. It starts with an introduction to the business of truck transportation and automation and risks classifications. Further, it presents a selection of methods for analysis and design work, which served as a foundation for the design of the new method.

3.1 Truck transportation

Truck transportation plays a significant role in the society and is a prerequisite for business and trades, job opportunities and economic growth (Sveriges Åkeriföretag, 2017). Of all the goods transportation in Sweden today, 80 % are carried out with trucks. The haulage industry behind this includes 10 000 haulage contractors, from one-man firms to larger companies. To assure proper working environments for everyone working in the industry, the European Union has developed certain rules and regulations regarding working and resting time (Transportstyrelsen.se, 2017). These aim to promote traffic safety, assure legitimate competition within the industry and enable social intercourse for the drivers.

3.2 Automation and classification

The vehicle industry is heading towards automation and today most manufacturers provide trucks with advanced driver support and safety systems. To facilitate the communication and collaboration within the area, the organization Society of Automotive Engineers (SAE) provides a standard with common taxonomy and definitions for automated driving. The standard presents a classification system for on-road motor vehicles, with six levels of driving automation: from “no automation” to “full automation” (Figure 10) (SAE, 2017).

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the <i>driving mode</i> -specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the <i>driving mode</i> -specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	System	Human driver	Human driver	Some driving modes
Automated driving system (“system”) monitors the driving environment						
3	Conditional Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	System	Human driver	Some driving modes
4	High Automation	the <i>driving mode</i> -specific performance by an automated driving system of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes

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Figure 10: SAE levels of automation.

Today, most manufacturers provide trucks operating at Level 1 – Driver Assistance, and a few vehicles at Level 2 – Partial Automation (Automated driving, 2014). Meanwhile the development of techniques for higher levels of automation – where the vehicle not only monitors the driving, but

also has a fall-back performance of the dynamic driving task – continues. Conditional Automation – SAE driving automation level 3 – is nevertheless debated; to suppose that the driver can take charge in certain occasions means essential risks (SAE, 2017; Bainbridge, 1983). With consideration to human factors, many manufacturers therefore aim to move directly to high automation, SAE level 4 (TechEmergence, 2017). In Full Automation – SAE level 5 – the system has the capability to handle all driving modes and a human driver is therefore no longer needed. The time to market introduction of the levels is arbitrary, and the same vehicle can include several levels for different operations (SAE, 2017).

3.3 Risks and classification

Trucks are complex products and failure of its hardware or software can lead to fatal consequences for as well the driver as other road users (ISO, 2017). Each year, there are over 20,000 road fatalities in the EU, out of which 15% are related to trucks (Ekfjorden et al., 2017). These accidents are seldom caused by one single factor, but rather an interaction between use errors, occasions in the environment and vehicle failures. As a principle, it is the driver who is responsible for the vehicle and the owner who is obligated to have a traffic insurance (Swedbank.se, 2017; IF, 2017). But with evolving automation, it could possibly be vehicle manufacturers rather than drivers that would be liable in eventual accidents (Swedbank.se, 2017).

Considering the evolving automation and vehicle safety in general, designers and engineers must constantly be aware of the likelihood and the risk of potential errors (Aven, 2013). The ability to predict, prevent and mitigate these is a key element in risk management, and analysis methods is a tool to address both risks and uncertainties. To ensure functional safety in vehicles, the ISO (*International Organization for Standardization*) has published the standard ISO 26262, *Road Vehicles – Function safety* (ISO, 2017). The standard is meant to assure quality, safety and efficiency of products, services and systems and implies that risks must be reduced to an acceptable level according to a standardized classification system.

3.4 Analysis methods

This chapter brings out a number of methods for risk analysis. These provided understanding for general analysis work and served as a foundation during the method development. The first two methods focus on risks related to mechanical systems, and the following four on human-machine interactions.

3.4.1 Hazard analysis

Hazard analysis is based on ISO26262 and aims to identify and classify potential malfunctions of systems (Bridal and Hansson, 2016). The results of the analysis are the starting point for defining and specifying appropriate risk reduction measures. It investigates system with respect to potential consequences and assesses how critical possible malfunctions are. Upon this, it helps to form corresponding goals with the objective to avoid or mitigate the problems. The analysis uses a table format to list and describe activities via hazards, situations, hazardous events, person at risk, severity, exposure and controllability. The result refers to the risk classes ASIL (Automotive Safety Integrity Levels) defined by ISO and a safety goal (Beckers et al., 2017).

3.4.2 FMEA – Failure Mode and Effects Analysis

FMEA (Failure Mode and Effects Analysis) is a method which identifies and helps to understand potential failure modes, their causes and effects on the system or users (Carlson, 2012). The analysis is performed early in the development process and often focuses on the design of subsystems or single components. Starting from information about the product and the process, risks can be identified and assessed stepwise in a matrix which considers failure mode, effects, severity, cause, occurrence, prevention, detection and a risk priority number (RPN). From this, recommendations of corrective actions are identified, prioritized and carried out to address the most serious concerns. The matrix also includes columns for follow-ups.

3.4.3 SWIFT – Structured What If Technique

SWIFT (Structured What-If Technique) is a risk identification technique based on structured brainstorming (Card, Ward and Clarkson, 2012). It uses questions in combination with defined guide words and headings to examine risks and hazards on system and/or subsystem level. In a matrix, each component or process step is listed and later questioned in relation to guidewords. Impact and outcome is then described and priority defined. The analysis is intended for groups and workshops, and aims to elicit risks from the participants by the questions *how could...?* and *what if..?* for hazard respectively risk identification. In comparison with FMEA, SWIFT does not go into the same level of detail and is therefore considerably faster. Nevertheless, it is important to remember that the purpose is effective brainstorming, not analysis and that the results rely much on the people performing the analysis.

3.4.4 ECW – Enhanced Cognitive Walkthrough

ECW (Enhanced Cognitive Walkthrough) is a usability problem analysis which identifies things that may hinder a user from accomplishing a task, and investigates the reason behind these (Bligård and Osvalder, 2012). For each step of the handling sequence the method checks whether the user's goal and knowledge leads to a correct action. The check is based on questions, which are prompt at tasks and operations to find out whether *the user will know about, notice and associate* certain functions or not. The answers are grades which refer to levels of success and the problem seriousness, followed by a motivation. Each problem is then classified by problem type with explanation. To give the analysis a semi-quantitative result, the findings are compiled into matrixes. The elements for the matrix are selected with respect to the scope of the analysis, and the result shows the sum of errors according to the classification.

3.4.5 PUEA – Predictive Use Error Analysis

PUEA (Predictive Use Error Analysis) is used to predict and analyse potential use errors in the interaction. The method uses questions, based on the principle *what if...?* to prompt the interaction stepwise and form a list of errors, which are further investigated by the means of pre-defined classifications and descriptive texts (Bligård and Osvalder, 2012). The investigation looks into error type, cause, consequences, possibilities of detection, recovery, protection and prevention. At last, the findings can be compiled into matrixes. As in the ECW, these give the analysis a semi-quantitative result which is based on the classification and considers scope of the analysis.

3.5 Design methods

The following chapter presents a selection of design methods, which were used both as inspiration and guidance in the design of the new method. Design methods provide approaches and tools for explorative and generative work, tasks which are important when aiming to identify situations.

3.5.1 Question who, what, where, when, why and how

Who, what, where, when, why and how is some of the most important questions in the analysis of a design (Boeijen et al., 2016). The answers can be used to form a structured and complete description, which help people to understand the problem, its stakeholders and facts and values involved. The description can be used to identify areas where more information is required, and to set up lists for prioritization. The session should preferably be based on an initial problem or task description. Questions can also be used to support idea generation. One method for this is the *how-to...?* technique, which means asking the question *how* in different ways. Both the questions and the answers stimulate creativity and provide a comprehensive and varying overview of the task or problem. In order to work efficiently, judgements should be postponed and quantity promoted in front of quality. It is also preferable to associate on each other's ideas.

3.5.2 Mediating tool

A *mediating tool* is an object, picture or model used to ease the understanding for scenarios and make sure all participants understand the circumstances. *Toolkit* is one type of mediating tool, consisting of physical elements used for modelling, visualization and play activities (Martin and Hanington, 2012). The elements can be in e.g. three-dimensional forms, constructions bricks, images and words, paper or cards. The elements aim to build metaphors, make stories or imagine real settings. The type depends on the activity and possibilities they aim to encourage. Either way, toolkits engage people in creative work and ease the expression of feelings, emotions, thoughts and desires which may be hard to articulate in other cases. One example of a mediating tool is picture cards. *Picture cards* are collections of images, texts and words which prompt people to recall experiences and form stories about these in e.g. during interviews. The content is determined by the subject and the purpose of the work. Nevertheless, also empty cards are preferable since new thoughts and details may emerge during the session. When working, one should promote cards to be added and subtracted when desired to create a more flexible process. Thanks to its visual and concrete form, picture cards provide an anchor for discussions and facilitate conversations. The major advance of the method is that it allows people to view experiences and reveal practices.

3.5.3 Design charette

Design charette is a workshop session where multidisciplinary groups generate ideas during subsequent rounds of work (Martin and Hanington, 2012). The essence of the methods is that a group of participants come up with a set of ideas and hand over the best to another group for evaluation, further development and consolidation. After some rounds, the results are most likely optimized ideas. To enable documentation and prompt creativity each group should have access to papers, pencils, colour markers and such. Upon generation of qualitative ideas, design charettes are powerful when exploring a problem space and when aiming to produce a large amount of rough ideas.

3.5.4 Design workshop

Design workshops are organized sessions where participants perform generative, evaluative, creative or other activities in relation to an assigned problem (Martin and Hanington, 2012). They can be used for idea generation, collaborative creation, verification and review of concepts and to collect insights during iterative design processes. The session can involve anything from discussions and role plays, to sketching, collages, map making, diagram analysis, creation of prototypes and storyboards. Either way, the findings need to be documented in some way. In short, workshops provide a fun and engaging way to collect valuable input and gain trust among stakeholders. However, they require intense and appropriate planning of time and logistics. To develop and determine the interaction between a user and a product, a workshop can involve simulation activities such as role-play (Boeijen et al., 2016). *Roleplaying* is a theatrical activity where designers act out the tasks of a user. The task involves behaviours and routines that the user experiences in the real scenario. A role-play helps to obtain a better understanding for the complexity of a situation, the concept and the interaction, and can be used to develop ideas of how a prospective scenario can look like. It can also create empathy and enlighten challenges and opportunities that can be met by design (Martin and Hanington, 2012).

3.5.5 Brainstorming

Brainstorming is a design approach made up of rules and procedures for idea generation (Boeijen et al., 2016). The method assumes that quantity leads to quality, and is usually carried out with a group of people. The rules prescribe that criticism should be postponed, any idea is welcomed, and that combinations and improvements are sought. Brainstorming is most useful for relatively simple problems and not areas which require specialized knowledge. Closely related to brainstorming comes, *brainwriting*, *braindrawing* and *body storming*. The first two supposes that participants write and draw ideas on papers which are passed on between each other several times. The third is a physical exercise which combines role-play and simulation to create empathy, prompt new ideas and spontaneous prototyping (Martin and Hanington, 2012).

3.5.6 Mind maps

Mind maps are graphical representations of ideas and the relation between these, which originate from centred guide words (Boeijen et al., 2016). They are used to bring structure and clarity to problems, and to identify issues related to these, both when discovering and analysing problems. Mind maps can help both individuals and small teams to generate ideas, develop concepts and summarize and test assumptions (Martin and Hanington, 2012). They are also used to show connections between various information, group this into themes and to identify patterns. The mapping starts from a guideword meant to prompt brainstorm of related aspects and issues (Boeijen et al., 2016). Ideas in the shape of simple words, symbols or sketches are then added to the map, and later cluster into clouds (Martin and Hanington, 2012).

4 Procedure

The master thesis consisted of two blocks: 1) the System study and 2) the Method development. The division meant to clarify that the new method should be based upon a founded study, and the development not rushed. The system study aimed to define needs and demands for the new method, and assure that the authors had knowledge and understanding about related topics. The phase of method development, intended to design the new method based on the findings from the study.

Each block involved two phases: a first meant to broaden the perspectives, and a second intended to narrow down the findings in accordance to the thesis objectives (Figure 11). The system study started with the system identification, where a broad understanding for the area of risk analyses was defined, and followed by the system exploration, meant to conduct, examine and compress information related to this. The method development begun with the concept creation which aimed to generate a large variety of diverse concepts, and was completed with the concept development where the concepts were evaluated and narrowed down into methods corresponding to the objectives.

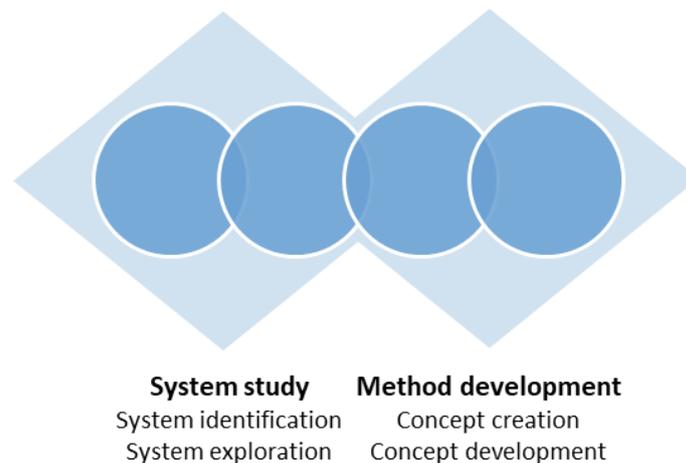


Figure 11: Procedure of two parts, four phases.

4.1 System identification

The thesis started with a system identification meant to define the system and form strategies for the system exploration. Based on the theoretical framework (Chapter 3), a system and a stakeholder map were defined.

4.1.1 System theory

A *system* is a set of parts, which together are more than the sum of its part (Bligård, 2011). The theory behind this statement is based on the assumption that a system only can be described when studying the order and the relation between its components. To provide an illustrative understanding for the problem, the authors started from the objective and theoretical framework and described a system around it. This system description was later set as the foundation for the system exploration.

4.1.2 Stakeholder study

A *stakeholder map* helps to visually communicate key players of a project and can serve as a reference point in research activities (Martin and Hanington, 2012). Based on the theoretical framework, potential stakeholders – both internal and external – were identified and visualized in a map. The map was later used as a support in the selection of the participants for interviews, think-aloud sessions and the literature. This was to assure that the system exploration covered interest from all stakeholders.

4.2 System exploration

The system exploration aimed to conduct information about the two systems and list guidelines to design the new method. To achieve this, literature was studied and interviews and think-aloud sessions performed. The findings from these were then analysed by the means of affinity diagrams and summarized into matrices and text. Upon the main aim, the exploration contributed as inspiration for the concept development and with content to the new method.

4.2.1 Literature study

The literature study aimed to conduct information about present and future critical situations and existing methods for design and analysis. Topics were selected with respect to the driver, the truck and the analysis. To obtain a better understanding for the driver, summaries of previous interviews with drivers and literature about cognitive ergonomics were conducted. To learn more about the truck, both internal and external articles, published and unpublished material were read. The topics related to new and upcoming technology for vehicles and infrastructure, accident statistics, general road safety and automation in other industries. While reading, key findings and quotes were marked and compiled.

4.2.2 Interviews

The interviews aimed to extract information about potentially critical situations and understand the working procedures of methods for risk analysis. In addition to the literature study, these sessions meant to cover the perspective of the engineer. In total, three interviews were conducted with employees at Volvo GTT. The interviews were semi-structured, meaning they were based on a set of defined questions (Appendix 3), but participants were encouraged to speak about related thoughts and experiences to feel more comfortable (Martin and Hanington, 2012). The questions considered: future drivers and traffics; attitudes, risks and possibilities towards automated trucks; and existing work procedures. The findings contributed to the understanding about potential risks and the work to prevent and mitigate these.

4.2.3 Think-aloud sessions

In addition to the interviews, two think-aloud sessions were held with one employee at Volvo GTT and an external expert of risk analysis method respectively. A *think-aloud session* allows identification of aspects that delights, confuses and frustrates the user (Martin and Hanington, 2012). The sessions were used to gain knowledge about presently used analysis methods. Each participant presented one analysis method, explained its process and provided illustrated examples. Meanwhile, they were asked to verbalize aspects related to the design and work procedure.

4.2.4 Affinity Diagram

To compile the exploration, key findings from the literature study, the interviews and the think-aloud sessions were organized into two affinity diagrams – one for each sub-system. An *affinity diagram*,

also called KJ-method, helps to process research information, and enable identification of underlying significance within the findings and the nature of the problem (Martin and Hanington, 2012). In short, it means findings from a study are written on sticky notes, sorted, clustered and categorized. To perform an affinity diagram, the authors printed information from the literature study and quotes from the interviews and cut these into separate notes. These were then analysed and assembled into two diagrams, which provided an organized overview of the findings (Figure 12). At last, each diagram was summarized into text and used to list the guidelines.

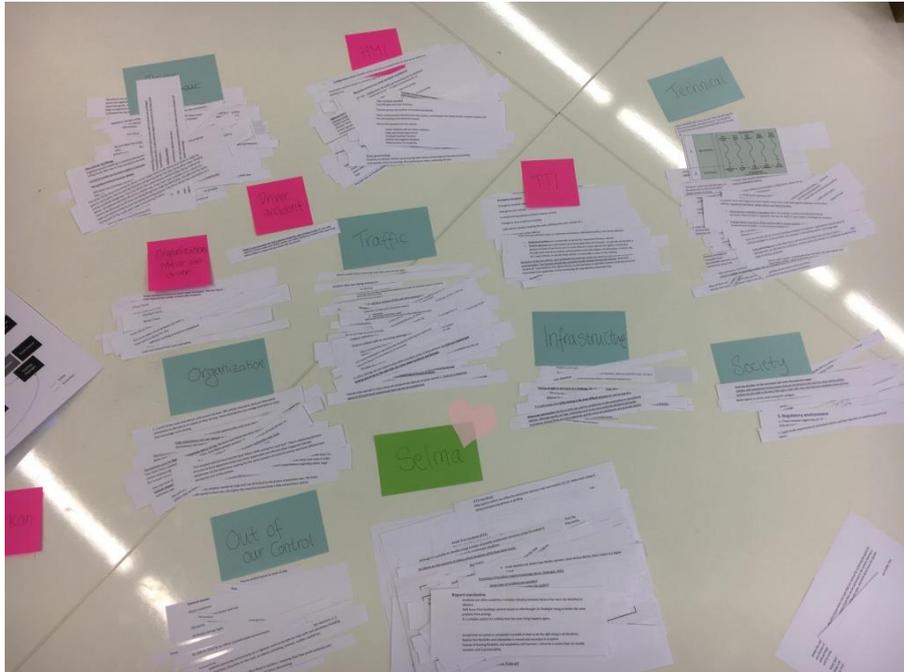


Figure 12: Affinity diagram during System exploration

4.2.5 Guidelines

Based on the summaries of system exploration, a list of guidelines was formed. *Guidelines* aim to support design work, and are especially useful when findings from studies should be summarized and translated into comprehensive design (Bligård, 2011). The list aimed to guide the method development by enlighten aspects of importance for a new method within the field. The guidelines were composed by analysing the summaries from the system exploration, organized according to the systems and categories defined by the affinity diagrams.

4.3 Concept creation

The concept creation was the first step of the method development. This work aimed to create a wide range of concepts for the concept development. The work consisted of two sessions of initial idea generation followed by concept creation. Lastly, all concepts were grouped.

4.3.1 How-to questions

The idea generation started with the method How-to...? (Chapter 3.5.1). The work aimed to come up with initial ideas for how the new method could look like, this by asking *how can we identify critical situations related to*, followed by a main factor identified in the system exploration (Chapter 6.2). By sketching potential solutions, ideas were generated. The authors performed a five-minute session for each factor and compiled ideas into a list of methods, which in its turn were assembled with existing

analysis and design methods presented in the theoretical framework (Chapter 3.4 and 3.5). To structure the methods, the list was analysed and grouped by the means of an affinity diagram.

4.3.2 Morphological matrix

To concretize the ideas into concepts, content of the affinity diagram was decomposed into a morphological matrix. A *morphological matrix* helps to generate concepts from ideas in a systematic way (Boeijen et al., 2016). In this, the ideas were divided into functions which represented stages of the analysis process. Ideas from the functions were then picked and combined randomly, and used to generate ideas for how a concept with the given function could work and look like. It was not meant to build complete and workable concepts, but the focus was rather on creating numbers of different variants. This work resulted in a first set of concepts.

4.3.3 Mind maps and design charette

A second set of concepts were created from another round of idea generation. Once again, the work started from the affinity diagram, but this time the ideas were generated by the means of mind maps (Chapter 3.5.6) and a design charette (Chapter 3.5.3). By combining the two methods, the authors aimed to successively associate on each other concepts and create more unexpected variants. Ideas from the affinity diagram were selected to be starting points in the mind maps, which were generated during charettes of three times five minutes. The maps were then subjectively evaluated, and ideas selected and combined into concepts.

To conclude the concept creation, the results were structured by an affinity diagram. This aimed to summarize the concepts, and enabled the upcoming development to start from conceptual tracks rather than individual concepts.

4.4 Concept development

The final step of the method development was the concept development. It aimed to further develop the concepts and select one concept for final design. The process was iterative and involved two rounds of creation and evaluation: the first and the second concept development.

4.4.1 Brainstorming

The concept development started with a brainstorming session intended to form a few different concepts (Figure 13). Before this, the authors selected the most promising concepts from the previous affinity diagram for further development. This was done during discussion and evaluation with the guidelines as a checklist. The selected concepts were then grouped into a new simplified affinity diagram, from which the brainstorming started. Concepts from groups with similar ideas were combined and developed (Chapter 3.5.5).



Figure 13: Discussion and evaluation during brainstorming.

4.4.2 Theoretical usability evaluation

To select concepts for further development an evaluation was performed. The work aimed to verify the concepts with respect to usability, and thereby assure they had potential to identify critical situations, with reasonable resources and a positive user experience. The evaluation form was based on the keywords of usability: *effectiveness*, *efficiency* and *satisfaction* (International Organization for Standardization, 2017). Effectiveness was divided into two parts: one which considered the possibility of identifying new and unpredictable situations, and another aimed to assure identification of situations related to findings from the system exploration. The perceived usability of each concept was then rated according to a three-point scale (-1, 0 or 1), where an existing risk analysis method served as neutral position. Apart from a mean value of the two effectiveness ratings, no weighting was applied. The results of the evaluation and discussion lead to a selection of the most promising concepts. These were at last categorized into new groups of diverse concepts.

4.4.3 How-to-questions

The second development was similar to the first, but aimed to create testable concepts. The work started from the groups from the first evaluation, and aimed to form one combined and improved concept within each of these. Pros and cons with the concepts were listed and used to create more optimized solutions. Various *how-to...?* questions were used to generate ideas for improvements and combinations. The work focused on the process of the methods, and aimed to form four different concepts. When these were defined, prototypes were built to enable practical evaluation.

4.4.4 Product usability evaluation

To evaluate and select concepts for further development, four employees at Volvo GTT and two supervisors of the master thesis were summoned to a two-hour workshop. The session was inspired by a *product usability evaluation*, where intended users and stakeholders are supposed to discover design representations from the perspective of usefulness and user experience (Boeijen et al., 2016).

After an introduction to the work, the participants were divided into two groups and the concepts tested one at a time (Figure 14).

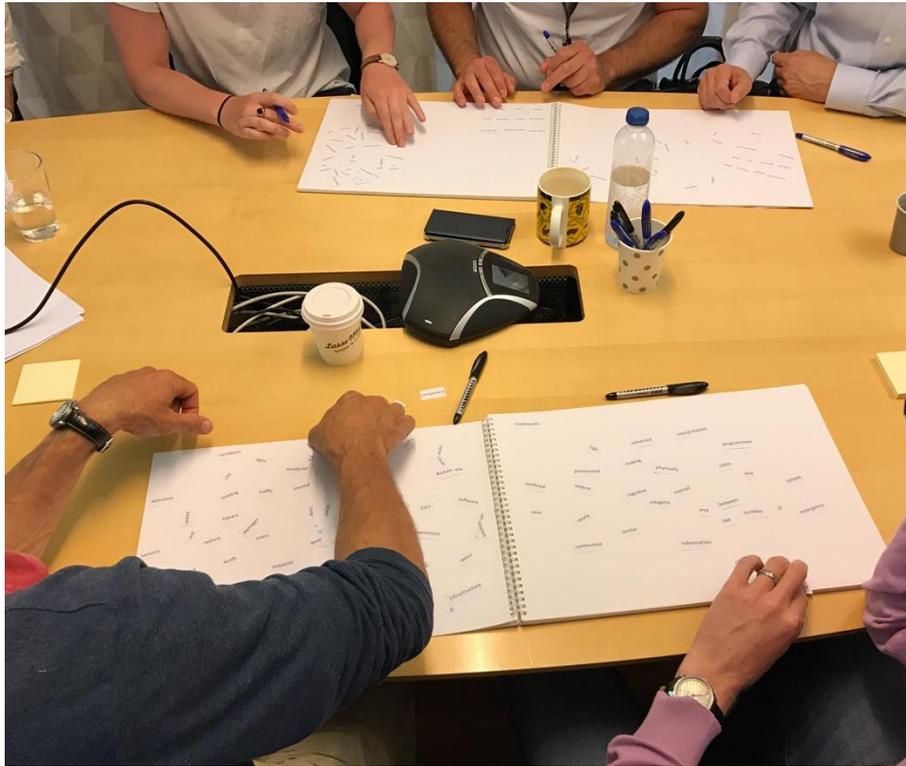


Figure 14: Usability evaluation during workshop.

4.4.5 Usability survey

After each test, findings and work procedure were discussed, and when all tests were completed, the participant filled out a survey (Appendix 4). The survey included one part for each concept, and involved ratings and questions related to usability. In the rating participants were supposed to grade each concept according to a statement which referred to effectiveness, efficiency and satisfaction. Also, they were asked to rate the most important of these statements. To collect more comments and understanding for the concepts, the conversations were recorded and transcribed. Quotes from the transcription and comments from the survey were then used to list pros and cons of each concept (Figure 15). By discussing these between the authors and considering the scores from the survey, concepts for the final design was selected.

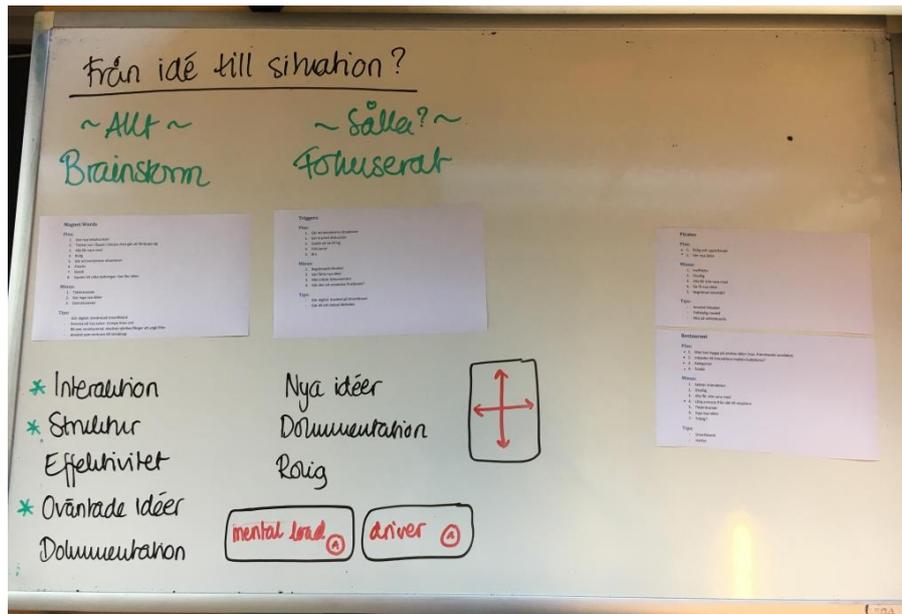
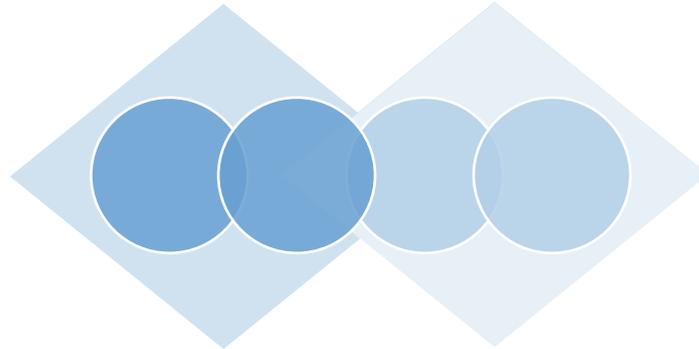


Figure 15: Discussion and listing of pros and cons.

4.4.6 Mind maps and design charette

To improve and evolve the concepts into a final design, an idea generation was performed. The methods used were mind maps and a design charette, and the base for the work findings from the second evaluation. Cons of the final concepts were compared with pros of the rejected, and the differences used as guidewords in the maps (Figure 16). The work aimed to identify how the final concepts could be improved with inspiration from previous ideas. Ideas from the design charette and comments from the second evaluation were together used to set the final design. A prototype of this was then built and used during the last evaluation.

Result – System study



System study	Method development
System identification	Concept creation
System exploration	Concept development

5 System identification

The system identification was the first phase of the system study. The work resulted in a system description and a stakeholder map, which is presented in the following chapter.

5.1 System theory

The system consists of two sub-systems with one user each: the driver and the engineer (Figure 17). The first sub-system, named *Engineer and Analysis* (E&A) focuses on the format of the new method. It defines the engineer as a user within the process of risk analyses and considers *how* the new method should be designed. The second sub-system, named *Driver and Truck* (D&T) focuses on the critical situations that an automated truck and its driver may be exposed to. It starts from its user, the driver and aims to answer *what* the new method should identify. The common denominator between the system is the analysis. It is the engineers' tool to investigate potentially critical situations which may face the driver and the truck. The sub-systems will also be referred to as system of E&A or D&T.

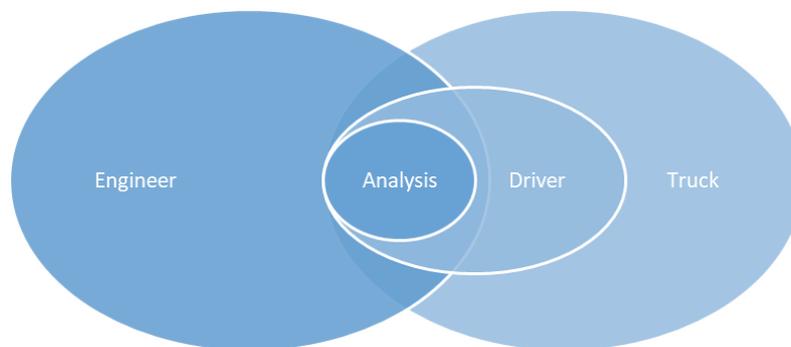


Figure 17: The system with its two subsystems: *Engineer and Analysis* and *Driver and Truck*.

5.2 Stakeholder study

The stakeholder map shows the people that have an interest in, are affected by or want to make sure that critical situations with automated trucks are identified and prevented (Figure 18).

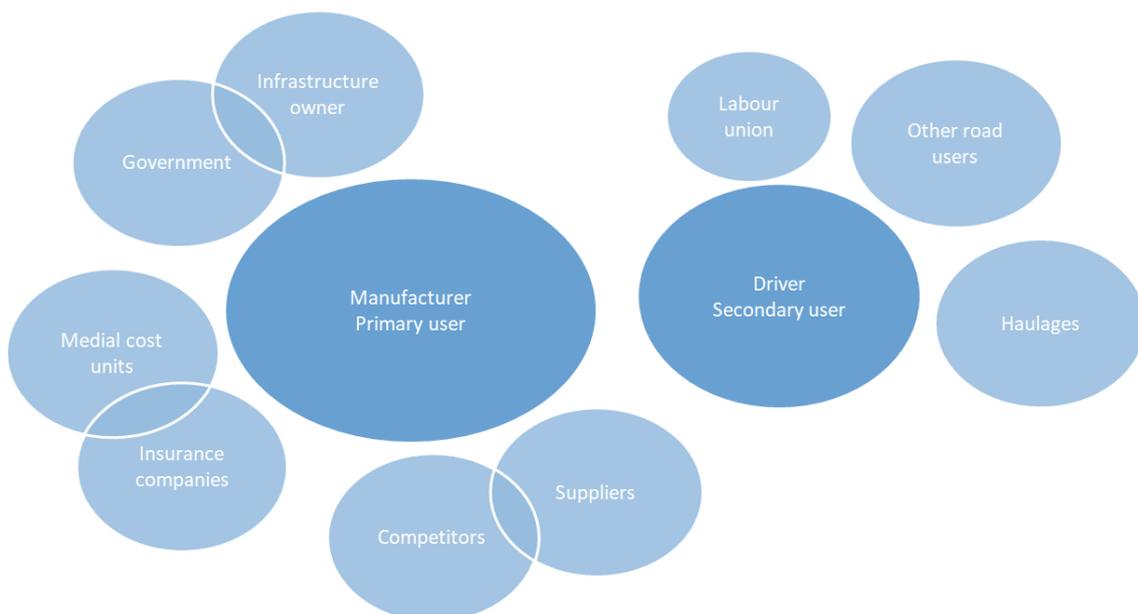


Figure 18: Stakeholder map, one internal and four external stakeholders.

The internal stakeholder is the manufacturer, including the company who develops and manufactures the truck and the engineers that develop and perform the analysis. They are the ones developing and carries out risk analysis and are therefore the primary user of the new method.

The remaining stakeholders are external. The driver is affected if a critical situation happens, and consequently affected by the result of a risk analysis. Furthermore, the driver is a central part of the analysis and is therefore a secondary user of the new method. Other road users are also at risk of being hit by or collide with the truck. The labour union shows interest in trucks being safe, both for the sake of the drivers and other road users. Decision-making instances such as the government and infrastructure owners are also interested of identifying and preventing critical situations; they want to make sure that operating trucks are safe on the roads.

Stakeholders considering profitable actors are: insurance companies and medical cost units, since reduced and prevented risks equals to lower cost. Moreover, haulages are interested in keeping the truck unbroken and functional and foremost their employees – the driver – safe in the truck. Other stakeholders who have an economic effect on the manufacturer are the competitors. They effect the development at the manufacturer, suppliers and other collaborators. Furthermore, suppliers are demanded depending on the outcome of an analysis and thereby the development of trucks.

5.3 Conclusion

During the system identification, it could be seen that there are two parts of the system to consider when designing a new method. To achieve the objective, both systems must be studied. The topics for these can be found by the means of the stakeholder map, which presents relevant areas within both systems. In conclusion: The system exploration should explore the systems of E&A and D&T, and use the stakeholder map as guidance.

6 System exploration

The system exploration was the final phase of the system study. It resulted in two summaries, one about the E&A exploration and one about the D&T exploration.

6.1 Engineer and Analysis

The following chapter is a summary of the exploration findings related to the system of E&A. It tells about some general approaches and aspects which stakeholders bring out as important and preferable when working with risk analyses. The summary aimed to inspire the design and procedure of the new method.

Documentation and communication

Depending on the type of analysis, the information required vary from basic and general system understanding to deeper and detailed knowledge about a specific product or user. It is therefore preferred to define and agree upon the aim and the process of the analysis before the work starts. This is to make sure that the work leads to its intended result. To keep this focus and prepare for eventual doubts during the process, and ease for first-time users it is also preferable to provide an instruction.

When performing a risk analysis, it is expressed as good to select one person responsible for documentation. Furthermore, it is favourable to document while the analysis is performed since it reduces the amount of supplementary work, and thereby makes the analysis more time efficient. It is also expressed good to use whiteboards and presentation boards for the notes. It could ease the subsequent documentation, involves the participants in the documentation and reduces the risk of misunderstandings.

To ease communication of the results, it is preferred to build the new method of terms that are well-known and recognizable among both engineers and suppliers. As the theoretical framework brings out, there is the standard ISO26262 (Chapter 3.3) from which companies can form and use in their own risk analysis methods, as long as it evaluates the defined classifications. Using a risk analysis method based on the standard is expressed to have major advantages, also within the organisation.

Identifying various risks

Initial system studies are the base for many design methods and analyses. In the case of risk analysis, they can provide useful information for the identification of critical situations, especially when human aspects and mechanical components interact. No matter the profit of improved understanding, the work often seems time-consuming. To make the process more efficient, information is often re-used from previous studies or collected from experiences of the user. However, it is debated whereas it could be a risk that inherited information only considers present and well-known situations, and leaves out potentially new and unpredictable which may occur in the future and in the case of automated trucks. Another risk with the methodology of risk analyses is that there is seldom any defined procedure to identify information which is not passed on from previous analysis steps. When the user of the method is supposed to come up with information without support, is a drawback for the complete analysis. Not the least since information enlarge and give rise to new findings along the process.

Many methods use questions to identify risks. This is preferable since it guides the analyses and helps the analysts to reflect upon the results. Furthermore, some mean it is even better to combine them with statements, guidewords, scenarios or personas as this makes sure the analysis covers all relevant areas. Guidewords are expressed to provide a balance between open and more restricted brainstorming. However, they are often based on pre-defined scenarios, which risks missing future and rare scenarios.

Analyses often involve categorization, ranking or grading based on pre-defined terms. This means identified risks are described by type and cause, and graded according to severity, likeliness, controllability or suchlike. It is expressed that methods which only focuses on one category or component have drawbacks. Furthermore, a method which does not only cover the most critical errors, but also small irritating things is perceived desirable.

6.2 Driver and truck

The following chapter is a summary of the exploration findings related to the system of D&T. It brings out and describes five main factors which can lead to risks in automated trucks (D&T factors). Additionally, one interacting factor which highlight risks due to interaction between the main factors driver and truck, which is a central part of the system (Figure 19). The summary aims to tell what content the new method should include.

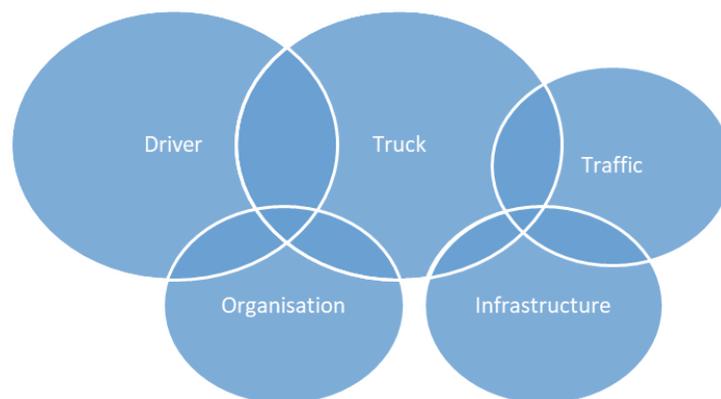


Figure 19: D&T factors.

6.2.1 Driver

Until trucks are fully automated, there is need of someone supervising the vehicle. However, the transition of automation will gradually change incentives, tasks and behaviour of the driver.

With automated trucks, drivers could possibly do other tasks than driving while the truck is in automation mode. Those working for small haulages do administrative and practical business, such as communicate with logistic centres and customers while driving, schedule routes and handle logistics and day-to-day business in-between the routes (Goodwin, 2015). Thereby, managing business could be one possibility for other tasks in an automated truck, but it seems that drivers would like to sleep or do workout if it was possible (Holder, 2016). To focus on a secondary task while driving is an issue for the safety of automated vehicles, especially semi-automated where the driver needs to get back in the loop quick if requested to take over and then respond properly to the situation (SAE, 2017). These and other cognitive aspects affect the driver's performance and abilities and could therefore lead to risks (Bligård, 2016).

Today, examples of tasks which drivers seem to prefer to do except for driving, is listening to radio or use tablets for games. However, it is perceived that the incentive is often to stay awake and aware, or as a consequence of boredom. At the same time, pressure and stress may increase the risk of traffic violations and makes the driver prioritize efficiency over safety and act less careful. Violation is an underlying risk in any human-machine system, which put drivers in a hazardous situation. E.g. not use seat belt or deactivate safety systems (Ekfjorden et al., 2017). In addition, fatigue, unhappiness and depression also affects the driver's ability to react upon system information and act immediate (Ekfjorden et al., 2017; Salvendy, 2012).

The position of the driver is central for the passive safety in vehicles. Today's safety systems are mainly dimensioned for longitudinal retardation, which could leave passengers more sensitive in other positions and rotations. In case of automated driving, the driver may not sit in a proper driving position, but rearrange position or placement in favour for other tasks. Seated opportunities arise in terms of changed seat position, rotation of the seat, seats behind the driver's place or somewhere else in the cabin (Daimler.com, 2017). It is possible that the driver also could go to sleep in the bed or stroll around in the cabin. Moving around is a critical scenario, since unbelted drivers will not be as protected as belted in case of an accident. Even if there are belts on each position, there is still a potential risk in moving between them. This is a case already seen in buses, where passengers can walk to and use the bathroom during longer rides and stand up in city traffic.

6.2.2 Truck

The truck may also affect the situations of automated driving. Both its hardware, responses and actions made by the system can lead to risks for the driver.

The availability and condition of mechanical components are essential for the safety of trucks. Risks can occur due to failure of both components and systems. Among the most critical are brakes, followed by defects on steering, tires and chassis (Dekra, 2017). Breakdowns happen today because of e.g. deficient manufacture and maintenance or high mileage, and may also happen in automated vehicles. Moreover, it is important to consider that risks can occur also due to the trailer. With these, comes the hazard of driving with unsecured or dangerous load (Dekra, 2009). The hardware which provides the systems with information is central for automated functions. This include radars and visions technologies, and equipment for Cooperative Intelligent Transport Systems (C-ITS) and vehicle-to-vehicle (V2V) communication, which together support active safety systems (Gibbs, 2017; International Transport Forum, 2015). In case these components are poorly manufactured, have impaired or no function critical situations may occur (BLM, 2015; Golson, 2016).

Interpretation of incoming information and decision making upon this, involves risk evaluation. As there are innumerable situations that may happen in the traffic, it is implied that not all can be foreseen, defined and programmed in advance. To come around this, system uses a combination of calculations and artificial intelligence, meaning it uses programmed recognition and differentiation to solve complex scenarios (Gibbs, 2017; Hars, 2016). This means systems may act different even though the situation is exactly the same, which further confirms statements asserting that automated driving can be as or even more unpredictable than humans. Irrespective of the system, random situations occur and require immediate action. This may, in its turn lead to critical events that can neither be foreseen nor planned for.

6.2.3 Driver-Truck Interaction

The interaction between the driver and the truck is central for risk evaluation of automated vehicles. Risks may occur due to human cognitive aspects and system design, and mismatches between these.

Risks can occur when the system fails to warn or inform the driver about a critical situation (BLM, 2015). The configuration and design of the system is another issue to consider, since too complex setups and operational tasks can lead to mistakes which can later fall out as disastrous. Automation may miss or hide errors, which a manual driver would have detected thanks to real observation (Salvendy, 2012). Deactivation of systems is a considerable problem for vehicle and traffic safety. Whether this is a risk also for automated trucks of level 4 depends on the possibility to activate and deactivate these systems. Inadvertent mistakes and errors are always a risk in the case of human-machine interaction, but good design can prevent and mitigate the consequences of these. However, misuse and violation remains a risk, since systems only to some extent can inhibit certain actions. That the driver could inappropriately rely on the system, either from presented information or the system actions is another issue to consider.

The task allocation between the driver and system is a minor risk factor for trucks operating at automated level 4. Anyhow, it is interesting to consider since the same vehicle can operate at various levels (International Transport Forum, 2015). Ambiguous allocation might lead to doubts and confusions regarding ability and responsibility. Furthermore, the driver will still be responsible for some driving modes, the transition between automation levels for setting and supervising the automated system. However, it is debated if automation in this case decreases, increases or conserves the cognitive effort (Salvendy, 2012). There is a risk that complex cognitive tasks are left to the operator and that difficult tasks become more difficult. This relates to risks from both motivational and task demanding perspectives.

Cognitive ergonomics are of wide interest for risk evaluation in human-machine systems, also when it comes to automation. Higher level of automation distances the driver from the process, which consequently may miss warnings or alert from the system (Salvendy, 2012). Upon this, low awareness of the situation and impaired proprioception leads to insufficient understanding for the context and potentially also risks for a non-driving driver. To consider if the driver is aware of the situation is therefore essential in risk evaluation (Google, 2015). Also, the timing of information is essential (Salvendy, 2012). To assess a situation and make decisions requires time which the system may not supply. Also, vigilance decrement is a major risk since driver are supposed to stay alert and attentive for many hours (Hars, 2016).

6.2.4 Organisation

Automation may bring new business opportunities and challenges for haulages and transportation firms. Reasons and incentives behind these will affect the driver.

With a higher level of automation and the interplay between drivers and haulages, the organization of logistics will change (Salvendy, 2012). Established work procedures may be obsolete, the knowledge about new technique and safety may be deficient and education could be required. If driver training is inadequate risks may occur (Ekfjorden et al., 2017). Furthermore, automation will imply new and revised regulations, which affects both the driver and the business. With evolving technology rules and regulations regarding driving and rest time, driver responsibilities and privacy

may be revised, potentially resulting in standalone rules for automated vehicles and context-dependent operating licenses (International Transport Forum, 2015).

As stated earlier, automation enables the driver to do other tasks while the truck is in charge. However, this is rather perceived as a comfort feature favouring the driver, than an incentive for efficiency and the company. It is also worth to consider that drivers tend to take less responsibility for shared vehicles, and that their incentives and behaviour may change due to new economics and cost connected to the truck and driving (International Transport Forum, 2015).

Business opportunity arises when the truck drives fully automated and there is no need of a driver and fleets can take advantages of reduced transport costs. Automated trucks may also lead to lower cost for service and repair as incidents can be foreseen, avoided or mitigated (Hars, 2016). In general, responsibilities may gradually shift from the driver to the technology. The formation of directions is in progress, but debates indicate that manufacturers rather than owners may take costs for repair and insurances (BLM, 2015).

6.2.5 Traffic

Traffic is the interaction between the truck and other vehicles, road users and obstacles on the road. Since some accidents and risks occur in relation to other vehicles (Ekfjorden et al., 2017), it is important that a new method includes also these aspects.

Failures in the interplay with other vehicles is the reason behind many incidents and accidents. Vehicles which are not equipped with advanced safety systems might initiate, accomplish and complete unsafe overtakes, or cause front, side and rear collisions (Dekra, 2017). Risks also occur due to uncontrolled and inattentive driving of others, incidents involving surrounding vehicles, unfolding accidents and occasions when the truck itself or another road user make way for stationary vehicles or emergency turnouts (Ekfjorden et al., 2017).

Active safety systems can detect other road users and prepare the truck for related eventualities, but when the speed is high, the course of event and risks are often immediate. The same risk holds for objects on and around the road, roadwork obstacles and temporary changes in the infrastructure (Ekfjorden et al., 2017). If an object suddenly appears, both the truck and the surrounding traffic are exposed to the risk. Upon this comes intense traffic, queues and road junctions which are complex situations also for automated vehicles (Dekra, 2009). All situations often involve unpredictable and rare scenarios.

Thanks to V2V communication, many of these risks may be prevented. One may be able to foresee complex scenarios and prevent accidents such as intersection collisions. However, risks still occur in case deployment of data is faulty or insufficient. Even though safety may be improved with automated vehicles, crashes and collisions can still occur (International Transport Forum, 2015). In addition, comes subsequent situations which often leads to collisions and more serious risks. This is essential also for automated trucks, since systems may not be able to foresee these scenarios (Ekfjorden et al., 2017).

6.2.6 Infrastructure

The infrastructure brings both challenges and opportunities for automated trucks.

Techniques for automated driving can easily be implemented and safety increased on well-maintained and uniformly designed motorways (International Transport Forum, 2015). As stated earlier, automated vehicles use a combination of input from sensors and radars, and communication to handle the driving. To merge information into proper driving actions is a complex task also for automated systems, and can lead to risks. The quality of the input is decisive for the automated driving to function properly. If lane lines, reflectors and road signs are defective, placed improperly or not existing, the system performance may be reduced and unsecure (Ekfjorden et al., 2017). Also, road work, temporary changes and newly built infrastructure could lead to risks. In addition, information from other communication systems may lead to risks if incorrect, insufficient or for some reason not available.

The interaction between the truck and the infrastructure raises some issues and potential risks. Among various traffic situations, the truck must be able to follow lanes, change lane, enter and exit ways and pass road junctions. (Gibbs, 2017; International Transport Forum, 2015). It must also be able to find a safe parking lot in case the automated driving faces resistance or something breaks. The complexity in this is high, as these actions must also consider the surrounding traffic continuously.

To assure safe driving, automated trucks need to handle all environmental conditions, at least those that can be managed by drivers. This also involves factors that cannot be controlled, such as the environment, weather condition and road condition. Snow, fog, rain, ice, wind, darkness, certain sunlight, and aquaplaning might affect the performance of the truck and the technique (BLM, 2015).

6.3 Guidelines

The guidelines conclude the findings from the system study. It brings out aspects from both the E&A summary (Chapter 6.1), to tell how the new method should be used and aspects from the D&T summary (Chapter 6.2) to define what situations it should look for. Apart from the initially use-related guidelines, the list is divided according to factors identified during the D&T exploration, namely: driver, truck, driver-truck interaction, organisation, traffic and infrastructure.

Returning to the thesis objective, which was to design a new method for identification of critical situations. The method should consider situations in relation to SAE Level 4 and long-haul trucks driving on highways and be used as a support for concept development. Besides from this and as a result from the system study, the new method should also...

- 1) identify situations of various severities.
- 2) be compatible with and used as a support to ISO 26262.
- 3) complement established risk analysis methods.
- 4) enable documentation during usage.
- 5) contain definitions and instructions of how to use it.

The new method should identify critical situations which occur...

Driver

- 6) when the driver performs a non-driving related task.
- 7) because of violent or unsafe behaviour of the driver.
- 8) when the driver is seated in the driving seat.
- 9) when the driver is still positioned elsewhere in the cabin.
- 10) when the driver moves around in the truck.

Truck

- 11) due to failures of mechanical components in the cabin, the truck and the trailer.
- 12) due to failure of software components such as radar and vision technologies.
- 13) when the truck is faces with an event which it is not programmed for.
- 14) because of unpredictable actions of the truck, possibly following different decision making, responses and actions in relation to similar situations.
- 15) when the truck fails to communicate with other vehicles.

Driver-Truck Interaction

- 16) when there is no, wrong or incomplete interaction between the truck and the driver
- 17) if the driver overrides the system.
- 18) due to ambiguous task allocation between the driver and the truck.
- 19) during the transition from automated driving to manual driving and vice versa.
- 20) due to low situational awareness of the driver.

Organisation

- 21) due to inadequate driver training.
- 22) because of new rules and regulation for automated vehicles.
- 23) when the driver feels less responsible and not motivated.
- 24) due to the organization's drive to reduce costs and improve efficiency.
- 25) due to a shift of responsibility where the manufacturer may answer for repairs and insurances.

Traffic

- 26) in relation to other vehicles.
- 27) in relation to emergency turnouts.
- 28) because of immediate response to critical events.
- 29) in relation to critical behaviour and accidents of other road users.
- 30) in relation to sudden appearance of animals and objects.
- 31) in various traffic scenarios and intensity.

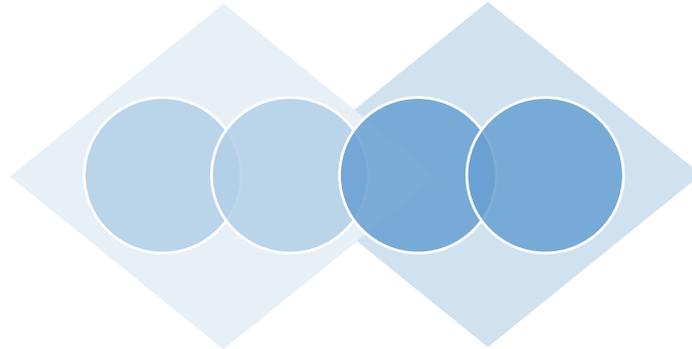
Infrastructure

- 32) due to various infrastructures.
- 33) due to deficient quality of the infrastructure.
- 34) due to changes in the infrastructure.
- 35) when there is no, wrong or incomplete interaction between truck and the infrastructure.
- 36) because of the weather.

6.4 Conclusion

During the system exploration, it could be seen that there are a lot of uncertainties in the area of automated trucks. Some potential risks can be identified, but some are almost impossible to imagine. Although, it could be seen that the D&T factors (driver, truck, organisation, traffic and infrastructure) should become central in the upcoming phase of method development. It could also be seen that situations can be identified within each factor, but the opportunities of identifying new situations comes when combining the factors. Furthermore, ideas of methods for not only identification, but also analysis and evaluation should be considered initially in the method development. This, since analysis and evaluation are the next steps in risk analysis methods and by consider these, it would provide greater understanding for the application of identified situations. In conclusion: The new method should focus on identifying critical situations by using the D&T factors.

Result- Method development



System study	Method development
System identification	Concept creation
System exploration	Concept development

7 Concept creation

The concept creation is the first phase of method development. It resulted in ideas and concepts of methods. The following chapter presents these ideas and concepts.

7.1 Idea generation

The first idea generation resulted in various ideas of how critical situations within each D&T factor could be identified. The ideas were brief and varied from creative methods such as games and entertainment activities to more structured methods like tables and matrices.

The ideas were structured by an affinity diagram and divided into three categories: 1) Identification, 2) Analysis, 3) Evaluation (Figure 20). Identification means methods which could be used to identify critical situations, the group includes both creative ideas such as brainstorming and games, and more structured like answering questions or filling in a matrix. Analysis refers to ideas of how to analyse critical situations, for example the use of questions or identifying interactions, combinations or categorizations. Evaluation is methods which evaluate the analysis and narrows down the result based on importance, often by grading.



Figure 20: Affinity diagram of idea generation.

The second iteration of the idea generation resulted in both ideas for methods, but also inspirational words and descriptions far evolved from the starting point. One of the starting points, *Table* lead to ideas of using programmed formulas in excel sheets and another, a group activity with inspiration from a dinner with several courses. Another, *Graph* generated ideas based on the shape of a wedding cake with several levels, and *Cards* lead to various methods which could fit in one's pocket or kept in an album with other composed methods. *Checkboxes* generated the idea of a method using boxes to pick cards from, such as the ones used in board games. *Graffiti walls* generated the idea of using magnet words people usually have on their refrigerator, as a method. From refrigerator to

vegetables and perishables; the idea of keeping the new method infinite and flexible for updates in the future was also generated (Figure 21).

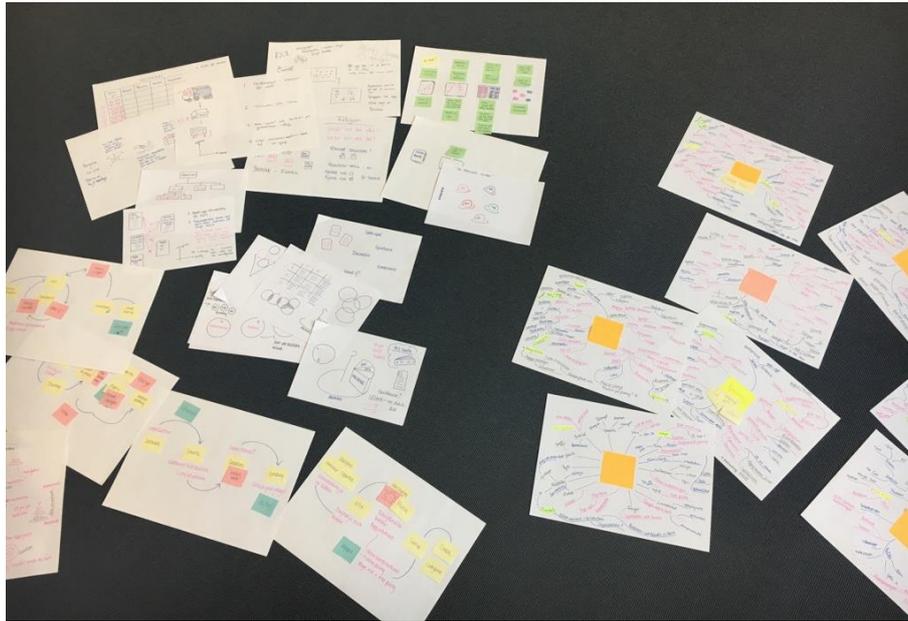


Figure 21: Result of idea generation.

7.2 Concept generation

Five functions were identified in the morphological matrix which divided the generated ideas. 1) System knowledge: ideas about methods to gain information about the area where critical situations could occur. 2) System structure: ideas for methods to sum up and structure the findings. 3) Generation: ideas about methods to generate new potential critical situations. 4) Analysis: ideas about methods to structure or grade the identified situations in order to gain more information about them. 5) Conclusion: ideas about methods to decide which situations are the most important to prevent (Figure 22).



Figure 22: Morphological matrix of concept generation.

When combining ideas from each function in the morphological matrix and choosing and optimizing ideas from the mind maps, approximately 40 concepts were generated. Moreover, when analysing these in the affinity diagram, five groups were identified: cards, activity, table, games and excel (Figure 23).



Figure 23: Affinity diagram of concept generation.

The group *Cards* consist of different type of card packs used separately or combined to generate situations. The ideas within this group cover both content of the cards and various alternatives for storage. *Activity* refers to ideas where people work actively and together in front of a board or a painting and use post-its, words or pictures to group and categorize situations. *Table* refers to ideas where participants sit around a table and use triggers, guided thinking, mind maps or other tools to generated situations together. *Games* refers to playful and creative methods used in a group to

generate situations, the majority of these are inspired by existing board games. *Excel* refers to ideas based on work in Excel. These ideas vary from suggestions of headlines, formulas and diagrams.

7.3 Conclusion

After the generation of ideas and concepts, there was a wide spread of various concepts. To remain open for any solution, the authors decided to keep the groups diverse and optimize concepts first in the concept development. Furthermore, it was decided that the development from now on only should focus on identification, not analysis and evaluation. This, since the objective of the thesis was identification of critical situations. In conclusion: The concept development should start from the five concept groups and lead to a new method for identification of critical situations.

8 Concept development

The concept development is the final phase of method development. It resulted in developed and decreased number of concepts and the design of the new method. The following chapter presents the results from the first, the second and the final development.

8.1 First development

The first concept development started from the five groups identified by the concept creation phase. Further development within each group resulted in eleven concepts, which are combinations of the previous and simpler concepts (Figure 24). All concepts consist of, just as the system study concluded, findings from the D&T exploration and divisions within the concepts originates from the D&T factors (Chapter 6.2).

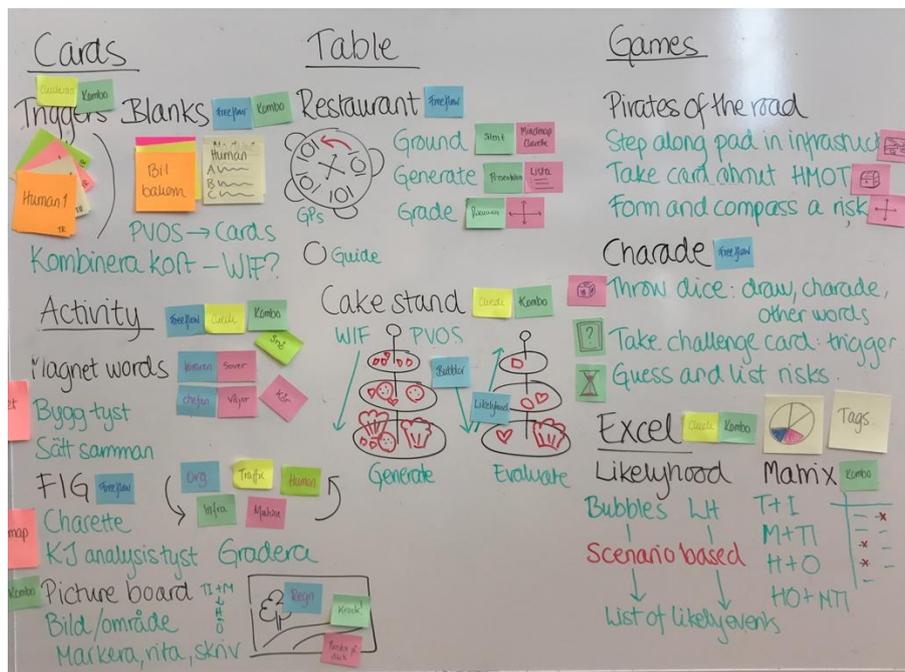


Figure 24: Result of first development.

Evaluation of the concepts resulted in seven concepts being rated above zero and thereby kept, these were Magnet words, FIG, Restaurant, Cake stand, Triggers, Pirates of the road and Charade. The remaining four concepts, which were rated zero or below were eliminated. Magnet words had the highest score in the evaluation since it is perceived to trigger new situations, enabling combination of situations and was perceived as flexible, easy and fun to use. Whereas both the Excel concepts which scored much lower than the rest, were perceived as very time consuming, boring and not triggering new situations (Figure 25). Complete evaluation can be found in Appendix 5.

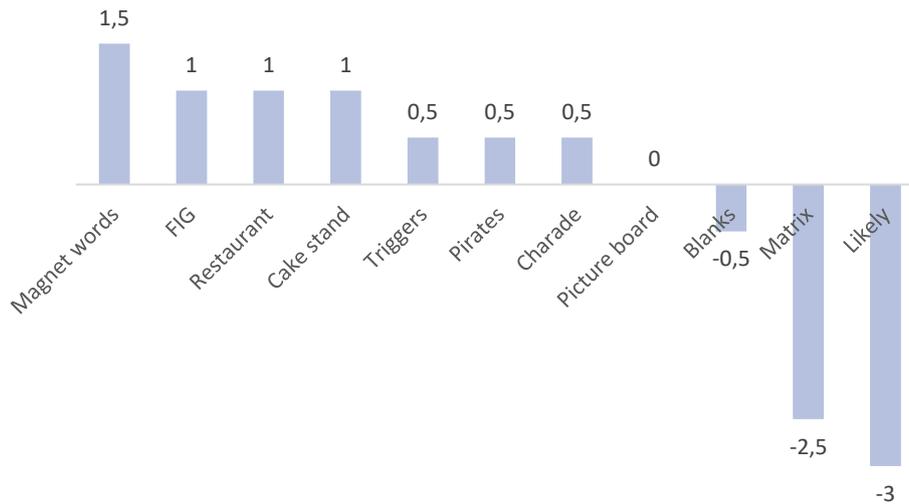


Figure 25: Theoretical usability evaluation.

The seven remaining concepts were re-grouped into three groups; *Cards* containing Triggers and Magnet words, *Activity* containing Restaurant, Cake stand and FIG, and *Games* containing Pirates of the road and Charade (Figure 26).

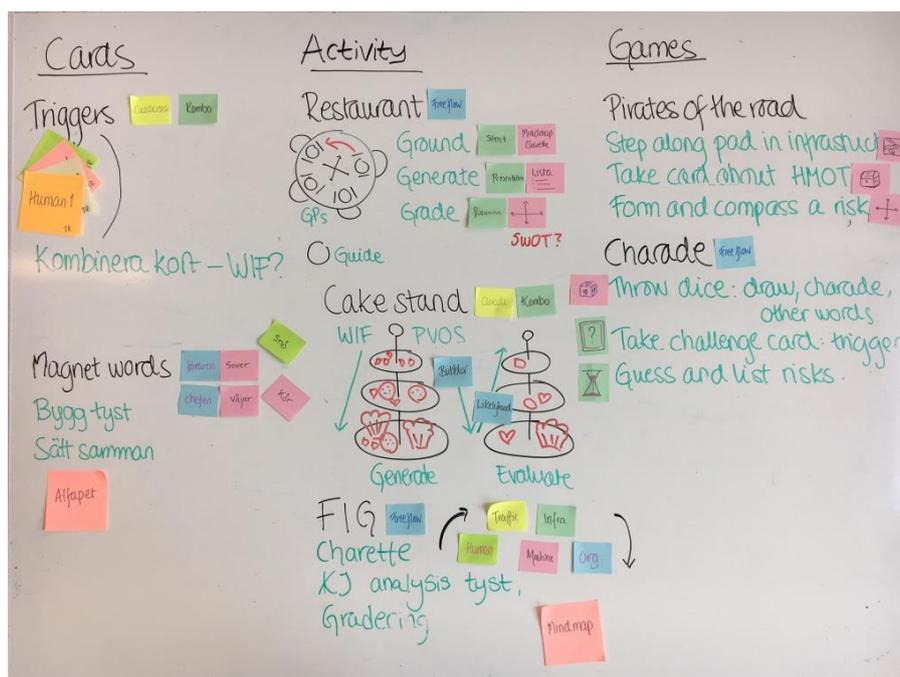


Figure 26: Result of evaluated concepts.

Cards

The group *Cards* includes two concepts: Triggers and Magnet words. *Triggers* is colour coded and has pre-written sentences which aims to tempt generation of critical situations. The user picks one card at a time, reads it and asks *how to...?* followed by the statement on the card. The answers are then written down. It is also possible to combine cards by placing them side by side and ask *what if...?*

Magnet words consist of a large number of words written on small badges with magnets on the back. The words are used to build sentences on a magnet board, and from these generate potentially critical situations. By combining words into random sentences, the concept initiates generation of new and unexpected situations.

Activity

The group Activity contains three concepts: Restaurant, Cake stand and FIG. *Restaurant* is based on the two steps *ground and generate*, and consists of five guests and a guide. The guests mission is to identify critical situations while the guide act as a moderator. The concept starts with grounding, were each guest uses a mind map to brainstorm around aspects, ideas and situations. The work is performed silently, and the mind maps are sent around the table as in a design charette. When the round is complete, the generation begins. This work includes presentation and discussion of the mind maps, and aims to pick out all relevant ideas and let these form critical situations. The guide makes sure all the situations are listed.

Cake stand consists of the idea of using a cake stand, with five levels. The user starts at the upper level of the cake stand and generates critical situations by asking *how to...?* Moving down to the next level, the user brings the identified situations and ask *what if...?* these situations occur on the new level. This work aims to generate new and unexpected situations. The procedure is iterated for each level of the stand. Cake stand is preferably performed in a group.

FIG is a focus group where participants together form situations building different mind maps during a design charette. When the rounds are finished, situations are written down on post-its and put on a wall where everyone can see them. The next step is to combine the post-its and identify critical situations. Everything is done during discussion.

Games

The group *Games* consists of two concepts: Pirates of the road and Charade. Both concepts are board games performed by a group of users divided into teams of two or more. They aim to support the user in identifying critical situations by triggering ideas during a fun, creative and competitive experience. *Pirates of the road* contains a board and pieces for each team. For each step, the team takes a card from a treasure chest, containing triggering sentences. When the team has identified a few situations based on the card, they advance one step on the board before the procedure is repeated by the next team.

The concept *Charade* include a pile of cards, an hourglass and a dice with the three alternatives draw, charade and other words. One member of a team starts by throwing the dice and picking a card. Depending on the outcome of the dice, the team member either draws, performs a charade or describes the content of the card in other words whilst the other members guess. The time for each card is limited by the hourglass, and if the team succeeds to state the content of the card they get one point. When the correct answer is revealed, all teams generate and list as many critical situations as possible from the card. After a certain time, the situations are counted and the team with the most are awarded with one point. The procedure is then repeated.

8.2 Second development

Further analysis and development of the seven resulted in four concepts within the three groups. Cards containing Magnet words and Triggers, Activity containing The restaurant and Games containing Pirates of the road (Figure 27).

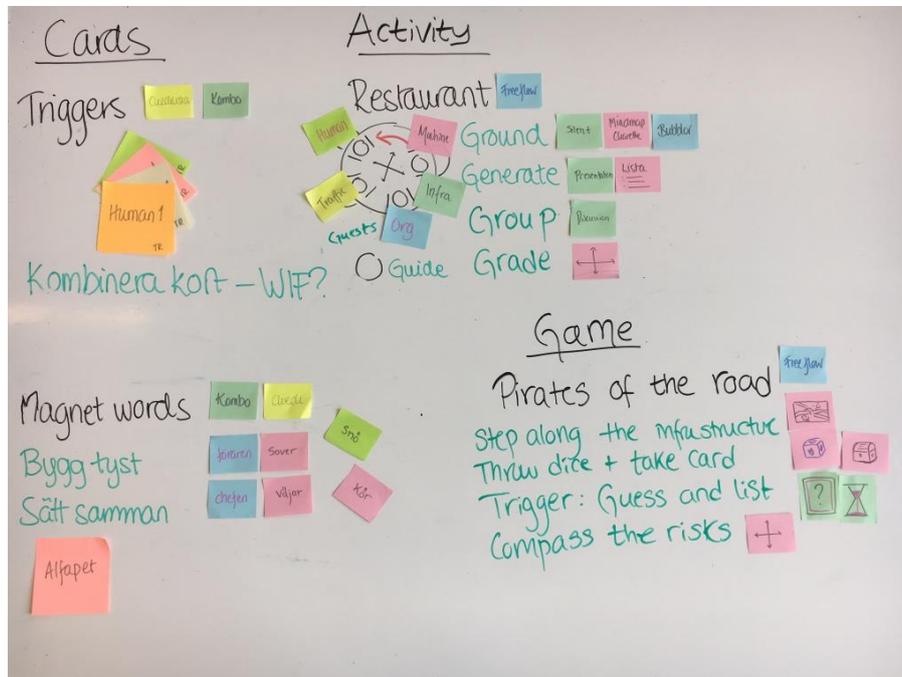


Figure 27: Result of second development.

Since Magnet words scored the highest in the first evaluation, the concept was kept unchanged. Words from the requirement list were cut into pieces and used as a prototype (Figure 28). By using words from the list of guidelines (Chapter 6.3), the method ensures critical situations already found in the system exploration, being identified.

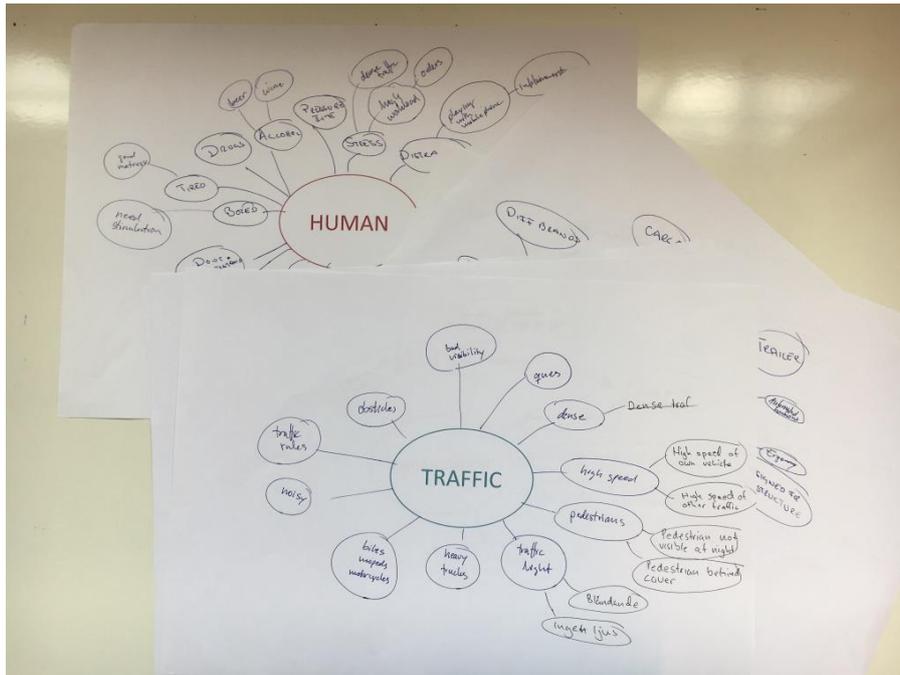


Figure 30: Prototype of The restaurant.

Pirates of the road and Charade are also combined into one concept; *Pirates*. It contains the game board, risk compass and treasure chest from *Pirates*, along with the hour glass, cards and dice from *Charade*. The cards are stored in the treasure chest and the teams move board pieces ahead through the board. For the prototype, a timer from a cell phone was used acting as the hour glass. Cards made for *Triggers* is also used in this concept. The sentences however are shortened and simplified. The dice was built by filling a box of small pieces of papers were the three alternatives are written (Figure 31).



Figure 31: Prototype of Pirates.

The workshop resulted in both positive and negative feedback and comments, but all four concepts were appreciated by the testing group. They were perceived as useful and able to fulfil different needs, in different stages or procedures of a development process. Therefore, a suggestion from the testing group was to combine some of the concepts.

Pirates is fun, energetic and delivered new ideas, but perceived as ineffective and not suitable for most people. Not everyone is social, outgoing or likes to play theatre. However, it was suggested by the test persons that the concept could be appreciated as an exercise during meeting breaks, to relieve the atmosphere and increase the energy levels a late afternoon. The Restaurant enables combination of ideas or usage of others' ideas and the obvious categorization was appreciated. However, it was time consuming and the instructions of the method were unclear. Magnet words has the advantages of being open and flexible, and it may well be used in early stages to inspire new approaches. However, it was perceived as unstructured and time consuming. Triggers is not as flexible and open minded as Magnet Words and would be useful further down in the process. However, it was perceived as quick and easy to understand and great for combining situations.

After evaluating comments and the usability-surveys, Magnet words and Triggers were chosen for the final design. Among the four, these two concepts had the most positive comments, least negative comments and almost the same, high rate in the survey (Figure 32). Pirates scored high on satisfaction but much lower on effectiveness. However, since the users rated effectiveness highest of importance between the three statements, it became predominant in the evaluation. (Figure 33). Complete evaluation and comments can be found in Appendix 5.

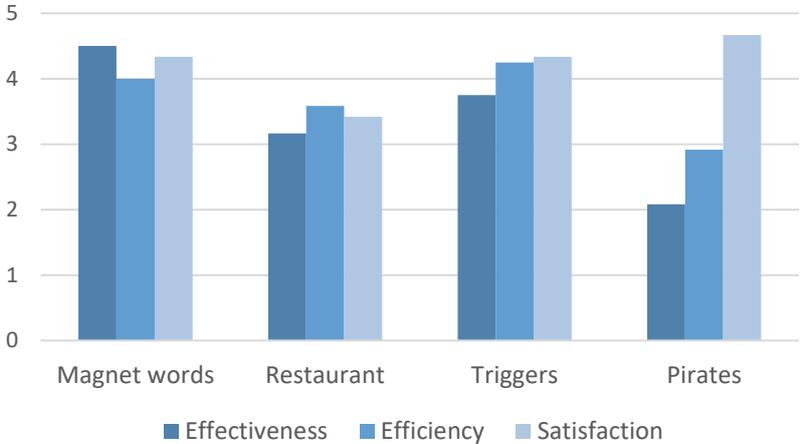


Figure 32: Result from usability evaluation.

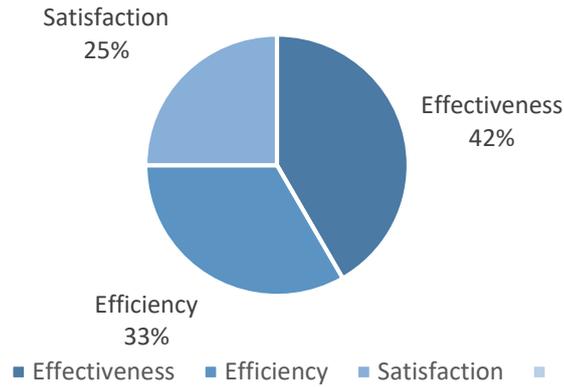


Figure 33: Importance of usability aspects.

8.3 Final development

Further development of Magnet words and Triggers resulted in the creation of a combination of the two in a final concept, SELMA. SELMA consists of guide words and guide cards which can be used in three different ways. The first approach, is to use one guide card, ask *what if...?* and answer the question by building a sentence of the guide words. This aims to find new answers to the situations by using the words. The second approach, is to form a situation with the guide words, add a guide card, ask *what if...?* and thereby to identify critical situations which occur in the combination of the situations in the sentence and on the card. The third approach, is to use either the guide words or the guide cards separately, combine them mutually and identify situations as the previous concepts.

The cards used in Triggers were reformulated, and new added so that all guidelines were covered (Chapter 6.3). Words from Magnet words were sorted out and supplying words such as *is*, *which* and *the* removed. Furthermore, the guide words were colour coded, using the same colours as in the guide cards. This means; words considering guidelines under the same D&T factor uses the same colour. The colours refer to structure the usage and differentiate words considering different factors. Cards and words were printed and cut into pieces to act as a prototype in the final evaluation (Figure 34).

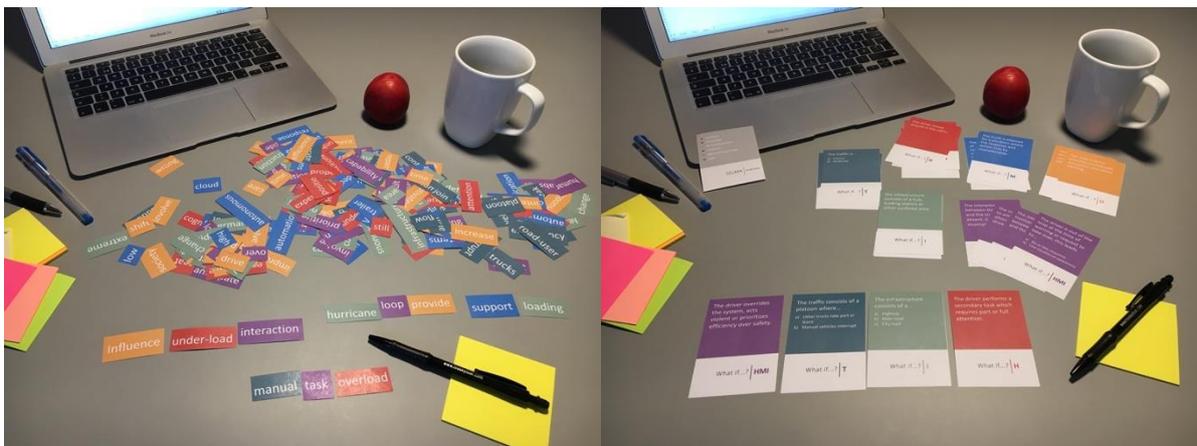


Figure 34: Prototype of SELMA.

During the evaluation, the first and second approaches of SELMA where guide words and guide cards are combined, were mainly evaluated as challenging. In all three approaches, the test person

struggled with building a full sentence with the words. In the first approach, it was difficult to build a sentence that would answer the guide card. However, taking one word at the time together with one guide card was perceived as much easier and triggered more ideas about critical situations. The word would then act as a situation combined with the card and not an answer to it. The second approach were interpreted in a similar way, the test person struggled with building a sentence for a situation with the words. Instead, only one or two words together, then adding a guide card, triggered the creativity. In the third approach using only the words, the test person tried to build a situation using one word of each colour. However, the test person focused more on the meaning of the colour of the words rather than the meaning of the actual words. This restrained the creativity and openness of the words. Again, taking one or two words together was perceived as easier and preferable. Combining only guide cards was perceived as the easiest approach. Although, the test person had a challenging time to find new and unpredictable situations also in this case. However, not all combinations may lead to critical situations.

8.4 Conclusion

After evaluating comments from the test person, it could be seen that the approaches using combinations of guide words and guide cards were perceived as confusing and difficult. The combination should therefore be removed. Furthermore, it could be seen that the colours in the guide words hindered different interpretation of the words and should therefore also be removed. In conclusion: The new method should consist of two separate tools and only guide cards should be colour coded.

9 Discussion

The discussion aims to interpret the results of the thesis. This by commenting upon and reasoning around its result.

9.1 Research questions

The objective of the master thesis was to design a new method for identification of critical situations in automated trucks. To accomplish this, the authors formed two research questions which were explored by the system study.

The first question; *what aspects and occasions may lead to critical situations for the driver of automated trucks*, was answered by the system study. Two factors – the driver and the truck – were identified already by the system identification and additionally three – the organisation, the traffic and the infrastructure – by the following system exploration. The last also concluded that the interaction between the factors is among the most important to consider. The second question; *how should a new method which aims to identify these situations be designed*, was also answered by the system exploration. Interviews provided an understanding for current risk analysis work, which together with the answer of the first questions – the factors and the importance of the interaction between them – defined how a new preferable method should be designed.

9.2 Procedure

The thesis divided its procedure into two blocks. These aimed to successively broaden and compress the work. The authors found the approach well-functioning. However, difficulties occurred when the two blocks were supposed to merge. The guidelines, which aimed to condense the exploration, were too broad and made the initial concept creation difficult. The idea generation started from a diffuse objective and the results were spread, not different as the intention. First, when more specific guidelines had been defined, the creation lead to useful results. In short, the findings from the exploration were too broad when the system study was completed and in a similar project, it would therefore be recommended to narrow down the guidelines earlier to make the idea generation less confusing.

The theoretical framework provided a large amount of different methods; both for risk analysis and design, which the authors gained learnings from. Especially design methods, were applied both in the procedure of designing SELMA but also as inspiration to SELMA during idea generation. Moreover, a number of other methods were applied throughout the process. In general, many of these were creative and inviting to personal interpretations from the authors. This and the selection of methods, interview participants, literature, idea and concepts may consequently have affected the process.

Some methods – mind maps, design charette and affinity diagrams – were recurrently and frequently applied. The reason for this was personal preference, but also that initial results following these were perceived as successful. However, this can be questioned. The use of mind maps is in general criticised for not supporting generation of new ideas, but rather formation of current. In one way, this was counteracted for by combining the mapping with the design charette. Thanks to this, the authors could evolve on each other's findings and generated ideas which probably would not have emerged from individual work. For the same reason, the design charette may also have increased the total number of ideas and been a favour for the authors which only consists of two people. Also, affinity diagrams were frequently used due to their ability of providing an esteemed overview of the

produced work and the possibility of narrowing down findings into manageable combinations. Nevertheless, the method is based on subjective views which influences the result.

The authors used previously made interviews of truck drivers instead of making new ones. This decision may have provided an overall view of the driver's situation, but in a similar project, it could be preferable to act as a carrying passenger with the driver in the truck. This, since a personal interaction may lead to a greater understanding and the result could had focused more on the driver and the interaction between the driver and the truck.

The outcome of the applied methods became restricted towards the end of the method development. The final design would probably have gained advantages from methods which had not been used previously in the process, particularly a method aimed to refine and optimize concepts. Also, the final evaluation had some drawbacks, especially its meagre number of participants which made it difficult to draw fair conclusions. Moreover, it could be questioned whether the participant – which represented the department of product development – was made justice or experienced an exposed position when evaluating a method for concept development by oneself.

9.3 Result

The result of the thesis is a new, creative method for identification of critical situations. Among many concepts along the work, rather many had similar inspiring approaches, and only a few more traditional. The reason for this, and the design of SELMA probably derive from the authors preference for and will to develop a creative tool. Also, the selection and use of creative methods during the method development may be a reason for the same. In addition, it was identified that computer based methods were already frequently used, and supposed that something different could prompt new and rare thinking.

During the exploration, the authors learned much about trucks in general and the development of automated vehicles. The area of automated trucks was found as innovative and entrepreneurial, but nevertheless unexplored and partly unstructured. Research and development is up and running and manufacturers eager to impress the evolution, but surprisingly little literature and few experts seemed to be well-founded. The reason for this may be secrecy. However, the result derives from thoughts, speculations and opinions rather than accurate knowledge and studies. Considering this, SELMA may be deficient in terms of the content and that a founded study could have led to a more superior result.

Besides, that the authors identified quite distant factors of being consequences of risks, was in a way surprisingly. This led to a result with a relatively broad perspective. If the authors had chosen to dig deeper into one or a few of the factors or if the exploration would have been more comprehensive, the result would probably had been quite different. Nevertheless, too much material risks to lower flexibility and creativity of the method and in fact, SELMA does aim to identify new and unexpected situations, not cover all possible.

The content of SELMA is one part of the result, the methodology another. Although the method is set, the content is not. Cards and words which represent key phrases from different risk factors, could be used also in other industries. In this case, factors should be defined from a study of the actual system. Moreover, the content of cards and words should be selected and formulated from this study. Risk management may in general benefit from a methodology which considers critical

situations that arise from the interaction of different underlying factors. In the context of risk analysis, SELMA has some differences from other methods. Its relatively unstructured approach may be a point for criticism, while its openness for unpredictable and eventual occasion may serve advantages. On the contrary, SELMA instead has similarities with a range of design methods and tools. In short, it applies a creative approach and serves as a support rather than a prescribed guide. To sum up, SELMA can be described as *a design method with the specific target to identify critical situations*. In accordance to some early discussion among the authors, this supports the idea that SELMA could be used during fika or placed in a lunch room to prompt as well relaxed discussions and creative generation.

9.4 Future work

The result of this thesis, the prototype of the method SELMA is possible to use by now. However, the progress of automated trucks and the development of technology, demand revision and update to assure continuous reliable results. In order to work properly, the content of cards and words must be actual and relevant. This could potentially be assured by regular exploration of the five risk factors. As the content of the guide cards and the guide words originates from an exploration where information was found to not be well-founded, SELMA could be made more accurate and reliable with information from broader studies within the field. Consider the above, it is recommended to select a person which is responsible for the reviews and set up an instruction for the eventual updates.

Further, it would be good to investigate how to enable a better and more efficient documentation. The current SELMA requires separate documentation which may take attention from the generation and hinder the creativity. Transforming SELMA into a digital tool could provide listing of situations in immediate relation to certain card combinations and sentences, and also the possibility of randomly generating combinations and ease the update of it. However, this has to be made in a manner that does not hinder generation and creativity even more.

10 Conclusion

To conclude the thesis, the authors like to return to its research questions and objective.

The thesis results show that critical situations in automated trucks emerge from the interaction between the five factors: driver, truck, organization, traffic and infrastructure. The thesis also found that methods, which aim to identify critical situations should be creative and encourage generation of new and unpredictable situations.

The master thesis resulted in a method called SELMA, which includes two tools. Both can be used to identify critical situations: one which focuses on situations that follow the interaction of risk factors, and one which aims to come up with unpredictable critical situations.

In accordance with the results, the thesis concludes that any method used to analyse and evaluate driver risks in automated truck should consider the interaction between the different risk factors. Automation of trucks brings new challenges and demand within these areas, and critical situations emerge from this interplay.

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List of appendices

Appendix 1 – SELMA Guide cards

Appendix 2 – SELMA Guide words

Appendix 3 – Interview questions

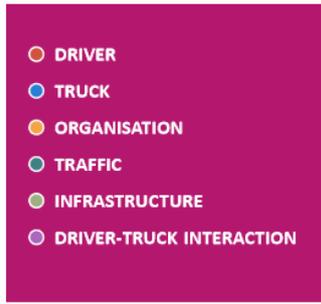
Appendix 4 – Survey

Appendix 5 – Usability evaluations

Appendix 1 – SELMA Guide cards



SELMA | GUIDE CARDS



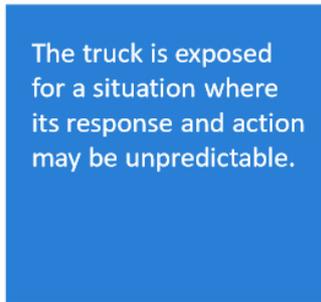
SELMA | GUIDE CARDS



What if...? | TRUCK



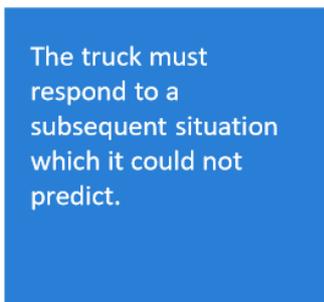
What if...? | TRUCK



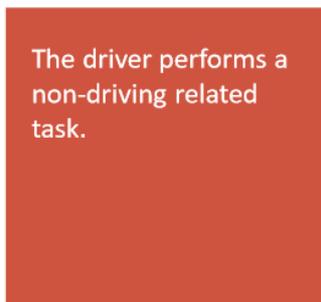
What if...? | TRUCK



What if...? | TRUCK



What if...? | TRUCK



What if...? | DRIVER



What if...? | DRIVER

The driver is still positioned elsewhere in the cabin.

Properly and safe or in another position.

What if...? | DRIVER

The driver moves around in the cabin.

What if...? | DRIVER

The driver acts violent or unsafe.

What if...? | DRIVER

The organisation faces a shift of responsibility related to truck repairs and insurances.

What if...? | ORGANISATION

The organisation provides inadequate education and driver training.

What if...? | ORGANISATION

The organisation makes the driver feel less responsible for the truck and not motivated to work.

What if...? | ORGANISATION

The organisation acts under new rules and regulations regarding driving and rest time.

What if...? | ORGANISATION

The organisation strives to reduce costs and improve time efficiency.

What if...? | ORGANISATION

The traffic involves interaction with other vehicles.

Manual and semi-automated vehicles, fully automated vehicles or a mix of vehicles.

What if...? | TRAFFIC

The traffic is intense or moderate.

Vehicles drive in a regular high or irregular low speed.

What if...? | TRAFFIC

The traffic is affected by an emergency turnouts.

What if...? | TRAFFIC

The traffic is affected by critical driving of others.

What if...? | TRAFFIC

The traffic is hindered by an accident or sudden appearance of an object.

What if...? | TRAFFIC

The infrastructure changes with the surrounding environment.

The road runs through a hilly country.

What if...? | INFRASTRUCTURE

The infrastructure interaction with the truck is absent, wrong or incomplete.

What if...? | INFRASTRUCTURE

The infrastructure involves an interchange or a construction zone.

What if...? | INFRASTRUCTURE

The infrastructure defects from inferior quality.

Road damages occur and road signs are defective due to bad maintenance.

What if...? | INFRASTRUCTURE

The infrastructure is affected by the weather.

Conditions are normal, extreme or involves sudden changes.

What if...? | INFRASTRUCTURE

The interaction between the driver and the truck is absent, incorrect or incomplete.

What if...? | DRIVER-TRUCK INTERACTION

The interaction involves a transition between the driver and the truck, or vice versa.

What if...? | DRIVER-TRUCK INTERACTION

The driver has low situational awareness at request intervene the truck.

What if...? | DRIVER-TRUCK INTERACTION

The driver overrides the automated system.

What if...? | DRIVER-TRUCK INTERACTION

The interaction leads to ambiguous task allocation between the driver and the truck.

What if...? | DRIVER-TRUCK INTERACTION

Appendix 2 – SELMA Guide words

a am appearance

a am are

a ambiguous are

about an around

above an as

accidents and as

action and as

advance and as

after and at

all animals at

allocation answer at

at	beside	cabin
automated	between	can
automation	between	can
autumn	between	care
awareness	but	cause
away	but	change
be	but	cold
bed	by	communicate
behavior	by	communicati
behavior	by	on
beneath	cabin	component

component	decision	driver
condition	deficient	driver
consequence	define	driver
construction	different	drunk
correct	different	due
correct	do	eat
cost	do	efficiency
critical	dream	elsewhere
critical	drive	emergency
day	drive	enormous
death	driver	event

failure

from

how

failure

go

huge

fast

green

human

feel

have

identify

feet

have

if

follow

head

immediate

follow

heavy

improve

for

heavy

in

for

here

in

forest

high

in

from

hot

inadequate

incomplete	it	like
incomplete	it	like
infrastructure	knowledge	live
infrastructure	language	low
insurance	late	machine
interaction	lazy	mad
interaction	less	make
interpretation	less	man
is	let	manual
is	lie	manufacturer
is	light	manufacturer

mean	new	of
mechanical	no	of
mist	no	of
mitigate	no	off
more	non-driving	off
motivated	not	old
moves	not	on
music	not	on
must	objects	one
need	occur	or
never	occur	or

or	prevent	related
organisation	program	relation
organisation	put	relation
organisation	quality	repair
other	radar	request
other	rain	response
over	recall	response
override	red	responsibility
perform	reduce	responsible
play	regulation	rest
position	related	road-users

rock

see

skin

rule

shadow

sky

run

shift

sleep

rust

shine

slow

sad

ship

smell

safety

show

smooth

said

similar

so

scenarios

sit

soar

sea

situation

software

seat

situation

some

seated

situational

spring

still

task

those

still

technology

those

stop

the

through

storm

the

through

subsequent

the

time

sudden

there

time

summer

there

tiny

sun

these

to

system

these

to

system

they

to

task

they

together

traffic

under

vision

traffic

unsafe

want

traffic

up

want

trailer

urge

warning

training

us

warning

transition

use

was

truck

various

was

truck

varying

watch

truck

vehicle

water

turnout

vehicles

weather

type

violent

what

what

who

with

when

why

woman

when

why

woman

where

will

wrong

where

will

wrong

which

wind

yellow

which

winter

yet

who

with

zone

Appendix 3 - Interview questions

Inled med en presentation av oss och vårt arbete.

- Fia och Mia, Chalmers.
- Exjobb på uppdrag av Human Factors och Passive Safety.
- Metod för analys av risker i självkörande lastbilar, fokus på föraren.
- Automation level 4.
- Våra use case: körning på motorväg/landsväg i hög respektive lägre hastighet.

General questions

Rikta frågorna så att de stämmer med området som personen i fråga arbetar med. Vi tar tacksamt emot generell fakta, men vill också veta utifrån respektive perspektiv.

Inledning

Kan du berätta lite kort om det du arbetar med?

Avrundning

Vad ser du för utmaningar under utveckling och införande av självkörande lastbilar? Med tanke på er verksamhet..

(Kan du säga något om den generella inställning till självkörande lastbilar? Inom organisationen, hos kund.)

Subject questions

Självkörnade bilar

Hur relaterar ert arbete till självkörande lastbilar?

Vilka möjligheter ser ni med självkörande lastbilar?

Kan du ge exempel på specifika situationer?

Vilka har ett intresse i utvecklingen? Bransch, individ..?

Ser ni risker med densamma utvecklingen?

Kan du ge exempel på specifika situationer?

Vem drabbas? Och på vilket sätt?

(Förändrar autonoma bilar systemet kring förare, bilen och organisation? På vilket vis?)

Vad för krav ställer åkerierna på framtidens lastbilar?

Metoder för riskanalys med fokus på föraren: idag och i framtiden

Hur arbetar ni med riskanalys på tidig konceptnivå idag? (Vem och var i organisationen genomförs analyser?)

Kan du nämna specifika metoder?

Vad är resultatet av dessa? Hur används det? Och av vem?

Skulle du säga att någon metod är mer tillämpbar, användbar och omtyckt?

Finns det någon som inte fungerar bra? Av vilken anledning?

Tror du att dessa metoder är användbara även i syfte att förutse risker i autonoma fordon?

På vilket vis?

Alt. Av vilken anledning går det inte? Vad saknas?

Nya krav

Följer det nya, förändrade eller högre krav på ergonomi och HMI när fordon blir alltmer självkörande?

Påverkar ert arbete och resultatet av den utvecklingen av tekniken?

Appendix 4 – Survey

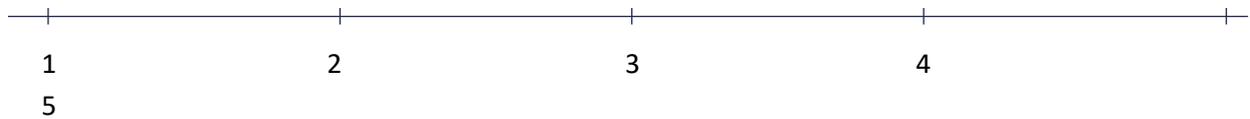
Hej,

Du har nu testat fyra olika koncept för identifiering av kritiska situationer i självkörande lastbilar. För att sammanfatta och utvärdera dessa ber vi dig ta ställning till i vilken grad de uppfyller följande påståenden.

Tack på förhand!

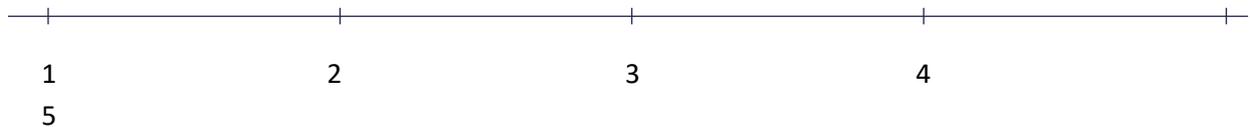
MAGNET WORDS

Metoden hjälper mig att lista kritiska situationer. *Syftet kan vara att hitta både 1) en stor mängd situationer, och 2) nya infallsvinklar.*



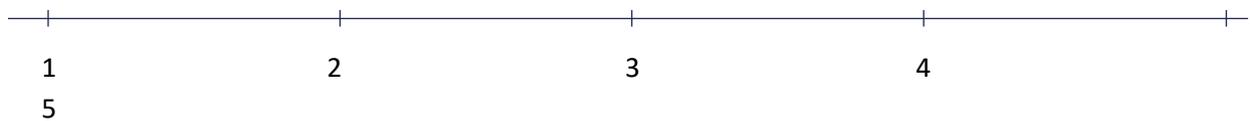
Kommentar:

Metoden är effektiv med avseende på tid och resurs.



Kommentar:

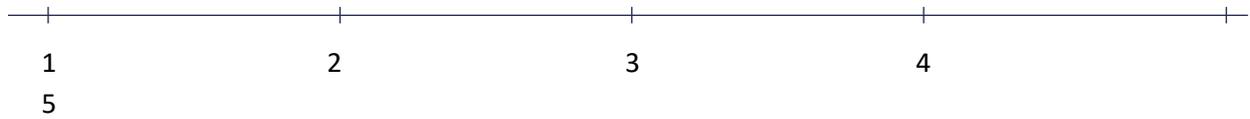
Metoden är tillfredsställande att använda.



Kommentar:

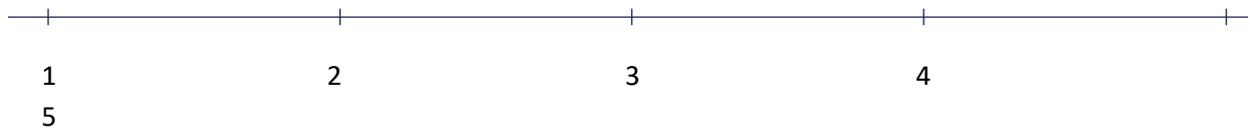
RESTAURANT

Metoden hjälper mig att lista kritiska situationer. *Syftet kan vara att hitta både 1) en stor mängd situationer, och 2) nya infallsvinklar.*



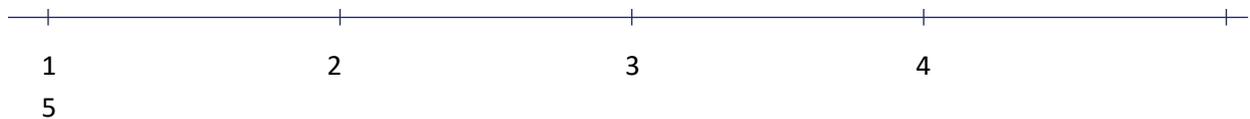
Kommentar:

Metoden är effektiv med avseende på tid och resurs.



Kommentar:

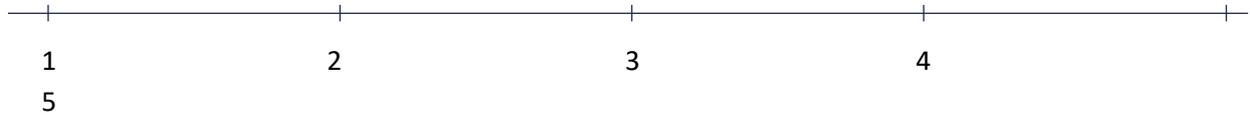
Metoden är tillfredsställande att använda.



Kommentar:

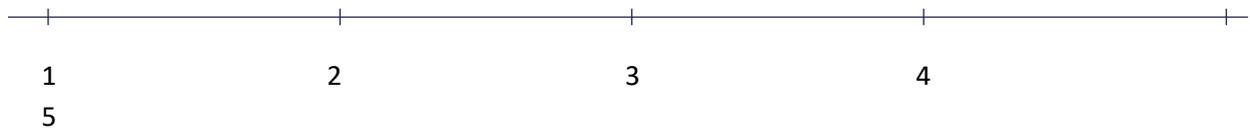
TRIGGERS

Metoden hjälper mig att lista kritiska situationer. *Syftet kan vara att hitta både 1) en stor mängd situationer, och 2) nya infallsvinklar.*



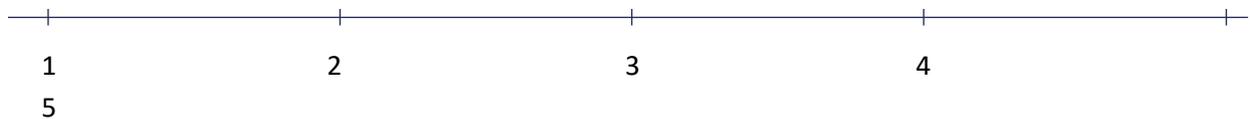
Kommentar:

Metoden är effektiv med avseende på tid och resurs.



Kommentar:

Metoden är tillfredsställande att använda.



Kommentar:

PIRATES

Metoden hjälper mig att lista kritiska situationer. Syftet kan vara att hitta både 1) en stor mängd situationer, och 2) nya infallsvinklar.

1	2	3	4	
5				

Kommentar:

Metoden är effektiv med avseende på tid och resurs.

1	2	3	4	
5				

Kommentar:

Metoden är tillfredsställande att använda.

1	2	3	4	
5				

Kommentar:

Slutligen, vill vi att du avgör vilket/vilka kriterier du anser viktigast, mest relevant eller intressant i samband med identifiering av kritiska situationer.

- Resultat
- Tid
- Känsla under arbete

Kommentar:

Tack!

Appendix 5 – Usability evaluations

Theoretical evaluation

	Effectiveness (new situations)	Effectiveness (fulfill guidelines)	Efficiency	Satisfaction	Total
Magnet words	0	1	0	1	1,5
FIG	1	-1	1	0	1
Restaurant	1	-1	1	0	1
Cake stand	0	0	0	1	1
Triggers	0	1	0	0	0,5
Pirates	0	1	-1	1	0,5
Charade	0	1	-1	1	0,5
Picture board	0	0	0	0	0
Blanks	1	0	-1	0	-0,5
Matrix	-1	0	-1	-1	-2,5
Likely	-1	-1	-1	-1	-3

Product usability evaluation

Magnet Words							
<i>Effectiveness</i>	5	5	4,5	3	4,5	5	4,5
<i>Efficiency</i>	2,5	5	5	3	4	4,5	4
<i>Satisfaction</i>	4	5	5	3	4	5	4,3
Restaurant							
<i>Effectiveness</i>	4	1	3	4	3	4	3,2
<i>Efficiency</i>	4	2	4	4	4,5	3	3,6
<i>Satisfaction</i>	4	2	4	4	2,5	4	3,4
Triggers							
<i>Effectiveness</i>	3	4	3	4	4	4,5	3,8
<i>Efficiency</i>	4	4	5	5	3,5	4	4,3
<i>Satisfaction</i>	4	4	4	5	4	5	4,3
Pirates							
<i>Effectiveness</i>	2	1	2,5	2	2,5	2,5	2,1
<i>Efficiency</i>	4	5	2	2	2,5	2	2,9
<i>Satisfaction</i>	5	5	3	5	5	5	4,7

	Rate					
Effectiveness	1		1	1	1	5
Efficiency	1	1		1	1	4
Satisfaction	1	1			1	3

	Usability factor	Comment	Pros/cons	
Magnet words	Effectiveness	Ja definitivt för nya infallsvinklar, inte stor mängd kanske men en hel del. Min favorit!	+	
		Väldigt bra för att hitta nya infallsvinklar	+	
	Efficiency	Hitta nya kombinationer som man inte skulle ha hittat på själv.	+	
		Klart kreativ	+	
	Satisfaction	Mycket bra för att hitta både en stor mängd situationer och nya infallsvinklar. Bäst resultat fås nog när man slumpar orden.	+	
		Kan bli flummigt om man inte jobbar ordentligt med dem	-	
	Restaurant	Effectiveness	Mkt snabb och krativ. Tilltalande	+
			Tar lång tid att samla ihop och få struktur	-
		Satisfaction	Metoden skapar både möjliga (nya) och konkreta situationer, samt tolkningar av dessa, både djupare och bredare diskussioner av dessa	+
			Tycker denna metod var mycket bra för att komma på nya situationer och infallsvinklar.	+
		Effectiveness	Bra att öppna upp för att sedan specificera med någon annan metod alt. Kombination med teman som i Restaurant.	+
				-
	-			
	-			
Restaurant	Effectiveness	Bra att bygga på andras idéer.	+	
		Bra med en individuell del också	+	
	Satisfaction	Kanske inte är lika bra som Magnet Words, då man här lättare håller sig till det man kan		
		Kan bli generell, svårt att hitta unika situationer	-	

Triggers	Efficiency	Förstod inte riktigt hur detta skulle leda mig tillsituationer. Fastnade i ett separat system	-	
		Snabb	+	
		Många idéer snabbt, ganska lätt att kategorisera efteråt då de halvt redan är i kategorier	+	
	Satisfaction	Kan ta tid om man är många personer som deltar i övningen	-	
		Kändes tidskrävande, speciellt när man skall sy ihop" interaktionen mellan olika system"	-	
		Kan vara svårare att knyta ihop säcken dvs att sammanfatta all input från metoden	-	
	Effectiveness	Inte lika tilltalande för mig, kanske för att jag inte riktigt förstod uppgiften	-	
		Ja, speciellt mängd situationer, tillsammans med resultat från Magnet Words kanske ett vinnande koncept?	+	
		När man tittar på mer specifika kombinationer av situationer så är den väldigt bra	+	
	Pirates	Efficiency	Mer specifik, lätt att hitta nya idéer. Bra med kombinationer.	+
			Inte lika många och nya idéer, men lättare att gå in på djupet	
			Svårt att lägga till nya kort	-
Satisfaction		Ja, kändes snabb och spontan	+	
		Lätt att bara köra igång och man får snabbt en bra indelning	+	
		Tydligt, rakt på situationen	+	
Effectiveness		Tilltalade mig	+	
		Tydlig, rätt fram, ger snabbt nya infallsvinklar	+	
		Mycket tillfredsställande	+	
Pirates	Effectiveness	Jätterolig, bra energizer.	+	
		Visst för att få människor mer öppna och peppade men kanske inte så bra för att tänka nytt.		
		Får inte fram så många unika idéer	-	
		Nej inte riktigt. Ger dock energi och gruppgemenskap	-	
		Inte så många idéer kom fram. Svårt att komma ihåg de som dök upp.	-	

Efficiency	Ja om man använder den som pausunderhållning	+
	Går snabbt att göra	+
	Mer kul än tidseffektivt	+
Satisfaction	Tidskrävande	-
	Beror på hur bekväm man känner sig i gruppen. Kan vara hämmande	-
	Underhållande!	+
	Väldigt rolig!	+
	Jättekul att göra	+
	Mycket kul	+
	Väldigt positiv, ger energi och därmed kreativ som kan användas till?	+