Off-piste skiers' risk perception
and the effects on behaviour and risk management

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Abstract
The purpose of this master thesis was to provide reliable information to improve off-piste skiers' knowledge, behaviour and risk management. This since research concerning human factors in the field of avalanches traditionally had been paid little attention. A literature review covering avalanche, traffic and risk literature and two surveys which gathered approximately 2000 responses were conducted. That led to conclusions like how skiers propensity to take risk increased with the use of rescue equipment, the avalanche danger scale was perceived differently, etc. Based on the conclusions a number of recommendations which could be used to improve off-piste skiers' knowledge, behaviour and risk management were suggested.

This report was written in Switzerland for the Swiss Federal Institute of Technology Zurich. The entire report as it was presented in Switzerland follows after the Lund University cover, Swedish summary and English summary.

Författaren svarar för innehållet i rapporten./ The author is responsible for the contents of this report

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Sammanfattning

Det schweiziska federala institutet för snö- och lavinforskning (SLF) har sedan 1936 studerat snöns egenskaper, hur laviner uppstår och metoder för att förhindra dem. Detta är nödvändigt då det i Schweiz årligen dör 25 personer i laviner. I 90% av olyckorna med dödlig utgång utlöses lavinen av den som dör eller någon i dennes grupp. Syftet med detta examensarbete är att ta fram tillämpbar information som kan användas för att förbättra offpistskidåkarnas kunskap, beteende och riskhantering genom att utvärdera:

- Skidåkarnas kunskap om laviner
- Hur skidåkarna uppfattar lavinrisker och hur detta påverkar beteende och riskhantering
- Om skidåkare utrustade med räddningsutrustning som transceiver och/eller avalanche airbag kompenserar en möjlig högre säkerhetskänsla med att ta större risker
- Om det finns skillnader vad gäller kunskap, beteende och riskhantering mellan olika kategorier av skidåkare (kön, ålder och skicklighetsnivå)
- Hur skidåkarna uppfattar lavinskalan som presenterar rådande lavinfara.

En litteraturstudie och två enkätundersökningar genomfördes. Ett antal nollhypoteser konstruerades och testades i två parallella enkätundersökningar, en i Davos och en på Internet. Ett brett fokus till ämnet valdes då skidåkares risktagande i lavinfarlig terräng är ett hittills relativt outforskat område. All tillgänglig litteratur så långt det var möjligt med koppling till laviner, människor och risk studerades för att få en bild av skidåkares lavinriskhantering. Trafikforskning studerades som komplement till bristfällig tillgänglig lavinrelaterad litteratur.

Risker i lavinfarlig terräng beror på aktivitet (skidåkning) och tillhörande faror (laviner). Risk ses med stöd av litteraturstudien som en balans mellan chansen för skada eller död i en lavin och njutning av att åka skidor. När människor uppfattar risk påverkas de av hur den framställs, tidigare erfarenheter, förväntningar, tankar och tillit till sin egen förmåga. En objektivt beräknad risk kan därför vara svår att förstå för den som inte är insatt i ämnet. Skidåkning är associerad med kontrollerbara och frivilliga risker. Detta kan medföra att skidåkarna underskattar riskerna och heller inte ser eller vill se tecken på fara. Riskhanteringsprocessen är en strukturerad process där risk identifieras, utvärderas och bedöms. Enbart mer information, färdigheter, räddningsutrustning och ingenjörsmässiga förbättringar kommer inte att minska lavinolyckorna, i alla fall enligt teorin bakom target level of risk och därför bör det istället satsas på att sänka den risknivå som skidåkarna uppfattar som acceptabel.

skidåkarnas acceptabla nivå av risktagande.

För att det empiriskt insamlade materialet från enkätundersökningarna skulle vara tillförlitliga jämfördes resultaten med varandra och tidigare resultat. Enkätundersökning i Davos har 527 svar och den webbaserade 1434. Av deltagarna i Davos är 382 män och 145 kvinnor, mellan 15-73 år gamla, en medelålder av 30.8 år och en medianålder på 29. I den onlinebaserade undersökningen är 1245 män och 189 kvinnor, mellan 12-69 år gamla, med en medelålder av 27.1 och en medianålder av 26.

Trafikforsning används som ett komplement eftersom det existerar mycket data jämfört med lavinforskning om människors risktagande och olycksstatistik. Nyttan med de olika riskfyllda verksamheterna skiljer sig och därför är information från trafikforskning använd med detta i åtanke.

Huvudslutsatserna i rapporten är:

- Skidåkarnas lavinkunskap är hög. Inblandningen i laviner beror mer på deras attityder.
- Skidåkare som anser sig vara i riskzonen för att hamna i en lavin är bättre på att ta försiktighetsåtgärder som att läsa lavinbulletinerna än de som inte anser sig vara under risk.
- Räddningsutrustning påverkar skidåkarna till att ta mera risker då de känner sig säkrare med utrustning.
- Räddningsutrustning påverkar också skidåkarna att vidta mera skyddsåtgärder såsom att läsa lavinbulletinerna oftare.
- Det är få skillnader mellan könen ifråga om kunskap, beteende och riskhantering i lavinfarlig terräng.
- Skidåkare under 30 år tar mera risker.
- Skidåkare som bara behärskar lätt terräng är sämre på att hantera risker jämfört med skickligare skidåkare då de exempelvis oftare åker med kompisar som saknar räddningsutrustning.
- Skidåkarna värderar lavinskalans siffra och motsvarande ord olika.

Från slutsatserna togs ett antal rekommendationer fram såsom att vidare förespråka användning av beslutshjälpmedel, interaktiva läroprogram, förespråkning av säkert beteende och att mera tala om möjliga konsekvenser som kan användas i lavinfarlig terräng.

Summary

The Swiss Federal Institute for Snow and Avalanche Research (SLF) in Davos has since 1936 studied the specifics of snow and snow cover, how avalanches arise and methods for protection from avalanches. This is needed when in Switzerland every year on average 25 persons die due to avalanches and 90% of the fatal avalanches have been released by the people caught in the avalanche, or by a member of the same group. The purpose of this master thesis is therefore to provide reliable information to improve off-piste skiers' knowledge, behaviour and risk management by evaluating:

- The skiers' knowledge about avalanches.
- How skiers perceive the avalanche risks and how this effects their behaviour and risk management.
- If skiers with a transceiver and/or avalanche airbag compensate a possible higher level of safety by taking more risks.
- If there are differences in between various categories of skiers (gender, age and level of skill).
- How the skiers perceive the avalanche danger scale.

To provide reliable information a literature review and two surveys were conducted. A number of hypotheses were constructed and tested in two parallel surveys, one in Davos and one online based. Since little previous research had been done in the field of human actions in avalanche terrain a broad focus to the subject was chosen. Therefore were information associated with avalanches, humans and risk studied to gain information regarding off-piste skiers' avalanche risk management. Furthermore traffic research was studied as a compliment since there is lack of avalanche related literature regarding how skiers take risks.

The risks in avalanche terrain depend on the activity (skiing) and the associated dangers (avalanches). Based on the literature review, risk is seen as a balance between the chance of damage, injury or death in an avalanche and the enjoyment of off-piste skiing. When people perceive risk they are affected by framing, past experience, attitudes, expectations, thoughts and beliefs. Framing a risk with an objectively calculated probability of death can therefore be difficult to understand. Skiing is associated with controllable and voluntarily risks where the skiers try to repeat pleasant feelings in the mountains. This can make the skiers underestimating the risks and also not seeing or wanting to see the signs of hazards. The risk management process is seen as a structured process in which risks are identified, evaluated and managed. Solely focusing on information, skills, rescue equipment and engineering improvements will not decrease the avalanche accidents according to the theory behind target level of risk and the focus should instead be on lowering the persons' acceptable level of risk.

To assure reliable and valid empirical material the two surveys' results are compared to each other and against previous research. The Davos survey has 527 responses and the online based has 1434. The participants in Davos include 382 men and 145 women and the respondents are between 15-73 years old with a mean age of 30.8 and a median age of 29. Of the 1434 skiers in the online based survey 1245 are men and 189 women. They are between 12 – 68 years old with a mean age of 27.1 and a median age of 26.

Traffic research is used as a compliment since in that field plenty of data exists, compared to avalanche research about people's propensity to take risk and accident statistics. However the

benefits from the different activities differ and the information from the traffic research is used with the differences in mind.

The main conclusions in the report are:

- The skiers' knowledge about avalanches is generally high. People get caught in avalanches more because of their attitudes.
- Skiers who believe themselves to be in the risk zone of getting caught in an avalanche take more precautions like reading the avalanche bulletins and are less willing to ski with friends without rescue equipment than those who do not believed to be at risk.
- Rescue equipment influences the skiers to take more risks since they feel safer when using the gear.
- Rescue equipment also makes the skiers to take more precautions as reading avalanche bulletins more prior taking the decision to ski off-piste.
- Quite few differences between the men and women's knowledge, behaviour and risk management.
- Skiers younger than 30 are the most risk-taking.
- The skiers' only managing easy terrain's behaviour and risk management are not good compared to more skilled skiers since they for example are more willing to ski off-piste with unequipped friends.
- The skiers rate the avalanche danger scales number and corresponding word differently.

The conclusions lead to recommendations of decision aids, interactive learning programmes, promotion of safe behaviour and highlighting possible consequences to be used in avalanche prone terrain.

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Swiss Federal Institute of Technology Zurich

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September 2007

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Search words: Avalanche, risk, risk perception, risk management, heuristics, human factors

Cover photo with permission from Cross Sportswear
Photographer: Scott Markewitz
Skier: Christian Björk

Executive summary

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I would like to mention a number of people who have been of great assistance for me when completing the report. To begin with I would like to thank my supervisors Marcus Abrahamsson, Benjamin Zweifel and Eric Montagne for their invaluable support during the process. Prof. Dr. Roman Boutellier and Robert Jönsson have during the work come with very good and useful suggestions and advice.

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Without David Abrahamsson I would have had difficulties to post the survey on Internet. I would also like to thank Jamie Bond and Andre Charland at Doglotion, Tobias Liljeroth at Åka Skidor, Peter Blom and Karen Eliasson at Cross Sportswear, Christian Fink at Freeskiers and Dan-Marcus Pethrus at Freeride for publishing the survey and helping me gather plenty of responses.

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Finally I would like to thank all who participated in the survey!

Enjoy the reading!

Christian Björk

Lund, September 2007

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1. Introduction

Off-piste skiing has increased in popularity the last years. Meanwhile the avalanche research's main focus has been on physical factors contributing to avalanches leaving much research to be done about people and avalanches.

1.1. Background

The Swiss Federal Institute for Snow and Avalanche Research (SLF) in Davos studies since 1936 the specifics of snow and snow cover, how avalanches arise and methods for protection from avalanches. One of many services SLF provides is the avalanche bulletin describing the current level of avalanche danger. Among other things SLF also keep statistics about avalanche accidents.

In Switzerland every year on average 25 (over a period of 63 years from 1936 to 1999) persons die and many more get injured due to avalanches (Harvey & Signorell, 2002). The same mistakes are repeated every year, people overestimate their abilities to deal with current conditions and/or they underestimate the avalanche danger (Fredston & Fesler, 1994).

In the avalanche literature the main focus has been on the physical factors (snowpack, terrain and weather) which create avalanches. The interaction between human and avalanches needs more research when 90% of the fatal avalanches are released by the people caught in the avalanche, or by a member of the same group (Fredston & Fesler 1994, Tremper 2001, Munter 2003, McClung & Schaerer 2006). Since the information to the public are based on complex physical and environmental factors there is a need for more human factors understanding (Munter 2003, Adams 2005). Especially since the majority of the avalanches involving skiers are caused by skiers' attitudes when they ski down slopes they know could be dangerous and not because they lack knowledge (Munter, 2003).

The number of people who ski untracked and unsecured slopes are increasing (Munter, 2003). The wider skis and snowboards have made the off-piste more accessible (Tremper 2001, McClung & Schaerer 2006). Extreme snow sports are highly visible in film and television, but possible consequences like death and injuries are rarely discussed which can lead people to underestimate the dangers in the mountains (O'Gorman, Hein & Leiss 2003, DiGiacomo 2006).

1.2. Task description

Human behaviour research in avalanche prone terrain is neglected. The purpose of this master thesis is to provide reliable information to improve off-piste skiers' knowledge, behaviour and risk management by evaluating:

- The skiers' knowledge about avalanches.
- How skiers perceive the avalanche risks and how this affects their behaviour and risk management.
- If skiers with a transceiver and/or avalanche airbag compensate a possible higher level of safety by taking more risks.
- If there are differences in between various categories of skiers (gender, age and level of skill).

- How the skiers perceive the avalanche danger scale.

1.3. Target group

The report is produced for SLF to provide further information on how skiers perceive, behave and manage risk in avalanche terrain. SLF will be able to use and spread this information to other snow science researchers, manufactures and retailers of rescue equipment, ski resorts, insurance companies, emergency rescue service and of course the skiers.

1.4. Disposition

This report begins with an introduction chapter which present background, task description, target group, disposition and restriction and limitations. Chapter two is the theory chapter, where important information is presented. In chapter three are the various methods (literature review, hypotheses, hypotheses testing and questionnaire) used in the reported described. Chapter four presents the results from the literature and chapter five the results from the surveys and the hypotheses testing. The discussion in chapter six discusss the results combined with the used theories and outcome from the literature review. The discussion leads to the conclusions, recommendations and suggestions for further studies in chapters 7-9. The main part ends with the list of references, an independence declaration and the task description in chapter 10-12. This part is followed by an appendix.

1.5. Restrictions and limitations

The term "skier" is in this report not only referred to skiers, but also to all those who engage in snow sports outside marked slopes, including snowboarders, telemarkers, snowshoe hikers, etc. Furthermore, only individuals going off-piste are of interest for this study. The focus is only on avalanche accidents occurring while skiing, while damage to people in for instance buildings and infrastructure is not considered. Ski related accidents due to other factors than avalanches are not included.

Since little previous research is done in the field of human actions in avalanche terrain a broad focus to the subject is chosen. Therefore all available information associated with avalanches, humans and risk are studied. Traffic research is studied to have better background for how humans act when they are under risk since it exits more research in how people take risks in the traffic. Risks for skiers in avalanche terrain and car drivers in the traffic are not the same, but some of the aspects are similar. For example are both risks seen as controllable and voluntarily. Therefore is traffic research used in the report, but with caution.

Plenty of data was gathered in the two surveys that were performed. The used surveys were designed to be easy and quickly answered in the slopes and on the Internet. This construction resulted in over 2000 responses. A more investigating questionnaire with more questions about the different topics in the report would have resulted in a longer and more time consuming questionnaire. Had such a questionnaire been used, not as many responses would have been gathered, since the skiers thought it was important that it would not take to long time to fill out the questionnaire. The results from the surveys can further be used on smaller samples of people to further and deeper investigate how skiers act and behave in the mountains.

2. Theory

This chapter describes important characteristics about avalanches and risk. It also presents how humans perceive and act upon risk, use heuristics and human factors to deal with everyday life. At the end the theory behind target level of risk and how risk can be managed in a structured process are presented.

2.1. Avalanches

Avalanches are sudden down-slope movement in the snowpack (O'Gorman, Hein & Leiss, 2003). They are categorised as loose snow avalanches, slab avalanches, wet snow avalanches and ice or glacier avalanches (McClung & Schaerer 2006, Munter 2003). Avalanches release spontaneously or artificially by either an increase in stress, by for example a skier, and/or a decrease in the snowpack's strength for instance by warming or rain (Schweizer et al., 2005). Normally avalanches occur in slopes with inclination between 25˚-55˚, where the span between 35-40˚ is the most common (McClung & Schaerer, 2006). There are rare examples of snow avalanches in slopes below 20˚ (McClung & Schaerer, 2006).

The avalanche triangle in Figure 1 describes the four factors; snowpack, weather, terrain and people, which influence the potential for avalanches that could be of harm to humans. The factors can be evaluated by asking the following questions stated by Fredston and Fesler (1994):

- Snowpack – could the snow slide?
- Weather – is the weather (e.g. snow, wind, sun, etc) contributory to instability?
- Terrain – is the terrain capable of producing avalanches?
- Human – what are the skiers' alternatives and the alternatives possible consequences?

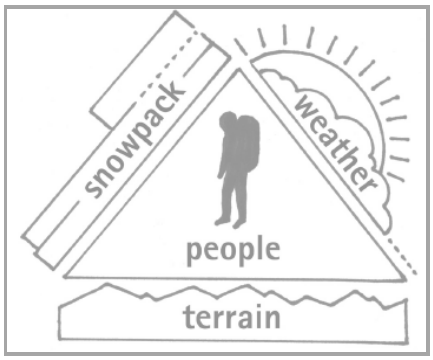

Figure 1 Factors involved in producing potential dangerous avalanches for humans (with permission) (Fesler & Fredston, 1994)

In the avalanche statistics, the following factors are common when humans have been involved: north-facing slopes, new snow combined with wind, rapidly and distinctly rising temperatures, weak layers within the snow cover etc. (Schweizer et al. 2005, McClung & Schaerer 2006, Tremper 2001, Munter 2003).

2.2. Risk

The term "risk" is often associated with the possibility that an undesired state of reality (adverse effects) may occur in the future as a result of natural events or human activities (Renn, 1998). Today there is no commonly accepted definition of risk – either in the sciences or in the public understanding (Renn, 1998).

Early risk research concentrated on risks expressed as a product of the probability of an event and the consequences thereof before Starr (1969) found people to value risk differently. He discovered voluntary risks such as off-piste skiing to be remarkably more acceptable and tolerable by individuals, than involuntary risks as nuclear power.

The questions if there is anything called objective risk and if accident statistics is a good measure of the "objective risk" have been discussed for a long time. According to Slovic (1999) the term "risk" was made up to explain and manage the dangers and hazards. He says there is no such thing as objective risk since all assessment is based at least on a small amount of subjective judgement or models. Danger is real, but risk is socially constructed (Slovic, 1999). Kaplan and Garrick (1981) say qualitatively, risk depends on what you do, what you know and what you do not know.

It can be useful to give risk a quantitative value. Kaplan and Garrick (1981) are critical to the early definition of risk as the product of an event and its consequences. Since that equals single scenarios with either low-probability and high-damage with high-probability and low-damage scenarios. They contributed to the field of risk research in the first issue of a famous risk management journal with a frequently used definition:

$R=\{<s_i, p_i, x_i>\}, i=1,2,..., N$

Kaplan and Garrick saw risk (R) as a set of triplets consisting of the scenarios (s_i), the probability of the different scenarios (p_i), and the consequences of the different scenarios (x_i) which essentially are answers to three for risk analysis important questions:

- What can happen? (i.e., What can go wrong?)
- How likely is it that that will happen?
- If it does happen what are the consequences?

Risk is often seen as a balance between cost (e.g. chance of damage, injury or death in an avalanche) and benefit (e.g. a nice run in good snow) (Slovic, Fischoff & Lichtenstein, 1978). High-risk activities tend to have greater benefits than low-risk activities and if people's attitude toward a source of risk is favourable they often judge the risk as low and the benefits as high (Slovic & Peters, 2006).

In this report risk is seen as the above mentioned balance between skiing and the chance of damage, injury or death. The risk depends on the activity (skiing) and the associated dangers (avalanches), how much the skiers know and also what they do not know about the hazards.

2.3. Risk perception

Perception applies to mental processes where a person takes in, deals with and assesses information from the environment via the senses (Renn, 2004). This means that people construct their own reality and evaluate risks according to their subjective perceptions. The ability to sense and avoid harmful conditions is necessary for survival (Adams, 1995). The perception of risk is aided by an ability to modify and learn from past experience (Slovic, 1987). Other important factors for the risk perception are attitudes, expectations, thoughts and beliefs (Sjöberg, 2000).

Slovic, Fischoff and Lichtenstein (1981) say that people's beliefs change very slowly when they are formed and new evidence appears reliable and informative only if it is consistent with one's initial beliefs. They also discuss that contradictory evidence tends to be dismissed as unreliable, erroneous, or unrepresentative. One example is if a skier assumes the snow to be stable, and will not release an avalanche, he/she will look for signs confirming it. Kahneman and Tversky (1979) state people to be easily affected by the formulation of the problem (framing) and using mental rules of thumbs (heuristics). Slovic, Fischoff and Lichtenstein (1978) discuss that people's acceptance and attitudes toward a source of risk are determined not only by the statistics, but also quantitative and qualitative characteristics. For example if the source of the risk is dreaded, controllable, familiar, certain to be fatal, catastrophic potential, is immediately manifested, etc.

Humans perceive and act upon risk in two fundamental ways; risk as feelings and risk as analysis (Slovic & Peters 2006). Risk as feeling refer to individuals' instinctive and intuitive reaction to danger which is automatic, natural, and nonverbal. Risk as analysis is a verbal process which brings logic, reason and scientific deliberation together. Slovic and Peters (2006) report that most risk analyses in daily life are handled quickly and automatically by feelings. Pleasant feelings as skiing in untracked snow motivate actions the skiers expect to reproduce those feelings and vice versa with unpleasant feelings.

How people perceive risk is an often studied subject and in a frequently cited study Lichtenstein et al (1978) show that individuals over-assessed small fatality risks and under-assessed large fatality risks. Which is proof for peoples' perception of risk is not always in line with the statistics. Skiing is associated with controllable and voluntarily risks where the skiers try to repeat pleasant feelings in the mountains. This can make the skiers underestimating the risks and also not seeing or wanting to for the signs of danger.

2.4. Heuristics and human factors

In the previous section risk as feelings are discussed, the automatic processes by which most of all decisions about risk are made. When faced with the difficult task of judging the probability of an unwanted event, people employ a limited number of rules of thumbs, which reduce these judgements to simpler ones called heuristics (Tverksy & Kahneman, 1974). In general, these heuristics are useful, but sometimes they lead to severe and systematic errors. When people make critical decisions based on their desire and assumptions rather than analysing and integrating relevant physical data it is called human factors (Fredston & Fesler, 1994).

In the avalanche literature the heuristic errors are described as heuristic traps (McCammon, 2002). The heuristics are simple to use and they have proven themselves functional in daily life. If, out of unconscious habit, a skier uses the heuristics wrong the decision can be catastrophic (McCammon, 2002). An example of a heuristic trap is "avalanches do not occur in forests", which is wrong. Avalanches are less likely in a forest due to terrain roughness and buried anchors, but not impossible (McClung & Schaerer, 2006). Avalanches can be released in a forest and the consequences for a skier are then often more severe compared to an avalanche in terrain without hard objects as trees and rocks.

According to Tremper (2001) skiers use human factors when they look for what they want to see; old track must mean the slope is safe, feeling safe in numbers, summit fever, powder rush, etc. Fredston and Fesler (1994) claims that the same mistakes are being repeated all the

time in avalanche terrain, the skiers underestimate the hazards and overestimate their ability to deal with the hazards. The skiers see the signs of danger, but ignore them. The perception of a given situation strongly depends on our pre-existing beliefs, experience, emotions, and the circumstances of the observation (Fredston & Fesler, 1994).

2.5. Target level of risk

In this section the balance between cost and benefits is further evaluated. Wilde (2001) discusses the target level of risk as the level of risk a person choose to accept in order to maximize the overall expected benefit from an activity. He discusses that in any activity, people accept a certain level of subjectively estimated risk to their health, safety and other things they value, in exchange for the benefits they hope to receive from these activities. If the level of subjectively experienced risk is lower, people tend to engage in actions which increase their exposure to risk. Wilde further says that mitigating measurements such as education, training, rescue equipment, engineering improvements will not lead to decreases in accidents if the skiers do not lower their acceptable level of risk. It is difficult when humans try to optimize the danger to maximize the benefits and not minimize the level of risk-taking. Wilde (2001) proposes that lowering the benefits the risks gives and future rewards for safer behaviour is likely to be successful, at least for car drivers. If this is applicable on skiers will be evaluated in the chapter four.

2.6. Risk management

According to the standardisation institute International Electrotechnical Commision (IEC) the risk management process consists of risk assessment and risk reduction/control (Figure 2) (IEC, 1995). Risk assessment consists of risk analysis in which risks and associated consequences are identified and the evaluation which evaluates if the risks are acceptable and analyses alternatives. Risk reduction/control contains the decisions, implementing and supervision.

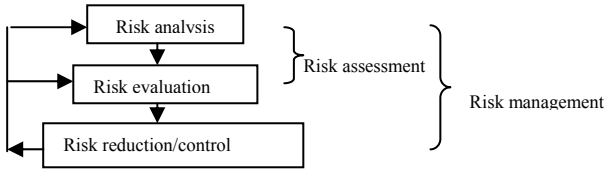

Figure 2 Risk management process according to IEC (1995)

Central in the risk analysis are the three previously presented questions by Kaplan and Garrick (1981). Haimes (1991) has constructed three additional questions for the entire risk management process:

- What are the available options?
- What are the associated tradeoffs?
- What are the impacts of current decision on future options?

2.7. Summary chapter two

The avalanche research has so far mainly focused on the psychical factors (snowpack, terrain and weather). Since decisions in avalanche terrain are decisions in uncertain situations where people often use heuristics and human factors more research is needed.
The risks in avalanche terrain depend on the activity (skiing) and the associated dangers (avalanches), how much the skiers know and also what they do not know. Risk is seen as a balance between the chance of damage, injury or death in an avalanche and the enjoyment of off-piste s. When people perceive risk they are affected by framing, past experience, attitudes, expectations, thoughts and beliefs. Framing a risk with an objectively calculated death risk can therefore be difficult to understand. Skiing is associated with controllable and voluntarily risks where the skiers try to repeat pleasant feelings in the mountains. This can make the skiers underestimating the risks and also not seeing or ignoring the signs of hazards.

According to the theory behind target level of risk a decrease in accidents is not likely with mitigating measurements, at least for car drivers. The focus should instead be at the persons' acceptable level of risk. The risk management is used to locate available options; see what the associated tradeoffs are, and have a better understanding of the impacts current decisions can have on future options.

3. Method

To provide reliable information usable for improvements of skiers' behaviour and risk management a literature review and two surveys were conducted. A number of hypotheses were constructed from the questions in the task description which were investigated in the surveys.

3.1. Literature review

A literature search was conducted to find previously presented material in the fields of avalanche and traffic research. The former chapter presented important background theory also gathered from the literature review. To be able to properly answer the task description further literature studies were performed and these results were presented in chapter four.

Traffic research was used as a complement when it exist plenty of accident statistics compared to avalanche research and also more information about people's propensity to take risk. Both risks were seen as controllable and voluntary. The benefits from the different activities differ though. Benefits from car driving were often part of everyday life (like driving to work, picking up kids, etc.) while skiing was more associated with pleasure and vacation. The information from the traffic research was used with these differences in mind.

The work was systematically performed by searching literature in data banks with the help of search words and using their references to find the source of origin or other relevant information (Backman 1998, Ejvegård 2003). The main search words were avalanche, risk, risk perception, target level of risk and risk management. The report investigated skiers' avalanche risk management and behaviour and the literature review can be described as in Figure 3.

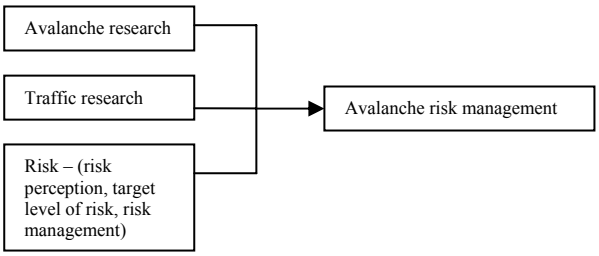

Figure 3 Schematically description of the literature review

3.2. Hypotheses

Hypothesis means assumption and in statistics hypotheses were used to try assumptions regarding a population (Körner & Wahlgren, 2005). A null hypothesis (H_0) and an alternative hypothesis (H_1) were formulated to test the assumption. The schematic way to work according to Körner and Wahlgren (2005) was:

- Questions
- The questions are translated to hypotheses
- Random selection. Numeric calculations
- The null hypothesis is accepted or rejected
- Verbal (understandable) conclusion

This report handled skiers' knowledge, behaviour and risk management and a null hypothesis could for example be: H_0 = skiers with a helmet are equally willing to ski fast as skiers without. The alternative hypothesis then described potential differences between the two groups of skiers. A hypothesis testing could lead to new questions and new hypotheses to be formulated and tried on a new random sample (Körner & Wahlgren, 2005).

Significance

The testing led to either a rejection of the null hypothesis or an acceptance of the null hypothesis. When accepting the alternative hypothesis (rejecting the null hypothesis) it was statistically secured that the difference was not a coincidence of chance (see Appendix 1) (Körner & Wahlgren, 2005).

The test's significance level was determined to which chance to reject the null hypothesis when it was true. The significance level was tested by calculating the p-value and comparing it to the commonly used values 5%, 1% and 0.1%, where a lower p-value was a stronger support for the alternative hypothesis. Values higher than 5% did not support the alternative hypothesis and the null hypothesis was accepted. The calculated value depends on the distribution of the sample and the test's degrees of freedom which depends on how many groups and different answer alternatives there were (Körner & Wahlgren, 2005). If the p-value was lower than 5% for the hypothesis test for skiers with or without helmet it was statistically secured that there were differences between the two groups of skiers' willingness to ski fast. To conclude which group of skiers who ski the fastest the numeric outcome of the responses were compared.

This was surveyed and hypothesis tested

In order to provide reliable information to be used to improve how skiers perceive, behave and manage the risks in avalanche terrain the questions in the task description were transformed to null hypotheses and numbered questions in a questionnaire (see section 3.3). The following subheadings display the statements from the task description and under them are the null hypotheses and the questions from the used questionnaire. The displayed numbers were the actual numbers and questions from the questionnaire. The null hypotheses investigated similarities in different groups.

The off-piste skiers' knowledge about avalanches

No null hypothesis was constructed for the first statement. Instead, as a basis for evaluating behaviour and risk management questions 6, 9 and 10 from the questionnaire investigated how much the skiers knew about:

6. During which degree of avalanche danger (scale from 1 to 5) do you think most of the avalanche fatalities occur in Switzerland?
9. From which steepness do you think avalanches can occur?
10. Standing above a slope what from the following factors affect your decision regarding whether to go off-piste or not?

How off-piste skiers perceive the avalanche risks and how this affects their behaviour and risk management

The skiers were in question 15 asked if they consider themselves to sometime be in the risk zone for getting caught in an avalanche? The null hypothesis was:

- H_0 = There are no differences between skiers who consider themselves to be in the avalanche risk zone compare to those who consider themselves not to be.

The null hypothesis was tested for questions 5, 11-13:

5. How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision regarding whether you ski/snowboard off-piste or not?
11. What kind of rescue equipment do you use when skiing/snowboarding off-piste?
12. If you are equipped with a transceiver how often do you exercise seeking with it?
13. Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?

If off-piste skiers with a transceiver and/or avalanche airbag compensate a possible higher level of safety by taking more risks

The theory behind the target level of risk said that equipped skiers will modify their behaviour and take more risk. Question 11 asked what kind of rescue equipment the skiers use. The investigated null hypothesis was:

- H_0 = there are no differences between equipped and unequipped skiers in how they behave, manage and take risks in the mountains

Hypotheses testing were performed for questions 5, 12-13 and 15:

5. How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision regarding whether you ski/snowboard off-piste or not?
12. If you are equipped with a transceiver how often do you exercise seeking with it?
13. Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?

Question 14 investigated if equipped skiers took more risks when they their use rescue equipment:

14. How much is your willingness to ski/snowboard off-piste affected by the rescue equipment that you use?

If there are differences in between various categories of skiers (gender, age, level of skill)

Three null hypotheses were constructed for gender, age and the level of skill:

- H_0 = there are no differences between how men and women behave, manage and take risks in the mountains
- H_0 = there are no differences between how different age groups behave, manage and take risks in the mountains
- H_0 = there are no differences between how persons with different level of skills behave, manage and take risks in the mountains

Hypotheses testing were conducted for the three null hypotheses for questions 4-5, 11-15:

4. How much do you on average ski/snowboard off-piste per year?
5. How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision whether you ski/snowboard off-piste or not?
11. What kind of rescue equipment do you use when skiing/snowboarding off-piste?
12. If you are equipped with a transceiver how often do you exercise seeking with it?
13. Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?
14. How much is your willingness to ski/snowboard off-piste affected by the rescue equipment that you use?
15. Do you consider yourself to sometime be in the risk zone for getting caught in an avalanche?

How the skiers perceive the avalanche danger scale

How did the skiers perceive the avalanche danger scale? The avalanche danger described the current avalanche danger with a number and corresponding word (see Appendix 2). The null hypothesis investigated if the skiers perceived the number and the word equally dangerous:

- H_0 = The skiers perceive the number and corresponding word equally dangerous

Hypothesis testing was performed for questions 7 and 8:

7. How do you rate the level "3" at the avalanche danger scale?
8. How do you rate the level "considerable" at the avalanche danger scale?

3.3. The surveys

Two surveys were conducted, one in Davos and one online based, see Appendix 3 for the used questionnaire. A well constructed questionnaire was essential for the gathered data to be useful and should be constructed so the respondents wanted to answer it, interpreted the questions in the way the constructor intended, and did not feel like a burden to answer (Dahmström, 2000). It was also constructed so it should not create biases, because performing analyses on biased data can result in erroneously enhanced statistical significance or completely enhanced statistical illusory effects (DiGiacomo, 2006). There are various methods to construct, distribute and perform hypothesis testing on a survey (see Appendix 1). Since the author never before have performed surveys of this magnitude there were chances that biases could occur. But when the questionnaire was designed precautions were taken to limit possible biases. Before the questionnaire was used it was tested to see how well it worked.

To gather reliable and valid empirical material the two surveys' results were compared to each other and against previous research. It was important to create a questionnaire which was interesting to answer, quickly filled out and easily understood when the gathering both took place on the mountains (in the slopes, lifts and restaurants) and online. The questionnaire began with easy demographic questions (gender, age) and continued with more investigating questions with closed answer alternatives on an ordinal scale where the χ^2-test could be used for the hypothesis testing (see Appendix 1 and 3).

In Davos, off-piste skiers were asked randomly in the mountains to participate in the survey between the 16th of March and the 21th of April. Approximately 25 replies were also gathered

at the Swiss Federal Institute of Technology Zurich (ETH) during a lecture in risk management and avalanches. All the persons participating in the survey with their name and email address had a chance to win one day of free skiing and avalanche education with an avalanche expert from SLF. In total three prizes were given away.

The parallel survey was conducted by posting it on the Internet. The online survey contained the same questions as the one in Davos with one exception since question 12 in the Davos survey had two similar answer alternatives. The online based version's link was distributed on the 12th of April with email to more than 100 people. The following days a number of off-piste skiing websites published the link (see Appendix 4). The data gathering continued to the middle of May. The persons answering the internet survey did not receive any reward.

4. Literature review

The literature review discusses previous avalanche research and traffic research. This to provide further information about risk, genders, age groups, level of skill, rescue equipment which lead to avalanche risk management.

4.1. Avalanche research

SLF has previously conducted a survey examining how much people know about avalanches and how they gather the information about the avalanche conditions (Zgraggen, 2004). This is also the topic in a survey about human behaviour and risk management concerning skiers/snowboarders which SLF has performed together with ETH on graduate students (Boutellier, Montagne & Barodte, 2007). The results indicate that inexperienced skiers lack avalanche knowledge.

The avalanche accident statistics involve quite few people and are often biased with the victims', bystanders' or rescue teams' own often faulty recollection of the event (Atkins, 2000). The actual numbers of avalanche related fatalities are reliable for obvious reasons. However the reliability of avalanche accidents statistics would be improved if it also was possible to estimate how often the avalanche victims visit avalanche terrain (DiGiacomo, 2006). In traffic research fatalities/km is often used to describe car crash statistics (Evans 1991). The studies made by Zweifel, Raez and Stucki (2006) and Grímsdóttir and McClung (2006) are so far the only ones investigating how many persons actually skiing off-piste in avalanche terrain. When knowing the actual numbers of off-piste skiers the avalanche accidents can be more accurately evaluated. This can also lead to more efficient evaluation of the effects mitigation (training, education, rescue equipment) have (DiGiacomo, 2006).

Grímsdóttir and McClung (2006) discuss how information from present accident statistics can lead to misleading guidelines and heuristics. They say that avalanche accidents often are more frequent on slopes offering better skiing quality and are therefore skied more which results in more avalanche accidents. North-facing aspect might not be as dangerous as the avalanche accidents statistics suggest if the actual avalanche accidents are compared to how often those slopes are skied (Grímsdóttir & McClung, 2006).

In avalanche terrain it is hard to get feedback. Was it the right decision not to ski a slope? Warning signs for avalanches might be present but without somebody skiing down the slope it is impossible to know for sure if the slope would have produced an avalanche. There are many factors contributing to the decision to ski a slope. Munter (2003) has in his 3x3-method showed in three by three categories important factors to consider. In matrix with a horizontal row consisting of weather and snow conditions, terrain and human factors and a vertical one with trip planning, assessing the local hazard and assessing specific slopes can avalanche hazard be evaluated.

Avalanche bulletins

Avalanche bulletins in Switzerland have been produced by SLF for more than 55 years. The avalanche bulletin (both national and regional) is a general description of current avalanche conditions and isolated slopes are not evaluated in the bulletin (Ammann & Stucki, 2005). It consists of weather information and snow conditions for the past 24 hours, latest weather developments relevant to avalanche danger and the forecast for the next two coming days

avalanche danger (Ammann & Stucki, 2005). The European five degree avalanche danger scale has been used by SLF since the winter of 1993/1994 (see Appendix 2). It ranges from low to very high (1-5) and every level are related to the snowpack stability, the triggering probability, the frequency and areal extent of dangerous slopes, the size and the type of the expected avalanches (Ammann & Stucki, 2005). It was developed from extensive practical experience and data on avalanche occurrence (McClung, 2000). The avalanche danger scale increases as the snowpack stability decreases. "Avalanche danger" denotes the possible occurrence of a potentially damaging avalanche.

Harvey (2002) describes that most avalanche fatalities occur during level "3" which is predicted 30% of the time. Nairz (2003) is uncertain if the skiers actually understand that the avalanche danger scale is constructed as an exponential scale. In Norway it is discussed if the wordings of the avalanche danger scale might contribute to dangerous situations (Brattlien, 2007). Since the only data available to assess avalanche danger scale are low-entropy data from accidents, death statistics and avalanche occurrences (or lack of them) more information is needed (McClung, 2000).

4.2. Risk, risk perception and target level of risk

As a compliment traffic literature is studied to find more information about human behaviour and risk management. This since risks in traffic have similarities with avalanche terrain since both fields includes risks which are associated with control and voluntariness. However are risks in avalanche terrain and in traffic not exactly comparable when the benefits in skiing are more associated with pleasure and car driving with everyday life (driving to work, picking up kids etc.). This is considered in the literature review.

Risky driving is often valued as more fun (Evans, 1991). The same can be said to be valid for off-piste skiing when the thrill of skiing a powder slope is a great feeling skiers try to repeat. Humans are generally bad at judging the risk they are exposed to (Tremper, 2001). Misleading experience might lead people to view themselves as immune to hazards. An example is that many poor car drivers make trip after trip without crashes with an increasing personal experience. Which manifest the drivers' extraordinary skill and safety they possess when their indirect personal experience gained from the media tells them that when accidents happen, they happen to others (Adams, 1995). The same applies in avalanche terrain when an avalanche is not released, which is the most probable outcome, the experience is intensely positive and the trust to the skiers' own ability is strengthen and will reinforce his/hers beliefs that avalanches will not happen to him/her (Slovic, Fischoff & Lichtenstein 1978, McCammon 2004, Slovic et al. 2002).

Gender

There are differences between how men and women perceive risk. Andersson and Lundborg (2007) found the same pattern as Lichtenstein et al. (1978), that men are more likely to underestimate their own risk while women often overestimate theirs. Men are often the main beneficiaries of hazardous activities (like off-piste skiing), which could explain part of the gender differences (Andersson & Lundborg, 2007). The women also often rate their knowledge about the risk activity lower than it actual is (Andersson & Lundborg, 2007). Men on the other side have bigger trust in their abilities at the same time as women are more positive towards security and safety measurements (Evans, 1991). Evans (1991) found more males to be involved and killed in car crashes. The same pattern is found in the avalanche

research when men are significantly more involved in avalanches (Tase, 2004). Evans (1991) also discusses how males, often young males tend to be more risk-taking and see more benefits in for example high speed driving.

Age

The tendencies to take risks are age dependent when they are based on a person's total life's experience and are difficult to change (McClung & Schaerer, 2006). It is a complex blend of one's life experiences and one's personality including views of nature, fate, control, skill, marital status and family details, culture factors, etc. (McClung & Schaerer 2006, Evans 1991).

The age affects the propensity to take risk which is seen both in the avalanche and traffic research. Young males are the most common in the accident statistics. Even if male drivers are more involved in crashes, younger females also show higher risk-taking behaviour than older ones (Evans, 1991). Drivers less than 30 years old are overrepresented in the traffic statistics followed by a decrease between 30-40 years and an increase after 40 years (Evans, 1991). It looks like the avalanche statistics follow the same trend at least until the skiers turn 40 years since the most likely avalanche fatality in Switzerland is a man between his 17 and 30 (see Figure 4). Above an age of 30 is a steady decrease in avalanche involvement detected (Harvey & Signorell, 2002). Possible reason for can be that the skiers under 30 years old are likely to be the biggest group of skiers. Tase (2004) on the other hand found skiers over 30 years old to have been more involved in avalanches than younger people. However she never asked the skiers how old they were when they were caught in the avalanche(s) which of course can be a bias.

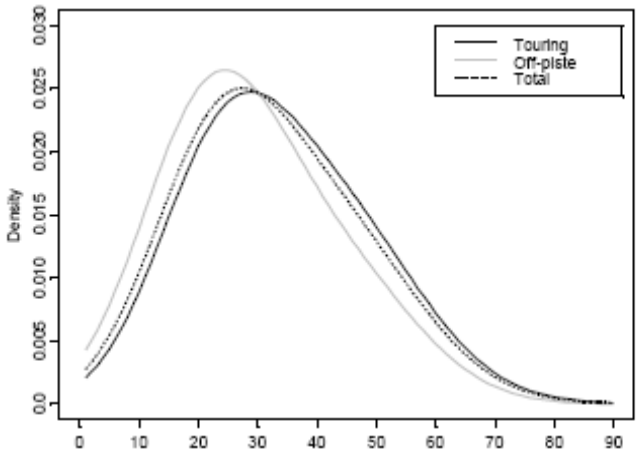

Figure 4 Age of caught people in recreational avalanche accidents. Total number of people considered: 1500 (with permission) (Harvey & Signorell (2002)

The younger drivers high involvement in car crashes depend according to Evans (1991) on that they expose themselves to more risky conditions, they are more likely to experience risk as rewarding, and they are inexperienced. He also says that younger drivers have better abilities (lower reaction time, visual acuity) which they use to drive wilder, with more risk-taking in accordance with the theory of target level of risk. As people age, they rank their abilities higher at the same time as their mental and sensory abilities declines. This can explain the increase in car crashes after the drivers turn 40 (Evans, 1991). The available statistics do not unveil the same pattern in the avalanche research.

Level of skill

Increasing skills lead to improving abilities and confidence which might lead the persons to increase their acceptance of higher risk and task difficulty, as driving faster (Wilde 2001, Evans 1991). However higher skills are not necessarily associated with lower crash rates when race drivers have more crashes compared to a control group (Evans, 1991). People with less training are often aware of their lack of ability and take it more careful (Wilde, 2001).

There are many skilled skiers, but few are equally competent avalanche evaluators. The avalanche knowledge and management does not match the skiing ability (Fredston & Fesler, 1994). McCammon (2004) says that since the majority of the off-piste skiers never will attain a high level of avalanche assessment capacity, most of them are probably overconfident in both their skills and their ability to survive in avalanche terrain.

According to Zgraggen (2004) competent people are more likely to use the avalanche bulletins. Skiers who prepare themselves, with training and equipment, to ski off-piste also show a higher involvement in avalanches and know of more persons injured or killed (Tase 2004, Atkins & McCammon 2004). Experienced skiers spend more time in the mountains but the completely (snow cover head and chest) burial and injury rate are the same compared to less experienced (Atkins & McCammon, 2004). The more experienced skiers do something right when they compared to the time they spend in the mountains have fewer avalanche accidents than the less experienced. However they are not perfect since many experts also get caught in avalanches (Fredston & Fesler, 1994). Still Atkins and McCammon (2004) think skiers should learn like the experts by experience and not only from training which is not efficient enough according to them. Both Tversky and Kahneman (1974) and Slovic (1987) state that experts overestimate risks in the same ways as laymen when they can not support their decisions with data and uses intuitive thinking and heuristics.

If accidents only depended on lack of skill, training and education would be a natural countermeasure (Evans, 1991). But since persons with lots of training and education are often found in the statistics it could indicate that accidents do not only decrease from training and education. Skill and knowledge is often learned by trial and error (Evans, 1991). Trial and error in avalanche terrain is dangerous, but if experts experience would be integrated in training and education for less experienced skiers, plenty could be gained (Adams, 2005).

Rescue equipment

Rescue equipment can be used to save a buried skier in case of an avalanche. A dangerous side-effect can be that the gear might modify the users' behaviour towards more risk-taking in accordance with the theory of target level of risk (Evans 1991, Wilde 2001, Tremper 2001). Traffic research has shown that the use of rescue equipments have not lead to the intended car crash decrease despite ABS-brakes, studded tires, mandatory belt wearing, etc. (Evans 1991, Wilde 2001). Similar effects have been noticed for equipped skiers who often take more risk when they use their rescue equipment (Tremper, 2001). Tremper (2001) suggest that skiers should ask themselves before they ski a slope if they would ski it without their rescue gear. A "No" to the question is a good advice for the skiers not to ski it.

The standard rescue equipment in off-piste terrain is transceiver, probe and shovel (Tremper 2001, Munter 2003). First aid kit and cell phone are also useful. More advanced equipment are ABS-backpack (could prevent deep burial) and Avalung (artificial air pocket) (Tremper 2001, Munter 2003, Tschirky, Brabec, & Kern 2000). A person who carries rescue equipment

is not automatically protected from avalanches. 13% of all persons caught in avalanches are killed, both from mechanical injuries and from burial (Tschirky, Brabec, & Kern 2000). No rescue equipment will protect it's user from injuries caused by hard objects (e.g. tree and rocks) which stand in the avalanche's path. The gears can however help a completely buried skier, but it is a race against time. A race where the death rate increases rapidly, from 10% after 15 minutes, to 50% after half an hour and after 60 minutes the survival chance are small (Tremper 2001, Munter 2003).

Practise with rescue equipment

Practise with transceivers and the other rescue equipment is essential if they should be useful. The practice must be done often and under realistic situations since the chance of surviving an avalanche burial is larger by the help of friends compared to a rescue crew, which take long time to gather (Ammann, Buser, & Vollenwyder, 1997). As a compliment to normal transceiver training when the skiers bury one (or more) transceiver(s) and practise searching, there are now ski resorts equipped with transceiver practise search parks (Christie, 2004). This is according to Christie (2004) a quicker, more efficient training method which also gives opportunities to practice multiply buries easier.

4.3. Avalanche risk management

Ski resorts' aim is to make money from the skiers when they use their lifts and facilities. The ski resorts manager have to weigh the risk that something unwanted, like an avalanche accident happen, against the money they will loose when the lift is standing still due to avalanche danger. To protect the skiers from avalanches the resort managers use avalanche bulletins, securing the off-piste with stabilizing skiing and explosives and as a last alternative they close the resort for the avalanche danger to settle (Schwarz, 2004). However closing the resort equals economical losses and if ski runs are not opened despite the avalanche danger has obviously decreased a loss in credibility for forecasted warnings can be the outcome (McClung & Schaerer, 2006). Furthermore avalanches are not the only dangers the ski resort managers need to deal with. The slopes have to be groomed and big machines are moving nearby skiers. Often the slopes are groomed during the nights but it happens that the machines are working during the open hours of the lifts. The ski resort should also make sure that close to the slopes all stubs are taken away, and that the skiers are protected from trees and lift fundaments (Schwarz, 2004).

The skiers' risk management is affected by the ski resort managers before they ski in a resort, since the resorts try to manage the avalanche risk before they open the lifts. Backcountry skiers are not affected by other persons risk management to the same extent. The ski resorts are not necessarily free from avalanches in spite of all precautions and open ski runs should be treated careful by the skiers. The skiers must ask themselves how much risk from avalanches they are willing to expose themselves to, to receive the benefits (fresh snow) and at which cost (damage goods, injury or death). Risk management for the skiers are for example reading the avalanche bulletins and the use of rescue equipment.

Skiing in avalanche terrain are events typically associated with voluntariness and excitement and as events with low probability, high consequences and high levels of uncertainty. It is difficult to estimate the snowpack's instability compared to a given triggering level (McClung, 2001). The number of avalanches involving skiers could be decreased if the skiers became more aware of how to manage the risks. Much of the problems in avalanche terrain

lay in the fact that the people do things they know could be dangerous rather than just lack of knowledge (Evans 1991, Fredston & Fesler 1994).

McCammon (2004) compares different campaigns aimed to decrease unhealthy behaviour as unprotected sex, drug use, fast driving, etc. to find out what could work for off-piste skiers. He stated that behavioural changes are unlikely results from teaching information, skills or rational decision strategies. Instead McCammon (2004) promotes simple risk metrics and mitigation measure in form of risk ladders where the users can, with different clues (e.g. avalanche danger level, terrain, etc.), indicate their position on the risk ladder and adjust their behaviour according to the current situation. The risk metrics can be used to make on-the-spot risk assessments. Today a number of different aids which can be useful exist:

- **Reduction method** by Munter (2003) consist of risk reduction factors based mostly on avoidance looking at topographic factors, steepness, aspect and avalanche danger scale.
- **Stop or Go** uses the avalanche danger scale, steepness, wind deposit snow, new avalanches, moister and settlement to support the skiers decision (Larcher, 1999).
- **SnowCard** is constructed by Engler and Mersch (2000) and with the help of three questions about the avalanche danger level, the steepness and the aspect decisions to ski can be made.
- **NivoTest** consists of 25 questions about metrology, snow conditions, topography, past avalanche history, and group conditions which will aid a skier if he/she should ski down a given slope or not (Bolognesi, 2000).
- **The Avaluator** by Haegli et al. (2006) is a rule-based awareness tool linked with the **Obvious Clues Method** by (McCammon 2006) which uses a checklist consisting of seven clues (avalanche danger rating, avalanches the last 48 hours, unstable snow, entering avalanche path, loading by new snow, terrain traps, and melting of snow surface).

Even if Zgraggen (2004) says that more experienced skiers know more about the Reduction method than less experienced the total usage of these methods are not known. The various methods are constructed and aimed for different countries and no survey has been performed to see how frequently these risk ladders are used and what the skiers think of them.

Social norms play the largest role in safe behaviour according to Evans (1991). He says a large change in traffic safety could occur if the life threatening use of vehicles becomes more associated with immaturity and failure than with glamour and excitement. Safe behaviour cannot be learned by direct feedback, which is too infrequent, but requires absorption of accumulated knowledge and experience of others (Evans, 1991). McClung & Schaerer (2006) whom are inspired by Wilde propose that target education and experience to be effective if they were combined and taught on grass root level. These since backcountry avalanche forecasting and decision-making are skills which are improving slowly over time. They are not only about "gut feeling", "heuristics", "intuition", and experience, but are instead based on well-founded principles (McClung & Schaerer, 2006). One way to better learn about avalanches and possible dangerous situations is the interactive CD "White Risk" (Harvey, 2006).

Potential consequences are often discussed to improve behaviour and management of risks and how the consequences could be lowered with the use of different rescue equipment (Evans, 1991). A picture of an injured car driver saved by his/her seatbelt is often efficient,

but more seldom is the discussion and promotion of the person who was not involved in an avalanche (DiGiacomo, 2006). This because it can be hard to identify the skier who did not die in an avalanche when he/she avoided a slope he/she found to be dangerous. It is much easier to discuss reported injuries and fatalities compared to those who did not happen because of safe behaviour.

4.4. Summary literature review

The avalanche statistic contains quite few incidents and it can therefore be hard to properly extract useful information from the data without better estimations of the actual number of off-piste skiers in the slopes. Some heuristics might hence be faulty when no concern has been taken to how often the slopes have been skied. The avalanche bulletins are a valuable aid before heading out in the off-piste, but it is unclear how well the skiers actually perceive the different ways the avalanche danger level is presented. The use of rescue gear can be a matter of life or death on the mountains, but they are no guarantee for surviving an avalanche.

Men and younger persons show a higher involvement in accidents which can depend on that their propensity to take risk is higher, they see risk as more rewarding and their abilities are actually better than older persons. However better abilities are no assurance to avoid accident which race driver are good proofs for, since they despite their better skills are more often involved in car crashes.

It is likely that solely more information, skills, rescue equipment and engineering improvements will not decrease the avalanche accidents. There are today a number of decision aids in form of risk ladders available which can be useful. It can also the promotion of safe behaviour and a better understanding of possible consequences be. Education should be taught on grass root level by experienced people who pass their experience on.

5. Results from the surveys

In this section the numeric data and analyses from the two surveys is presented under subheadings which are the statements from the task description. Under every subheading are the questions and null hypotheses described in section 3.2 and Appendix 3 handled.

5.1. Analysis

The two surveys are analyzed side by side to test the reliability of the surveys. When a hypothesis testing is performed the outcome for the χ^2-test is presented as the p-value. P-value less than 0,1% is denoted ***, p-value less than 1% (but higher than 0,1%) is denoted ** and p-value less than 5% (but higher than 1%) is denoted *. The more stars, the stronger support for the alternative hypothesis (H_1). The null hypotheses (H_0) are assumptions that the investigated categories think and/or act equally. Rejection of a null hypothesis means that significant differences in the analysed categories are found with the χ^2-test.

General information

The Davos survey (see Appendix 5) has 591 answers with 527 responses which are completely filled out. The participants include 382 men and 145 women and the respondents are between 15-73 years old with a mean age of 30.8 and a median age of 29 (see Figure 5).

The online based survey (see Appendix 6) received 775 responses in four days and in the middle of May the total of 1515 answers is collected where 1434 are completely filled out. Of the 1434 skiers 1245 are men and 189 women. They are between 12 – 68 years old with a mean age of 27.1 and a median age of 26 (see Figure 6).

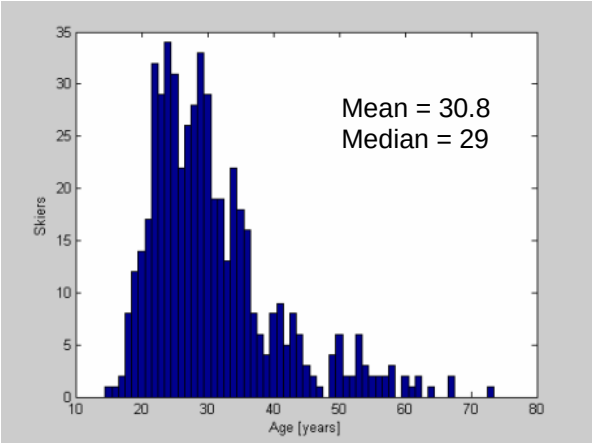

Figure 5 Age distribution, Davos survey

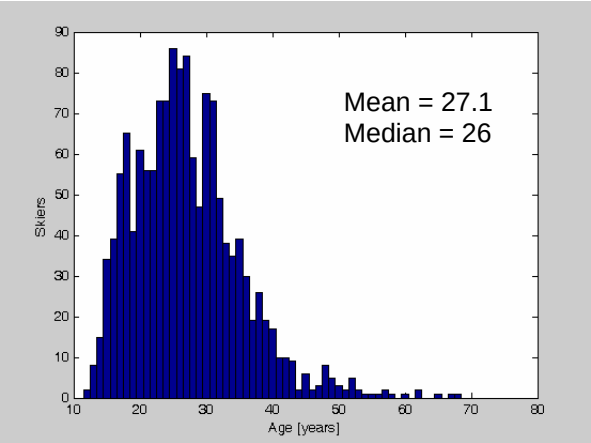

Figure 6 Age distribution, online based survey

The online based survey has a higher percent of men and young skiers participating compared to the Davos survey. When tests are performed for age, the skiers are divided in three age groups, <30, 31-40 and >41 years old. This is done because the most likely avalanche victim in Switzerland is a man under the age of 30 years. In the traffic research it has been discovered that the accident rate peak at 30 years and decreases until 40 years to start increase again (Evans, 1991) meanwhile in avalanche terrain, the pattern is followed until 40 years, but then continues to decrease (see Figure 4). How do the skiers in these surveys act?

The skiers are asked to fill out what kind of terrain they manage which is used to categorise them. Both surveys show similar distribution were the intermediate and challenging terrain skiers are the largest group (≈50%) followed by the expert skiers who are about 40% and the rest 10% are easy terrain skiers (see Figure 7 and 8). In the traffic research skilled drivers are often involved in more accidents compared to less experienced ones (Evans, 1991). Experienced skiers visit the avalanche terrain more often but when considering the time spent in the mountains their accident rate is low (Tase 2004, Atkins & McCammon 2004). Men are more likely to rank themselves managing more difficult terrain than the women.

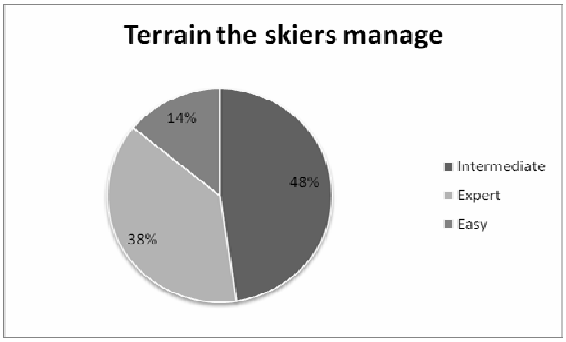

Figure 7 The level of skill, Davos survey

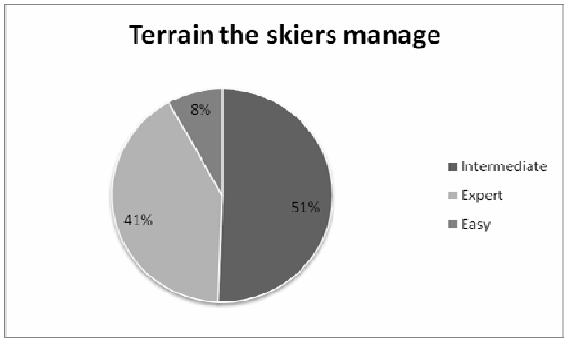

Figure 8 The level of skill, online based survey

The off-piste skiers' knowledge about avalanches

How much basic knowledge do the skiers posses? Previous research shows that the avalanche knowledge for skilled skiers is quite high and lower for less experienced skiers (Atkins & McCammon 2004, Boutellier, Montagne & Barodte 2007). The following results show the knowledge of the skiers.

Question 6: During which degree of avalanche danger (scale from 1 to 5) do you think most of the avalanche fatalities occur in Switzerland?

Most fatalities occur under level "3" (Harvey, 2002). The easy terrain skiers have the lowest right answer rate (about 60%) which still is high (see Appendix 7).

Question 9: From which steepness do you think avalanches can occur?

A "by the book" answer to this question is that avalanches can occur from steepness under 25˚, but it is unusual. Avalanches are more likely to release from slopes steeper than 30˚ and most common is between 35-40˚ (McClung & Schaerer, 2006). Answers between 25-30˚ can be interpreted as the skiers posses at least basic knowledge about avalanches. The majority (>75%) of the skiers in both surveys have answered either 25˚ or 30˚ which is good (see Appendix 7).

Question 10: Standing above a slope what from the following factors affect your decision regarding whether to go off-piste or not?

There are many factors influencing a skier prior to skiing down a slope and question 10 in the questionnaire asks the skiers to rank the five factors they think are the most important. Figure 9 displays the result from both surveys. In the figure every factor's total amount of answers from the surveys are divided with the total number of participants timed with five. This is done to compare the surveys. Avalanche bulletins and physical factors such as snowpack, terrain and weather are valued high, human factors such as group size, responsibility and discipline are rated low.

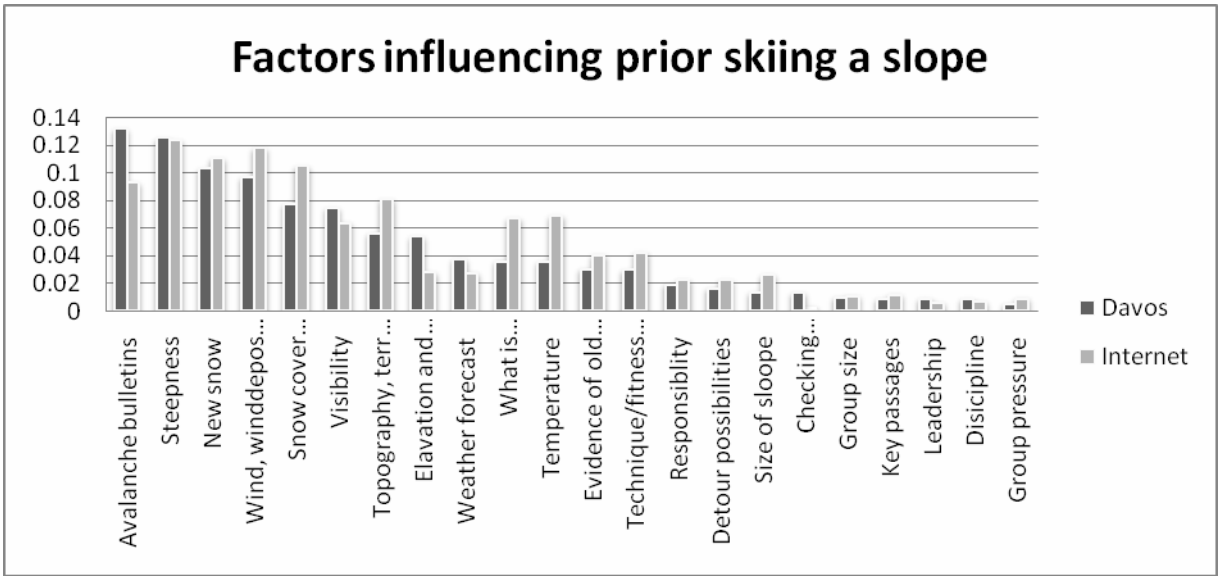

Figure 9 The factors the skiers think are important prior skiing a slope

How off-piste skiers perceive the avalanche risks and how this affects their behaviour and risk management

Humans are according to (Tremper 2001) normally bad at perceiving the risk they are exposed to. Still as many as 75% (397 of 527) of the skiers in Davos and 71% (1013 of 1434) in the online based survey consider themselves to sometimes be in the risk zone of getting caught in an avalanche (see Figure 10 and 11).

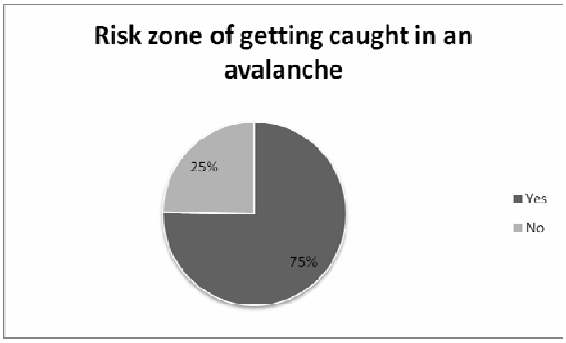

Figure 10 Skiers in the avalanche risk zone, Davos survey

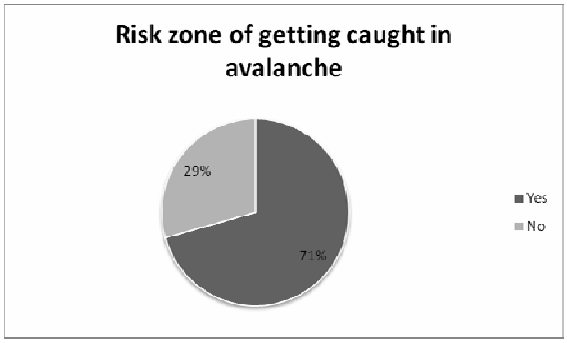

Figure 11 Skiers in the avalanche risk zone, the online based survey

The null hypotheses investigate similarities between these skiers and the ones who did not consider themselves to be in the risk zone for questions 5, 11-13. In Appendix 5 and 6 is it seen that the major part of the skiers who believe themselves to be in the risk zone of getting caught in an avalanche also ski off-piste more often.

Question 5: How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision regarding whether you ski/snowboard off-piste or not?

The skiers who consider themselves to be in the risk zone for getting caught in an avalanche check the avalanche bulletins more frequently as expected as they manage more difficult terrain and ski more (see Appendix 8). Even if the surveys show that in both categories more than 60% of the skiers use the avalanche bulletins at least half the times before skiing, the

distribution of the replies differs and the calculated p-values reject on 1% significant level the null hypothesis in the Davos survey and on the 5% significant level in the online base survey. This means that the skiers who believe themselves to be in the risk zone of getting caught in an avalanche use the avalanche bulletins significantly more.

Question 11: What kind of rescue equipment do you use when skiing/snowboarding off-piste?

Figure 12 shows that the most frequently used rescue equipment except the cell phone (which is best used to call for help) is the transceiver. Therefore in the analysis the tests are performed for skiers using transceivers versus those who do not. The null hypothesis test if skiers who consider themselves either to be or not to be in the risk zone for getting caught in an avalanche use transceivers to similar extent. In appendix 8 the results are displayed. Skiers in the avalanche risk zone use transceiver more than the other skiers (>80% compared to about 50%) which indicates that they take more precautious when they consider themselves to be at risk. The hypothesis test supports this since the null hypotheses are rejected on the 0.1% significance level for both surveys.

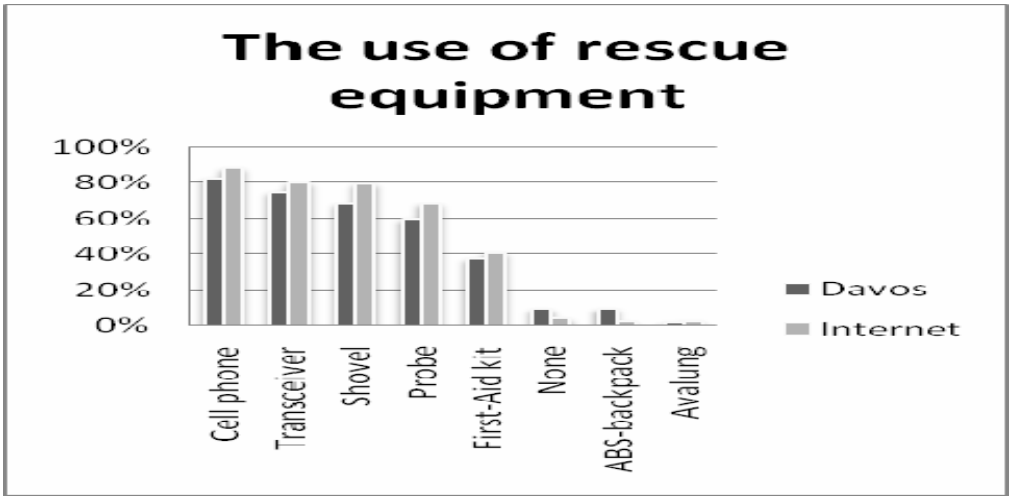

Figure 12 The use of rescue equipment

Question 12: If you are equipped with a transceiver how often do you exercise seeking with it?

The most used rescue equipment is the transceiver. Therefore practise with the transceiver for skiers who believe themselves to be in the risk zone of getting caught in an avalanche is compared to those who believe not to be at risk. This is only analysed in the online based survey because the answer alternatives for the Davos survey has two similar answer alternatives and can therefore not be used. Except for question 12 the surveys are identical. More than 50% of all skiers practise with the transceiver at least once every season (see Appendix 8) and it can be seen on the 0.1% significance level that skiers who consider themselves to be in the risk zone of getting caught in an avalanche practise the most which indicate that they are better prepared.

Question 13: Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?

The null hypothesis tests if skiers considering them to be or not to be in the risk zone of getting caught in an avalanche are equally willing to ski off-piste with unequipped friends.

The null hypothesis is strongly accepted in the Davos survey and strongly rejected in the online based survey (see Appendix 8). When the responses are analysed for the alternative "yes" and "no" it can be seen that the Davos skiers are less willing to ski with unequipped friends but more importantly that skiers who believe themselves to be in the risk zone for getting caught in an avalanche take more precautious and will not ski off-piste with unequipped friends.

If off-piste skiers with a transceiver and/or avalanche airbag compensate a possible higher level of safety by taking more risks?

The theory of target level of risk says that skiers equipped with rescue equipment will have a higher propensity to take risks (Wilde, 2001). The null hypotheses analysis if there are no differences between equipped and unequipped skiers in how they behave, manage and take risks in the mountains. The hypotheses testing are performed for questions 5, 12-15 and the transceiver which is the most used gear and represents the rescue equipment (see Figure 12). Almost every skier using transceiver use probe and shovel too, according to the standard (Tremper 2001, Munter 2003). Skiers using more advanced gears such as the ABS-backpack and the Avalung use the transceiver without exceptions. In the Davos survey 75% (393 of 527) and in the online based survey 80% (1143 of 1434) of the skiers use transceivers (see Figure 13 and 14). However a transceiver will not protect its user from an avalanche. Tremper (2001) says that skiers using one will expose him/her for a greater risk of avalanches. Nevertheless, in case of a complete burial without visible parts of the buried person, a transceiver is the devise which gives its user the best chance of survival.

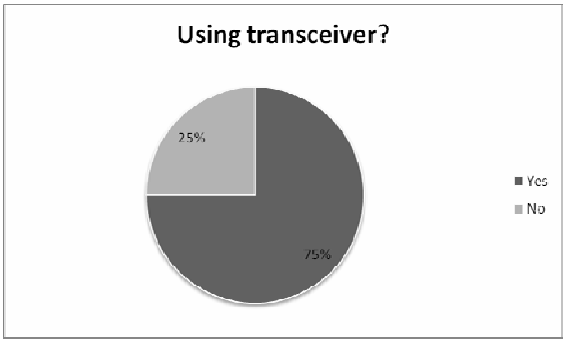

Figure 13 The use of rescue equipment, Davos survey

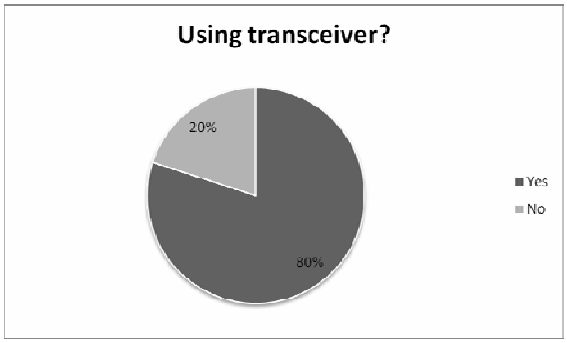

Figure 14 The use of rescue equipment, online based survey

Question 5: How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision regarding whether you ski/snowboard off-piste or not?

The decisions to ski off-piste by skiers who use a transceiver are more affected by the avalanche bulletins than the unequipped skiers. This is also revealed by the rejection of the null hypothesis on the 0.1% significance level (see Appendix 9). The people therefore show a more cautious behaviour before they ski off-piste compared to the skiers who do not use rescue equipment.

Question 12: If you are equipped with a transceiver how often do you exercise seeking with it?

The result of how much the skiers practise with their transceivers are only presented from the Internet survey, since the Davos survey has two almost identical answer alternatives and can

therefore not be used. The amount of practise for the skiers is quite high when almost 60% (678 of 1143) of the skiers practise at least once every season (see Appendix 9).

Question 13: Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?

To survey behaviour and risk management the willingness to ski off-piste with friend not using rescue equipment is interesting. In Appendix 9 is the result shown from the hypothesis testing between equipped and unequipped skiers. It is obvious that the use of transceiver affect the skiers to try to manage risk more since they are less willing to ski with others who do not have gears. This is supported since the null hypothesis is rejected on the 0.1% significance level.

Question 14: How much is your willingness to ski/snowboard off-piste affected by the rescue equipment that you use?

The concept of target level of risk says that gears will alter peoples' propensity towards taking more risk (Wilde, 2001). This question is only investigated for skiers with transceivers. And it is seen in Figure 15 and 16 that they are affected by their equipment which makes them take more risks. The enhancement of taking risk when equipped with rescue gears has a stronger support for the online based survey.

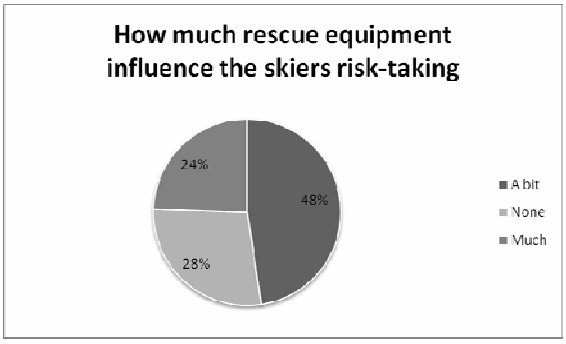

Figure 15 How the propensity to take risk is affected by rescue equipment in the Davos survey

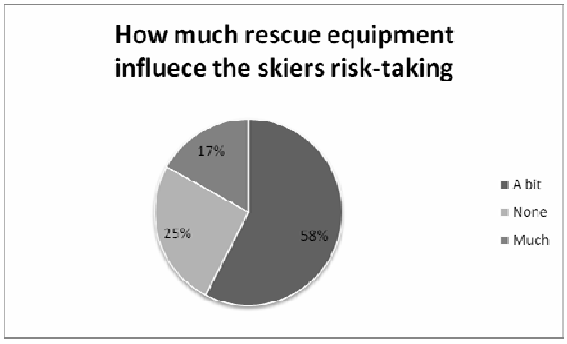

Figure 16 How the propensity to take risk is affected by rescue equipment in the online based survey

If there are differences in between various categories of skiers (gender, age and level of skill)

It is investigated if there are differences in various categories of skiers. When the skiers rank which terrain they manage, men more often rank themselves managing more advance terrain than the women (see Appendix 5 and 6). In Appendix 5 and 6 can also differences in how the age groups rank themselves be seen. Even if the variations not are as obvious, the skiers between 31-40 years old are more likely to rank their level of skill higher which also Tase (2004) has found. The null hypotheses surveys similarities for gender, age and level of skill separately for questions 4-5, 11-15:

Question 4: How much do you on average ski/snowboard off-piste per year?

Persons ranking themselves managing more difficult terrain also skied more every year and are subsequently also more exposed to avalanches which correspond to Tase's (2004) result Appendix 5 and 6).

Question 5: How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision regarding whether you ski/snowboard off-piste or not?

Gender
The avalanche bulletins are good aids to decide to ski off-piste or not. The results from the analysis can be seen in Appendix 10. The distribution between the surveys differs for gender, since the women use the avalanche bulletins the most (for category "76-100%"). The significance tests do not produce reliable answers when they support the null hypothesis in the Davos survey and the alternative hypothesis in the online based survey.

Age groups
The age groups use the avalanche bulletins differently, especially when the usage is compared to the ones who check the bulletins 76-100% of the time before skiing off-piste. The use of bulletins increase with age which is confirmed with the rejection of the null hypothesis on the 5% significance level in the Davos survey and the 0.1% significance level in the online based survey. This indicates older skiers to be more careful.

Level of skill
There are differences between how experienced and less experienced skiers use the bulletins, which the rejection of the null hypothesis on the 5% significance level shows. But the results are widely spread between the different answer alternatives and therefore not seen as reliable.

Question 11: What kind of rescue equipment do you use when skiing/snowboarding off-piste?

When the significance tests are done to test differences between skiers equipped with rescue gears or not, the transceiver represents the equipment. The total usage of transceivers in the surveys is high, about 75% in Davos and 80% on the Internet (see figure 13 and 14). Men and women use rescue equipment almost equally meanwhile skiers older than 31 use the gears significantly more compared to the younger age groups (see Appendix 10). Still the use of transceiver is high for the youngest skiers (>70%). The usage of rescue equipment also increases with the level of skill. The usage of transceivers for the easy terrain skiers are about 50%, the intermediate and challenging terrain skiers over 70% and for the expert skiers use more than 90% transceivers which results in significant difference on the 0.1% level.

Question 12: If you are equipped with a transceiver how often do you exercise seeking with it?

Gender
As mentioned before are only the results from the online based survey used for question 12. The majority of the skiers practise once every season and there are no significant difference between how often men and women practise with their transceivers (see Appendix 10).

Age groups
There are also similarities on how often the age groups practise.

Level of skill
The practise with transceivers increases with increasing level of skill which indicates these skiers to be more precautious. This is also supported by the rejection of the null hypothesis on the 0.1% significance level.

Question 13: Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?

Gender
The willingness to ski off-piste with a friend not carrying any rescue equipment is low for the different categories (see Appendix 10). About 80% of both the men and the women would at least think about not going off-piste with other skiers not having gears. The χ^2-test supports the null hypothesis and therefore it could be said that there were similarities in how both men and women are equally unwilling to ski off-piste with unequipped friends.

Age groups
The two surveys differ for the age groups (see Appendix 10). Even if most of the skiers are sceptical (≈75%) to ski off-piste with unequipped friends, the skiers in Davos seem to be more careful since there are more skiers saying "no" for all ages. The χ^2-test shows similarities for the Davos skiers' willingness to go off-piste with others who do not have gears. For the online based survey differences are shown when the null hypothesis is rejected on the 0.1% significance level. It is the youngest skiers who are the least concerned with whom they ski with.

Level of skill
The easy terrain skiers and the intermediate and challenging terrain skiers show almost identically willingness to ski off-piste with unequipped friends (see Appendix 10). The expert terrain skiers are more conservative and less willing to go with others who do not have rescue equipment. The null hypotheses are rejected on the 5% significance level in Davos and on the 0.1% significance level in the online based survey. It is the expert terrain skiers' behaviour which differs since they are the least willing to ski off-piste with unequipped friends which indicate that they are more aware of risk in the avalanche terrain.

Question 14: How much is your willingness to ski/snowboard off-piste affected by the rescue equipment that you use?

Gender
It has earlier been shown how the skiers with rescue equipment are affected by the gears and take more risks in accordance with the theory behind the target level of risk. The analysis and χ^2-test are done for gender, age groups and level of skill (Appendix 10). About 70% of both men and women are at least "a bit" influenced by the rescue equipment they use and take more risk with equipment. The null hypothesis is accepted since the result show men and women to have a similar increase in their risk-taking when using rescue equipment.

Age groups
About 50% of the oldest skiers are not affected at all by the rescue equipment they use which indicates that those skiers benefit from their use of the gears since they do not increase their risk-taking. At the same time the younger skiers are more influenced of the gears. The null hypothesis about the similarities between the age groups is rejected in Davos on the 1% significance level and on 5% significance level in the online based survey. This shows that the younger skiers will take more risk when using their equipment.

Level of skill
Over 60% of all the skiers in all three level of skill groups are at least a bit affected and take more risks at the same time as the use rescue equipment. Since the null hypothesis is accepted all categories of skiers show similar increase in risk-taking when equipped with rescue gears.

Question 15: Do you consider yourself to sometime be in the risk zone for getting caught in an avalanche?

Humans are generally bad at judging the risk they are exposed to (Tremper 2001). Contradicting this, most of the skiers in both surveys say that they are in risk zone of getting caught in an avalanche (see Figures 11 and 12). The null hypotheses tests if there are similarities in between how the different categories value their risk.

Gender
Even if the majority of the women believed themselves to be in the avalanche risk zone there are a higher percent of men claiming to be in the risk zone of avalanches (see Appendix 10). The χ^2-test supported differences on the 1% level in Davos and on the 0.1% level in the online based survey.

Age groups
Both surveys have similar results for the two younger age groups, but the skiers over 41 years old differs (see Appendix 10). In Davos believe more than 80% of the oldest skiers themselves to be in the risk zone for getting caught in an avalanche. Meanwhile fewer than 60% of the oldest skiers in the online based survey say that. This produces uncertainty when the null hypothesis is accepted for the Davos survey and rejected in the online based survey which is thoroughly discussed in the next chapter.

Level of skill
The persons with different levels of skill's perceiving of the avalanche risk follows the same pattern as the usage of transceivers, since with increasing skill the belief to be in the risk zone for getting caught in an avalanches also increases (see Appendix 10). The null hypothesis is rejected on the 0.1% significance level for both surveys. With increasing skill the skiers visit more challenging and potential dangerous terrain which is a possible reason for the difference.

How the skiers perceive the avalanche danger scale.

From the literature study it is noticeable to see that skiers are bad at perceiving the different ways the avalanche danger is presented. That is why the null hypothesis is:

H_0 = The skiers value the number and corresponding word equally dangerous

Data is collected to see if the skiers value level "3" and "considerable" equally dangerous when both describes the same avalanche danger level. Table 1 display that the skiers in both survey value "considerable" as more dangerous than level "3". Obviously do the skiers perceive "considerable" to be more dangerous than level "3" which also the rejection of the null hypothesis on the 0.1% significance level for both the Davos and the online based surveys supports.

Table 1 How skier perceive level "3" and "considerable"

Davos	**Safe**	**Intermediate**	**Dangerous**	**Sum**
Level "3"	6 (1.1%)	228 (43.3%)	293 (55.6%)	527 (100%)
"Considerable"	6 (1.1%)	141 (26.8%)	380 (72.1%)	527 (100%)
χ^2-test	**1.27E-07*** **			
Degrees of freedom	2			
Internet	**Safe**	**Intermediate**	**Dangerous**	**Sum**
Level "3"	64 (4.5%)	786 (54.8%)	584 (40.7%)	1434 (100%)
"Considerable"	32 (2.2%)	477 (33.3%)	925 (64.5%)	1434 (100%)
χ^2-test	**3.43E-36*** **			
Degrees of freedom	2			

6. Discussion

The discussion draws conclusions from previous chapters. The statements which are posed in the task description are discussed under separately subheadings. Finally are avalanche risk management and possible biases discussed.

6.1. The off-piste skiers' knowledge about avalanches

Most of the available accident statistics are based on the absolute numbers of accidents and not how many times the different slopes have been skied. These surveys do of course not cover the entire off-piste skiing population but they show tendencies for how skiers behave in avalanche terrain. Based on the gathered information in this report it is seen that the skiers possess decent avalanche knowledge and awareness and the factors they value as important are indeed important to check prior to skiing. However the literature review shows that the inexperienced skiers' avalanche knowledge should be improved. The majority of the skiers choose physical factors (snowpack, terrain and weather) and the avalanche bulletins. Human factors such as group size, responsibility, discipline, etc. are not valued so high by the skiers to influence their decision. It would be good to perform the investigation one more time, with a different order of the factors. The physical factors come first in the questionnaire which might affect the responses.

Skiers use heuristics to make decisions in avalanche terrain. Often the heuristics work well but when they do not, dangerous situations can arise. Some of the heuristic skiers use might be faulty which Grímsdóttir and McClung (2006) have found. It seems like north facing aspects might not be as dangerous as previously thought since slopes with avalanche accidents are more frequently skied compared to slopes without many avalanche accidents. It would therefore be good to further measure how many skiers who actually visit the avalanche terrain and continue the works of Grímsdóttir and McClung (2006) and Zweifel, Raez and Stucki (2006).

6.2. How off-piste skiers perceive the avalanche risks and how this affects their behaviour and risk management

It is interesting to notice that so many of the skiers participating in the surveys believe they are at risk when humans generally are bad at judging the risk they are exposed to (Tremper, 2001). This affects their behaviour and risk management. These skiers are in general more influenced by the avalanche bulletins before they ski off-piste, they use and practise with their rescue equipment more and are less willing to ski off-piste with unequipped friends. This shows that the skiers know it is risky to ski in avalanche terrain and that their perception of avalanche risks also affect their behaviour, by making them more careful and conscious about the risks and ways to manage them. It also shows that the skiers who know they are exposing themselves to the risk of avalanches are more conscious about different precautions to take, which correspond to Tase (2004) and Atkins and McCammon (2004).

One difference between the skiers believing to be at risk and those who do not is that the skiers in the latter category who mostly are easy terrain skiers ski less off-piste every year which correspond to Atkins and McCammon (2004). This could mean that since they do not ski so often, they believe avalanche will not happen to them, which affect their behaviour and risk management. All categories of skiers are represented in the avalanche statistics, but

considering the time the experts spend on the mountains their fatality rate is lower than the less experienced skiers (Atkins and McCammon, 2004).

However, there are also differences between the two surveys; the skiers from Davos checked the bulletins more often. One possible explanation for this is that Davos is the resort where SLF resides, which might cause the skiers to get more influenced by the bulletins and other safety precautions. The same behaviour could also be seen in the willingness to ski with unequipped friends.

To be effective in improvements in behaviour and risk management, the efforts need to be aimed at the off-piste skiers, who expose themselves to avalanches but do not consider themselves to be at risk, which are mostly easy terrain skiers. Perhaps they do not ski much off-piste compared to the experts, but their behaviour and management of risks need to be improved to avoid avalanche accidents. How to succeed with this are discussed in the end of this chapter.

6.3. If off-piste skiers with a transceiver and/or avalanche airbag compensate a possible higher level of safety by taking more risks

The theory of target level of risk (Wilde, 2001) says skiers equipped with rescue gears will modify their behaviour and take more risks. This is also found in the surveys. However, even if carrying rescue equipment might modify behaviour, it would be reckless to ski off-piste without. It is therefore positive to see the widespread usage and practise with transceivers. This since skiing without reduces the chance of surviving an avalanche burial. It would be interesting to further investigate how many of the equipped versus the unequipped skiers who actual die in avalanches compared to how large these groups are. The majority of the skiers practise at least once every year, which is good. However, it would have been useful to have more answer alternatives to see how much they actually practise since training is essential for the skiers to improve their ability to locate their buried friends in an avalanche. Transceivers work and they work well, but plenty of practice is needed. Training once every season might therefore not be good enough. The danger to look out for is when skiers overly rely on a quick rescue in case of an avalanche. The skier's friends might not have proper training, a rescue team takes time to gather and a skier can die of mechanical injuries caused by hard objects.

The equipped skiers take more risks when they carry their gears, but it is discovered that compared to the unequipped they had better behaviour and risk management because they are:

- checking and being more influenced by the avalanche bulletins
- less likely to ski with friends not carrying rescue equipment
- considering themselves to be in the risk zone of getting caught in an avalanche

The two first findings show positive risk management for the users of rescue equipment. The last indicate that the equipped skiers perceive that they are exposed to the danger of avalanches and try to manage those. However, it is concerning that their propensity to take risk is increasing with the use of rescue equipment, which the theory of target level of risk says it will. This means that the skiers' acceptable level of risk will not be lowered since all their safety measurements will give them more room to take larger risks in avalanche prone terrain.

Even if off-piste skiing is a voluntarily risk something must be done to lower the skiers' propensity to take risks. Nobody wants to take away the benefits with beautiful mountains and untouched snow from the off-piste skiers. The skiers are aware of the danger in the mountains, and they know of people getting killed or injured but they still ignore signs of hazard to reach the benefits for skiing. The skiers need to halt for a second and at least ask themselves if they would ski any given slope if they were not equipped with rescue gears (Tremper, 2001).

6.4. If there are differences in between various categories of skiers (gender, age and level of skill)

The various categories (gender, age, level of skill) are discussed separately.

Gender

In the majority of the studied avalanche literature there is an uneven gender distribution among the skiers where the men seem to ski more off-piste (Tase 2004, Zgraggen 2004, Adams 2005). This report's two surveys show the same, that more men than women are skiing off-piste. However, there are surprisingly few differences noticed between the genders. One expected difference is that men rank themselves to manage more difficult terrain than the women which Evans (1991) discusses when he describes how males consider themselves to be better drivers.

An interesting and unexpected result is that women value their risk lower which contradict other surveys (e.g. Andersson & Lundborg, 2007). One possible explanation is the fact that the women in the surveys ski fewer weeks than the men and then probably do not feel exposed to avalanches as much as the men. Women are normally more aware of risks and therefore take more precautious to avoid exposure which also can explain the differences (Andersson & Lundborg, 2007).

The surveys show young males to be the largest group in terms of participants which could explain that so many of them are found in the accident statistics. It would be very interesting if it was possible to further develop Grímsdóttir and McClung (2006) and Zweifel, Raez and Stucki (2006) studies to also include gender. Especially since the report's surveys have more men participating. This information would lead to more accurate evaluation of which group who is the least cautious one.

Age

If the accidents are compared to how many skiers there are in every group different results might be reached. But until such data is available efforts need to be aimed to lower the skiers' propensity to take risk. Especially the younger ones who according to these surveys and the literature review take the most risks.

The results from the performed surveys show, as the skiers are aging they take more precautions. The usage of avalanche bulletins and rescue equipment increases at the same time as the willingness to ski off-piste with unequipped friends decreases. The older skiers' propensity to take risk when using rescue equipment is not affected as much as the younger skiers. This means that they better benefit from the use of the gear. The older skiers might also value their abilities higher with increasing age and therefore believes to be safe

regardless which equipment they use (Evans, 1991). However the surveys' results indicate younger skiers to be a larger group and foremost more careless and risk-taking and should therefore be the focus group for improving efforts.

Level of skill

The categorisation of the skiers in different level of skills is used to investigate how the various groups of skiers behave and manage the risks since the avalanche evaluation knowledge often does not match the skiing skills (Fredston & Fesler, 1994). In the report's surveys many of the skiers state themselves to be experts. They differ from the two other groups since they spend more time in the mountains and show more careful behaviour and risk management as they are:

- checking and being more influenced by the avalanche bulletins
- using and practising more with their rescue equipment
- being less willing to ski with friends not carrying rescue equipment
- considering themselves to be in the risk zone of getting caught in an avalanche

The awareness and preparation for avalanche risks are higher for the expert terrain skiers. Previous research has discovered how high risk groups often underestimated their risk and low risk groups overestimated the risks (Andersson & Lundborg, 2007). This report has found the opposite since the expert terrain skiers are more likely to rank themselves to be in the risk zone of getting caught in an avalanche which easy terrain skier do not. Expert terrain skiers ski more in avalanche prone terrain than the easy terrain skiers which can be reasons why the less skilled skiers do not consider themselves to be at risk. Another reason can be that experts often know of more people injured or killed in avalanches than less experienced (Atkins and McCammon, 2004).

Most of the efforts to improve skiers' behaviour and risk management should be focused on the less experienced skiers since their behaviour and risk management need to be improved. The experts spend more time in the mountains and are more prepared to deal with the dangers in avalanche terrain, but still they can learn a lot especially concerning human factors. Evans (1991) says that it takes time to learn by trial and error, but it can be effective for drivers. For skiers it can be fatal. A combination where the less experienced skiers could learn from the experts experiences could improve their skills and knowledge.

6.5. How the skiers perceive the avalanche danger scale.

To estimate how dangerous a certain avalanche danger level is difficult. The avalanche danger scale describes the current avalanche danger with a number and corresponding word. The avalanche danger level can be perceived in various ways depending on what kind of slope that is considered. A flat slope (<25˚) with no steep section is likely to be assumed safer than a steeper slope. However the hypothesis testing investigates only if the skiers perceive level "3" and "considerable" equally dangerous. This because potential differences between the descriptions for the same avalanche danger level is interesting since the avalanche scale is widely used and it is unclear how well the skiers actual know how it works (Nairz, 2003).

The surveys show that the skiers do rate level "3" and "considerable" differently. The fact that the number is rated as less dangerous indicates that the skiers think of the avalanche danger scale as linear and not as the exponential scale it is. Nairz (2003) thinks it might be better to

change the avalanche danger scale numbers (1-5) to letters (A-E). The working hours to improve the avalanche danger scale have already been many. But something must be done when so many value level "3" and "considerable" so differently.

6.6. General discussion

When risk and risk management are described six important questions are mentioned: What can go wrong? What is the likelihood of this happening? If it does happen what are the consequences? What are the available options? What are the associated tradeoffs? What are the impacts of current decision on future options? The skiers should ask themselves these questions while they ski in avalanche terrain. Many of the skiers possess avalanche skills and knowledge, but do not use them properly when they overestimate their abilities and underestimate the hazards (Fredston & Fesler, 1994). By implementing the risk management process the skiers could be better on locating available options; see what the associated tradeoffs are, and have a better understanding of the impacts current decisions can have on future options.

Peoples' perception of risk is affected by past experience, attitudes, expectations, thoughts and beliefs. It is also affected by how the risk is presented. An objectively calculated risk to die in an avalanche is unlikely to be effective for accident decrease since the sense of freedom and wonderful feeling of skiing powder snow is two of many things which motivate skiers. Risk presented in such a way would be hard to understand for the skiers when avalanche death feels abstract and unlikely to happen to them and is therefore inefficient. An example of how framing a risk can be efficient is a friend of the author who was a smoker. One day when he should buy cigarettes he got a package with a warning text saying that cigarettes make men impotent. This affected and scared him. Not perhaps to quit immediately but at least to change to a package which he "only" would get cancer from instead. It is highly likely that the skiers also reason in the same way; the risk to die in an avalanche feels so abstract and unlikely, but a serious injury is felt more real. Therefore it is the author's conviction that highlighting possible consequences not leading to death could lower the skiers' propensity to take risks. Wilde (2001) says that lowering the benefits from the risky behaviour is likely to work, at least for car drivers. The same would be very difficult to do for the skiers when the benefits of skiing come from being in the mountains and enjoying the skiing which nobody wants to take away.

The avalanche accidents statistics do not mention the seriousness of the injuries. Surviving an avalanche could result in that the skier never will, or not in a long time, ski again. DiGiacomo (2006) discusses the importance of promoting safe behaviour. This combined with highlighting potential consequences could be effective in lowering the skiers' risk-taking.

Promoting safe behaviour and discussing possible consequences combined with risk ladders which aides the skiers' decisions to ski or not to ski a given slope is likely to work. Since the skiers already possess knowledge and skill about avalanches more information, skills, rescue equipment and engineering improvements will not decrease the avalanche accidents. Experienced skiers are, if comparing the time they spend in the mountains, less involved in avalanches compared to less experienced skiers (Atkins & McCammon, 2004). If the risk ladders are used, an attitude change is reached and safe behaviour is taught on grass root level by experienced people who passes their experience on great improvement can be achieved.

One thing which must be the focus for all kinds of off-piste skiers is the propensity to take risk when equipped with rescue equipment. Tremper (2001) says it well when he thinks skiers should ask themselves if they would ski the slope they stand above without the gears. If the answer is no, do not ski it.

6.7. Biases

The five week survey period in Davos was late in the season, but since the avalanche and weather conditions were stable the responses should not be affected by daily variations. To gather useful data, it was made clear that the survey was to be answered by off-piste skiers only. The Davos survey was easily controlled since the skiers, prior to filling out the questionnaire were asked if they ski off-piste. Before entering the online based survey it was explained clearly that only off-piste skiers should answer the survey. The author's hope was that the respondent would act like Sjöberg (2000) says; people interested in the subject were more likely to answer. The interest was obviously very high since the online based survey received over 1500 responses in just a couple of weeks.

This could mean that the skiers who answered were the ones with a greater interest in their activity and therefore possess a greater interest in their safety and perhaps higher knowledge about avalanches. Davos is the resort for SLF and the centre for avalanche research in Switzerland and SLF was likely to affect the skiers in the surrounding resorts. There were noticeable differences on a couple of the questions, where the skiers in Davos seem to have a higher knowledge and also were more safety conscious than the skiers in the online based survey. It was good to compare the online based survey against the Davos survey to be sure that the results were reliable.

Different languages are used in the surveys which can lead to biases since some words are hard to translate to other languages without losing some of its essential meaning, or without adding new meanings (Sjöberg, 2000). The skiers in the Davos survey had two languages to chose between, English and German and the skiers participating in the online based survey had the additional choice of answering in Swedish. All responses were gathered in the same file and it is impossible to evaluate the possible biases the different languages might have contributed with.

Internet has increased in popularity, and often the internet users are young. The persons answering the online based survey version are younger than the Davos skiers. Many of the skiers in the Internet survey are younger than 18 years old and therefore their knowledge and experiences from avalanche dangerous terrain can be assumed to be limited. But no such effects from their responses are seen in the analysis.

7. Conclusions

The purpose of this master thesis is to provide reliable information to improve skiers' behaviour and risk management since the avalanche research so far has focused on the physical factors (snowpack, weather and terrain) creating avalanches. The surveys have over 2000 responses which indicate that reliable information is found.

- It is mostly not because of lacking knowledge skiers get caught in avalanches. Attitudes and overestimation of a person's ability to manage the risks contributes more.
- The majority of the skiers perceive that they are in the risk zone of getting caught in an avalanche. This has positive effects on their behaviour and risk management. These skiers are more conscious about safety measurements as checking the avalanche bulletins, using and practising more with their rescue equipment and are less willing to ski off-piste with unequipped friends.
- The efforts need to be aimed at the easy terrain skiers who ski less off-piste than more experienced but still expose themselves to avalanches but do not consider themselves to be in the risk zone of getting caught in an avalanche. These skiers are involved in more avalanche accidents compared to more experienced skiers when the time spent in avalanche prone terrain is considered.
- Rescue equipment influence skiers to take more risks. The use of the gears would be more effective if the skiers ski as cautious as they do when they not are equipped.
- Equipped skiers however show positive behaviour and risk management since they check the avalanche bulletins more often, are less likely to ski with friends not carrying rescue equipment and are more aware of avalanche dangers since they consider themselves to be in the risk zone of getting caught in an avalanche
- Men rank their level of skill higher, ski more and then expose themselves to more risks compared to the women.
- Skiers younger than 30 years old show negative behaviour and risk management compared to older skiers. They are also the largest group, both measured in numbers of skiers and avalanche accidents.
- The less experienced skiers use the avalanche bulletins and rescue equipment less, are more willing to ski with unequipped skiers and are less aware of the avalanche risks.
- The skiers rate the avalanche danger scales number and corresponding word differently.

8. Recommendations

Since it is not because of lacking knowledge skiers get caught in avalanches, focusing only more education will not work. Attitudes and overestimation of a person's ability to manage the risks contributes more and these are hard to change, especially since no one wants to lower the benefits off-piste skiing gives. The efforts to improve skiers' behaviour and risk management should mainly be aimed at the easy terrain skiers, and particularly young men, who show negative behaviour and risk management compared to more experienced and older skiers. Combinations of the following advices can lead to improvements for the skiers:

- Promotion of decision aids in form of risk ladders which simplify risk management in the mountains.
- Interactive learning programmes such as White Risk.
- Learning safe behaviour from experts' experiences.
- Highlighting possible consequences not leading to death.
- Promotion of safe behaviour which lower the attitudes to glamorize risk-taking behaviour.
- If a skier would not ski a slope without rescue equipment he/she should not ski it even though equipped with gears.
- The information to the public has mostly been based on complex and hard understandable physical and environmental factors and there is a need for better understanding human factors.

9. Further studies

This report has a broad focus to investigate skiers' behaviour and risk management. Many questions have been raised and it would be interesting to further and more deeply study the following:

- The human factors influence in avalanche terrain would be clearer if further research is done.
- It would be very interesting if it is possible to perform more accurately measurement how many in various categories (gender, age, level of skill) who actually ski off-piste. This information would lead to more precise evaluation of avalanche accidents among many things.
- How much the skiers would lower their risk-taking if they – when equipped with transceivers – asked themselves if they would ski any given slope without transceiver.
- Rescue equipment influence skiers to take more risks and therefore further studies how to make sure that the benefits from the use can be improved would be interesting.
- How much information regarding possible consequences not leading to death would affect the skiers.
- How much promotion regarding safe behaviour would lower the attitudes to glamorise risk-taking behaviour.
- The various risk ladders are constructed and aimed for different countries and no survey has been performed to investigate how frequently these risk ladders are used or if the skiers think they work.
- The skiers obviously use the avalanche danger scale often, but how much do they really know about it? How much do they read from it? Just the current avalanche danger level or the more detailed information?

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11. Declaration of independence

Hereby I assure, that this Master Thesis has been independent and only under the use of the described sources and aids authored. The work will not in the present or similar way to other grade authorities be presented.

Hiermit versichere ich, dass ich die vorliegende Diplomarbeit selbständig und nur unter Verwendung der angegebenen Quellen und Hilfsmittel verfasst habe. Die Arbeit wurde bisher in gleicher oder ähnlicher Form keiner anderen Prüfungsbehörde vorgelegt

12. Task description

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Task description for your Master Thesis

Characterisation of the risk perception concerning individuals going off-piste and the effects on their behaviour and risk management

The Swiss Federal Institute for Snow and Avalanches Research (SLF) studies the specifics of snow and snow cover, how avalanches arise and methods for protection from avalanches. One of many services that SLF provides is the avalanche bulletins that describe the current level of avalanche danger. SLF also keeps statistic about avalanche accidents among other things.

Background

Every year people get killed by avalanches around the world. In Switzerland on average 25 persons die and many more get injured due to avalanches every year (www.slf.ch). This is occurring even though the common knowledge about avalanches is increasing.

In an ongoing study, SLF measures the total amount of individuals going off-piste every year in a couple of areas in Davos. The measurement has been used to calculate the individual risk to die in an avalanche by comparing the numbers of killed in avalanches the last twenty years in those areas and the assumption that the amount of individuals going off-piste have been similar during that time period. Other previous studies SLF has conducted have examined how much people know about avalanches and how they gather the information about the avalanche conditions. This was also the topic in a survey about human behaviour and risk management concerning skiers/snowboarders that SLF has conducted together with the Swiss Federal Institute of Technology Zurich (ETH). Those studies have shown that people lack knowledge about avalanches and that many of the persons use the avalanche bulletins to assess the avalanche danger but not how the people manage the risks of avalanches.

The studies mentioned above also tried to investigate how many of the skiers that use safety equipment as avalanche beepers, shovels and avalanche airbag. The studies differ, meaning that the use of safety equipment need to be further evaluated. SLF has in their research seen a positive change in the last years in the skiers/snowboarders that really use safety equipment, especially avalanche beepers when those individuals have become better in finding their buried friends (www.slf.ch).

But still as much as 25 persons die due to avalanches in Switzerland every year. Could it be because of some sort of risk compensation? Risk compensation is a term describing how individuals tend to act more reckless when their perceived level of safety is high. An example is the car industry's introduction of the antilock breaking system (ABS) which led to some drivers beginning to compensate the increased perceived level of safety with better brakes with higher speed. In this way the risk stays constant even after the use of safety-technology (Wilde (2001), Evans (1991)).

Task description

The numbers of skiers/snowboarders that leave the controlled ski area and expose themselves to the risk of getting caught in an avalanche is increasing. The purposes of this master thesis are to:

- Evaluate the characterisation of the risk perception concerning individuals going off-piste and the effects on their behaviour and risk management. Do people estimate the risks right?
- Evaluate if skiers/snowboarders with an avalanche beeper/avalanche airbag tend to compensate a possible experienced higher level of safety by taking more risks?
- Evaluate if there are any difference between individuals that spend a lot of time in the mountains and the "recreation" skiers/snowboarders?

Method

Studies of literature will be conducted from the 12th March to the 1th of June, both to get a basis for a question form and to further study risk perception, human behaviour and risk management.

Previous work from SLF, the SLF folder "Caution Avalanches!" and the SLF and ETH survey will also be parts of the basis to the question form. The question form will be essential for the gathering of empirical material to describe the risk perception of individuals going off-piste and the effects on their behaviour and risk management. Empirical material will be collected from professional skiers/snowboarders. To get a comparison with "recreation" skiers/snowboarders visits to ski resorts will bemade . The gathering of empirical material will take place in Davos from the 12th of March to the 4th of May. Since SLF has measured how many of the individuals going off-piste in a couple of areas in Davos it is possible to use this information in the evaluation to see how many of the skiers/snowboarders that go off-piste there really act if those persons answers the question form.

The empirical material will be compared to the studies regarding how people tend to compensate risks in the traffic to see if individuals with safety equipment as avalanche beeper/avalanche airbag compensate their perceived level of safety by taking more risk skiing/snowboarding in avalanche terrain.

The final report will be finished the 14th of September and will begin with a presentation of a model for risk management from the lift owners' perspective down to individuals going off-piste to carefully describe how their risk management look like with focus on the individuals going off-piste. Next part will include the question form, how it was created and the gathered empirical material. After that the most essential part, the analysisof the empirical material and the studied literature comes. The analysis will occur between the 30th of April to the 15th of June and will lead to the conclusions which will try to answer the questions posed in purpose section.

We expect a well formulated, meaningful and significant report that shows in definite way the concept of the solution, the argumentation of the proposed procedure and your own proposition. The start time of your work will be the 12th of March and will end, based on the guidelines of the department on the 14th of September. The report has to base on requirements of a scientific work and the method of Zurich's System Engineering..

The support of your work at SLF will be guided by Benjamin Zweifel, +41 814 17 01 28. At the chair you will be supported by Eric Montagne, +41 44 632 05 87, emontagne@ethz.ch.

We wish you an interesting and successful work.

Best regards

Prof. Dr. Roman Boutellier Eric Montagne

Appendix

Appendix 1 – Constructing a questionnaire

A well constructed questionnaire was essential for the gathered data to be useful and it was constructed so the respondents wanted to answer it, interpreted the questions in the way the constructor intended, and did not feel like a burden to answer (Dahmström, 2000). Körner & Wahlgren (2005) have listed what was good to think about:

- Limit the number of questions
- Use short sentences and easily understood language
- Explain technical language
- Avoid prestigious questions
- Avoid leading questions
- Explain one thing at the time.

There are errors in all measurements and they can either be sampling errors and/or measurement errors (Dahmström, 2000). Performing statistical analyses on biased data, or in manner which, ignores important elements of data, can result in erroneously enhanced statistical significance or completely enhanced statistical illusory effects (DiGiacomo, 2006).

Layout

Dahmström (2000) said a questionnaire should be airy and clear but still not to thin to provide a high response rate. When discussing the response rate Dahmström (2000) also suggested to have easy ”safe” questions in the beginning and questions which is more difficult in the end.

Answer alternatives

There were various ways to design the answer alternatives, be open or closed (Körner & Wahlgren, 2005). When using open answer alternatives the respondent self formulated their answers and the qualitative aspects can be thoroughly investigated. A negative side effect is the time consuming coding of the answers. The closed answer alternatives demanded less effort for the respondents when they only need to put mark/marks for the alternative/alternatives they think fit their opinion or behaviour. This method was easily worked with in the analysis process. One risk could be that the pre printed answer alternatives did not cover all possible answers and/or were bad thought-out (Körner & Wahlgren, 2005).

Measurement scales

When working with the gathered data the chosen measurement scale must contain precise and accurate values which were practical, valid and reliable (Körner & Wahlgren, 2005). Different kinds of scales could be used. The nominal scale consists of descriptive variables in no particular order between the alternatives. The ordinal scale fits all of the requirements of the nominal scale but also have the property of order but nothing was known about the size of the interval between the alternatives. The interval and ratio scale provided even more details than the ordinal scale. Sjöberg (2000) said it has previous been useful when asking people to make a rating of size of perceived risk to use scales with a limited number of response categories.

Significance tests

There were different significance tests. When performing a survey with ordinal scales the χ^2-test was useful. Other possible test for hypothesis was for example the t-test which was used for interval and ratio scales.

The χ^2-test compared absolute frequencies with expected frequencies according to the null hypothesis and investigated if differences could be explained by chance (Körner & Wahlgren, 2005). The events were assumed to be independent and had the same distribution, and the outcomes of each event must be equally exclusive. The χ^2-test was calculated by finding the difference between each observed and theoretical frequency for each possible outcome, squaring them, dividing each by the theoretical frequency, and taking the sum of the results (Körner & Wahlgren, 2005):

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

O_i = an observed frequency;
E_i = an expected (theoretical) frequency, asserted by the null hypothesis.

The calculated value of χ^2 was compared to the tabulated α-value depending on the calculation's degrees of freedom. χ^2-value higher than the corresponding value for α equalled difference between the studied populations on a significance level. It was also possible to directly calculate the p-value, which was done in the report.

Reliability and validity

The gathered data should be reliable and valid. Reliability measures the authenticity and repeated measurements of the same variable for the same individual or group should give approximately the same result (Körner & Wahlgren, 2005). Validity referred to how well the variables designed in the questionnaire represented the phenomenon of interest and how well the actual measurements represented these variables (Körner & Wahlgren, 2005). The reliability can be tested, and four used methods were: Re-testing (the same individuals are tested twice) Dividing the answers randomly in two halves and compared them. Parallel method (two different surveys intended to measure the same thing) .Control questions (question with another formulation but with the same meaning as earlier asked question) (Ejvegård, 2003).

Reliability is a requirement, but not sufficient to prove the validity of a test (Ejvegård, 2003). If a test is not reliable it cannot be valid. However, a test which is reliable is not necessarily valid (Ejvegård, 2003). Proof of the validity was more difficult than the reliability. When it is difficult to conduct, if there were no other measurement to compare to see if the questionnaire really measures what it was supposed to (Ejvegård, 2003).

Distribution of the questionnaire

Constructing the questionnaire was not the only hard task, choosing the participants and the distribution was also important (Ejvegård, 2003). Since it was virtual impossible to cover an entire population, many investigators had used convenient samples, which for some reason were available and, willing to participate and then try to draw conclusion about a population (Sjöberg, 2000)

Appendix 2 – European Avalanche danger scale with recommendations

	Danger level	Snowpack stability	Avalanche triggering probability	Consequences for transportation routes and settlements / recommendations	Consequences for persons outside secured zones / recommendations
1	low	The snowpack is generally well bonded and stable.	Triggering is generally possible only with high additional loads** on very few extreme slopes. Only natural sluffs and small avalanches are possible.	No danger	Generally safe conditions
2	moderate	The snowpack is only moderately well bonded on some steep slopes*, otherwise it is generally well bonded.	Triggering is possible, particularly through high additional loads**, mainly on steep slopes indicated in the bulletin. Large natural avalanches are not expected.	Low danger of natural avalanches.	Mostly favourable conditions. Careful route selection, especially on steep slopes of indicated aspects and altitude zones.
3	considerable	The snowpack is moderately to weakly bonded on many steep slopes*.	Triggering is possible, even through low additional loads** mainly on steep slopes indicated in the bulletin. In certain conditions, some medium and occasionally large natural avalanches are possible.	Isolated exposed sectors are endangered. Some safety measures recommended in those places.	Partially unfavourable conditions. Experience in the assessment of avalanche danger is required. Steep slopes of indicated aspects and altitude zones should be avoided if possible.
4	high	The snowpack is weakly bonded on most steep slopes*.	Triggering is probable even through low additional loads** on many steep slopes. In certain conditions, many medium and multiple large natural avalanches are expected.	Many exposed sectors are endangered. Safety measures recommended in those places.	Unfavourable conditions. Extensive experience in the assessment of avalanche danger is required. Remain in moderately steep terrain / heed avalanche run out zones.
5	very high	The snowpack is generally weakly bonded and largely unstable.	Many large natural avalanches are expected, even in moderately steep terrain.	Acute danger. Comprehensive safety measures.	Highly unfavourable conditions. Avoid open terrain.

Explanations:

** Additional load:
- high (e.g. group of skiers without spacing, snowmobile/groomer, avalanche blasting)
- low (e.g. single skier, snowboarder, snowshoe hiker)

* generally explained in greater detail in Avalanche Bulletin (e.g. altitude zone, aspect, type of terrain)

→ moderately steep terrain: slopes flatter than about 30 degrees

→ steep slopes: slopes with an angle of more than about 30 degrees

→ extreme slopes: those which are particularly unfavourable as regards slope angle (usually steeper than about 40°), terrain profile, proximity to ridge, roughness of underlying ground

- natural: without human assistance
- aspect: the compass direction in which a downward slope faces
- exposed: especially exposed to danger

(Ammann & Stucki, 2005)

Appendix 3 The questionnaire

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Avalanches - risk investigation

The following questions are only to be answered by skiers/snowboarders that ski/snowboard off-piste

Please tick only one answer per question when nothing else is mentioned

1. Gender

☐ Male ☐ Female

2. Age:_____years

3. How good off-piste skier/snowboarder do you consider yourself to be?

☐ I manage easy off-piste terrain
☐ I manage moderate and challenging off-piste terrain
☐ Expert

4. How much do you on average ski/snowboard off-piste per year?

☐ <1 week ☐ 5-8 weeks
☐ 1-4 weeks ☐ >9 weeks

5. How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision regarding whether you ski/snowboard off-piste or not?

☐ 0-25% of the time ☐ 51-75% of the time
☐ 26-50% of the time ☐ 76-100% of the time

6. During which degree of avalanche danger (scale from 1 to 5) do you think most of the avalanche fatalities occur in Switzerland?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7. How do you rate the level “3” at the avalanche danger scale?

☐ Safe ☐ Intermediate ☐ Dangerous

8. How do you rate the level “considerable” at the avalanche danger scale?

☐ Safe ☐ Intermediate ☐ Dangerous

9. From which steepness do you think avalanches can occur?

☐ 25˚ ☐ 30˚ ☐ 35˚ ☐ 40˚ ☐ 45˚

10. Standing above a slope what from the following factors affect your decision regarding whether to go off-piste or not? *Please choose 5 factors and make a ranking (5 affects you the most, then 4 and so on to 1).*

- ☐ Avalanche bulletins
- ☐ Weather forecast
- ☐ New snow
- ☐ Wind, wind-deposited snow
- ☐ Temperature
- ☐ Visibility
- ☐ Snow cover conditions
- ☐ Evidence of old tracks
- ☐ Maps, guidebooks
- ☐ Steepness
- ☐ Key passages
- ☐ What that is above/below the slope?
- ☐ Topography, terrain
- ☐ Size of the slope
- ☐ Elevation and aspect
- ☐ Detour possibilities
- ☐ Group size
- ☐ Technique and fitness of the group members
- ☐ Responsibility
- ☐ Disicipline
- ☐ Leadership
- ☐ Pressure from other group members

11. What kind of rescue equipment do you use when skiing/snowboarding off-piste? *More than one tick is possible*.

- ☐ I do not use anything
- ☐ Avalanche beeper
- ☐ Avalanche probe
- ☐ Shovel
- ☐ ABS-backpack (Avalanche airbag)
- ☐ Avalung
- ☐ First Aid kit
- ☐ Cell phone
- ☐ Other_____

12. If you are equipped with a transceiver how often do you exercise seeking with it?

- ☐ Never
- ☐ about one time in 3 seasons
- ☐ about one time in 2 seasons
- ☐ more than 1 time a season

13. Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?

- ☐ Yes
- ☐ Maybe
- ☐ No

14. How much is your willingness to ski/snowboard off-piste affected by the rescue equipment that you use?

- ☐ None (I take the same risk with rescue equipment as without)
- ☐ A bit (I take less risks without rescue equipment than with rescue equipment)
- ☐ Much (I take more risks with rescue equipment)

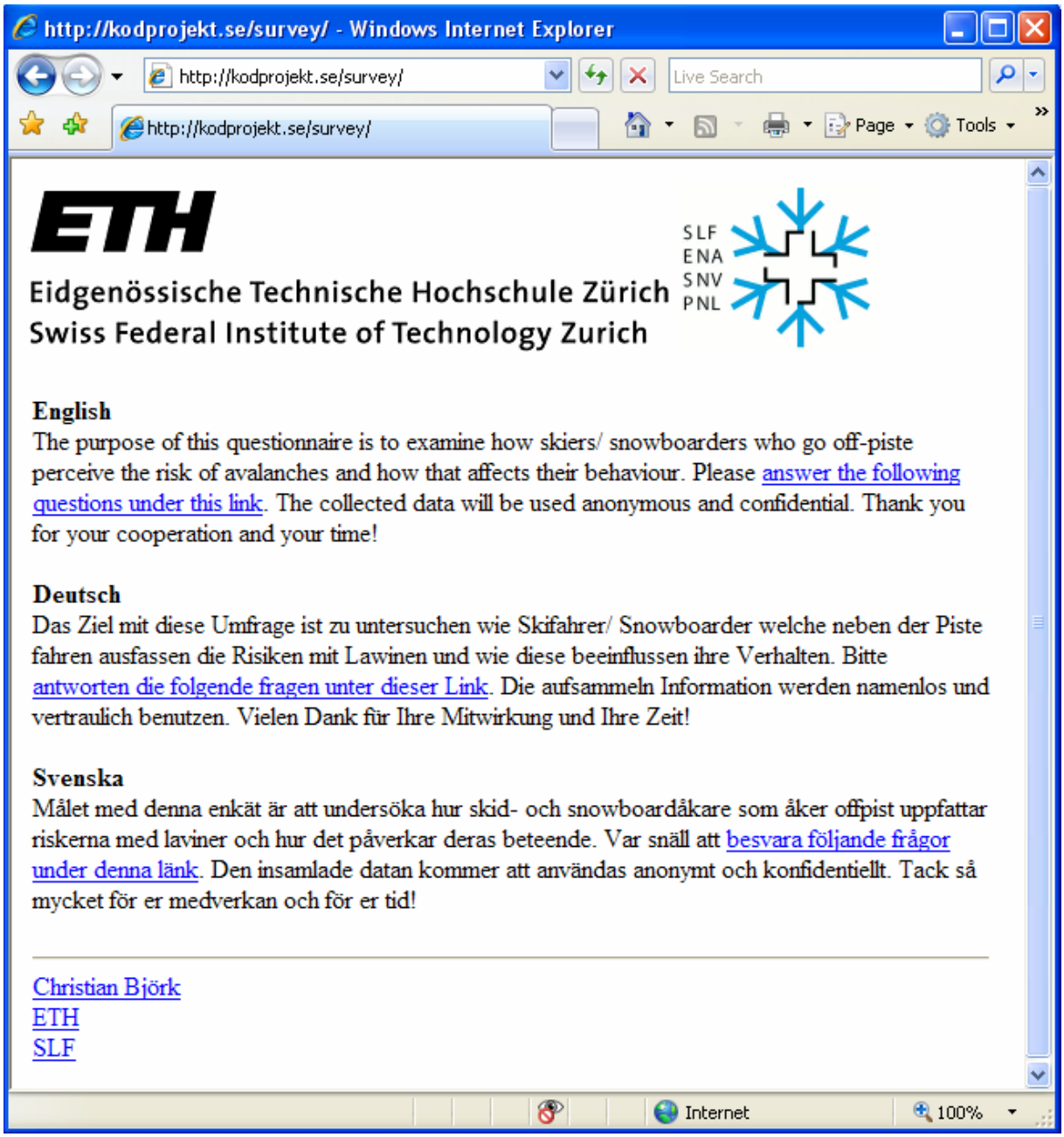
15. Do you consider yourself to sometime be in the risk zone for getting caught in an avalanche?

- ☐ Yes
- ☐ No

Thank you for filling in the questionnaire!

Appendix 4 – Freeskiing sites

The online based survey's link was found under www.kodprojekt.se/survey

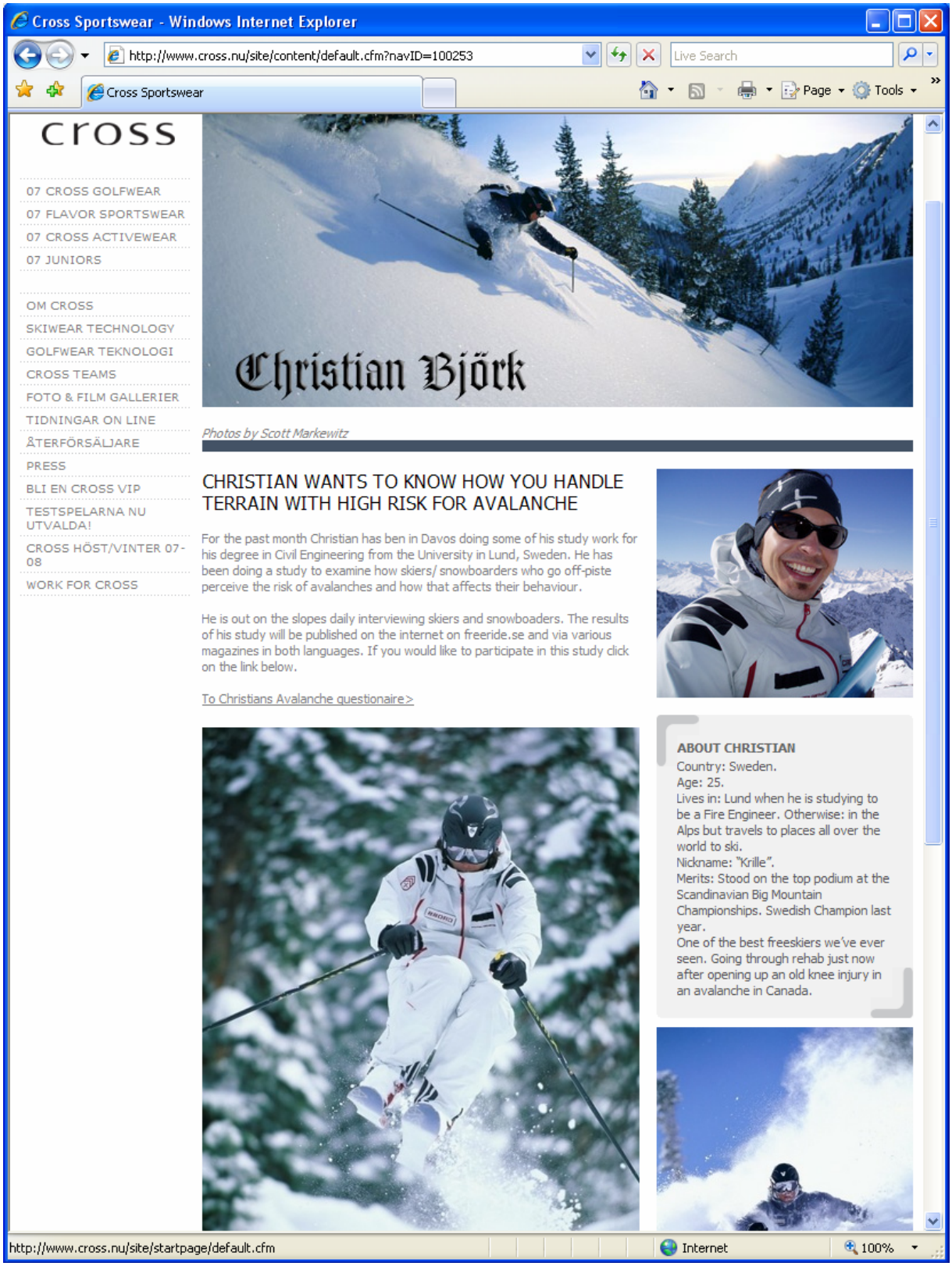


The Canadian skiing site Doglotion.com posted the link to the survey the 12th of April (11th Canadian time) at http://www.doglotion.com/avalanche-survey

Sweden and Scandinavian's biggest site for off-piste skiing Freeride.se posted the link 11.30 on the 13th April at http://www.freeride.se/content/1375/. Within the first 30 minutes after the posting 70 answers came in.

Sweden's main ski magazine Åka Skidor posted the link the 13th April at their web site at the address http://www.akaskidor.com/IziPage/ShortInfo_01.asp?ShortInfoID=663.

Cross Sportswear, a big Swedish clothing company posted the link the 14th of April on http://www.cross.nu/site/content/default.cfm?navID=100253



The biggest site for off-piste skiing in Germany Freeskiers.net posted the link the 3rd of May on:
http://www.freeskiers.net/index.php?option=com_content&task=view&id=743&Itemid=173

Appendix 5 – Davos survey

Davos	Men	Women	<30 years	31-40 years	>41 years	Easy terrain	Intermediate terrain	Expert terrain	<1 week	1-4 weeks	5-8 weeks	>9 weeks	0-25%	26-50%	51-75%	76-100%	None	Transceiver	Probe	Shovel	ABS-backpack	Avalung	First-Aid kit	Cell phone	Yes	Maybe	No	None	A bit	Much	Yes	No
Men	382		219	103	60	35	180	167	77	152	66	87	41	53	102	186	34	287	230	264	42	8	146	317	72	132	178	119	184	79	300	82
Women		145	100	30	15	39	71	35	43	62	21	19	13	12	31	89	14	106	83	94	7	1	51	116	17	49	79	44	61	40	97	48
<30 years	219	100	319			47	152	120	85	122	57	55	34	40	97	148	28	224	178	204	18	5	108	267	54	121	144	86	161	72	232	87
31-40 years	103	30		133		22	54	57	23	58	22	30	12	14	23	84	13	107	91	100	20	3	56	107	20	40	73	40	60	33	104	29
>41 years	60	15			75	5	45	25	12	34	8	21	8	11	13	43	7	62	44	54	11	1	33	59	15	20	40	37	24	14	61	14
Easy terrain	35	39	47	22	5	74			53	16	1	4	15	6	14	39	18	31	16	20	2		6	47	14	29	31	27	33	14	25	49
Intermediate terrain	180	71	152	54	45		251		59	120	46	26	24	38	69	120	27	180	135	160	13	2	87	206	51	90	110	84	120	47	190	61
Expert terrain	167	35	120	57	25			202	8	78	40	76	15	21	50	116	3	182	162	178	34	7	104	180	24	62	116	52	92	58	182	20
<1 week	77	43	85	23	12	53	59	8	120				24	10	27	59	22	57	30	44			14	92	32	43	45	46	51	23	51	69
1-4 weeks	152	62	122	58	34	16	120	78		214			10	29	61	114	19	163	123	149	18	2	80	172	35	81	98	67	102	45	168	46
5-8 weeks	66	21	57	22	8	1	46	40			87		11	13	22	41	2	77	68	68	9	1	49	77	14	28	45	22	48	17	76	11
>9 weeks	87	19	55	30	21	4	26	76				106	9	13	23	61	5	96	92	97	22	6	54	92	8	29	69	28	44	34	102	4
0-25%	41	13	34	12	8	15	24	15	24	10	11	9	54				10	27	22	21	7	5	18	38	15	16	23	21	21	12	29	25
26-50%	53	12	40	14	11	6	38	21	10	29	13	13		65			6	47	34	44	4	3	18	53	16	23	26	21	34	10	50	15
51-75%	102	31	97	23	13	14	69	50	27	61	22	23			133		13	97	70	90	9		42	107	23	56	54	39	67	27	105	28
76-100%	186	89	148	84	43	39	120	116	59	114	41	61				275	19	222	187	203	29	1	119	235	35	86	154	82	123	70	213	62
None	34	14	28	13	7	18	27	3	22	19	2	5	10	6	13	13	48							3	21	17	10	24	16	8	17	31
Transceiver	287	106	224	107	62	31	180	182	57	163	77	96	27	47	97	222		393	303	346	49	9	189	347	33	125	235	110	187	96	331	62
Probe	230	83	178	91	44	16	135	162	30	123	68	92	22	34	70	187		303	313	302	39	9	177	284	19	107	187	86	146	81	278	35
Shovel	264	94	204	100	54	20	160	178	44	149	68	97	21	44	90	203		346	302	358	42	9	186	326	26	116	216	101	170	87	312	46
ABS-backpack	42	7	18	20	11	2	13	34		18	3	22	7	4	9	29		49	39	42	49	3	30	43	6	9	34	10	23	16	45	4
Avalung	8	1	5	3	1		2	7		2	1	6	5	3		1		9	9	9	3	9	7	8	1	2	6	1	4	4	8	1
First-Aid kit	146	51	108	56	33	6	87	104	14	80	49	54	18	18	42	119		189	177	186	30	7	197	187	8	61	128	61	90	46	174	23
Cell phone	317	116	267	107	59	47	206	180	92	172	77	92	38	53	107	235	3	347	284	326	43	8	187	433	62	148	223	130	207	96	342	91
Yes	72	17	54	20	15	14	51	24	32	35	14	8	15	16	23	35	21	33	19	26	6	1	8	62	89			42	33	14	61	28
Maybe	132	49	121	40	20	29	90	62	43	81	28	29	16	23	56	86	17	125	107	116	9	2	61	148		181		42	116	23	137	44
No	178	79	144	73	40	31	110	116	45	98	45	69	23	26	54	154	10	235	187	216	34	6	128	223			257	79	96	82	199	58
None	119	44	86	40	37	27	84	52	46	67	22	28	21	21	39	82	24	110	86	101	10	1	61	130	42	42	79	163			110	53
A bit	184	61	161	60	24	33	120	92	51	102	48	44	21	34	67	123	16	187	146	170	23	4	90	207	33	116	96		245		196	49
Much	79	40	72	33	14	14	47	58	23	45	17	34	12	10	27	70	8	96	81	87	16	4	46	96	14	23	82			119	91	28
Yes	300	97	232	104	61	25	190	182	51	168	76	102	29	50	105	213	17	331	278	312	45	8	174	342	61	137	199	110	196	91	397	
No	82	48	87	29	14	49	61	20	69	46	11	4	25	15	28	62	31	62	35	46	4	1	23	91	28	44	58	53	49	28		130
																															Tot	527

Appendix 6 – Online based survey

Internet	Men	Women	<30 years	31-40 years	>41 years	Easy terrain	Intermediate terrain	Expert terrain	<1 week	1-4 weeks	5-8 weeks	>9 weeks	0-25%	26-50%	51-75%	76-100%	None	Transceiver	Probe	Shovel	ABS-backpack	Avalung	First-Aid kit	Cell phone	Yes	Maybe	No	None	A bit	Much	Yes	No
Men	1245		862	309	74	81	607	557	106	640	298	201	154	266	384	441	52	991	850	991	26	33	512	1099	302	513	430	360	683	202	899	346
Women		189	148	36	5	35	119	35	25	98	32	34	24	34	42	89	3	152	124	145	2	1	69	161	35	75	79	57	101	31	114	75
<30 years	862	148	1010			94	541	375	100	503	235	172	136	234	314	326	30	757	651	752	8	11	335	904	257	427	326	260	578	172	707	303
31-40 years	309	36		345		17	142	186	24	192	76	53	33	58	98	156	20	314	263	312	13	13	190	291	69	126	150	120	171	54	261	84
>41 years	74	5			79	5	43	31	7	43	19	10	9	8	14	48	5	72	60	70	7	10	56	65	11	35	33	37	35	7	45	34
Easy terrain	81	35	94	17	5	116			53	53	6	4	23	22	23	48	12	59	43	58	1	1	28	99	32	49	35	45	57	14	34	82
Intermediate terrain	607	119	541	142	43		726		71	457	138	60	82	166	216	262	34	532	439	531	12	6	245	634	203	303	220	218	394	114	459	267
Expert terrain	557	35	375	186	31			592	7	228	186	171	73	112	187	220	9	552	492	547	15	27	308	527	102	236	254	154	333	105	520	72
<1 week	106	25	100	24	7	53	71	7	131				24	26	33	48	17	61	45	60	1		22	122	44	58	29	58	53	20	45	86
1-4 weeks	640	98	503	192	43	53	457	228		738			89	163	198	288	32	562	458	556	9	10	248	665	200	310	228	209	408	121	497	241
5-8 weeks	298	32	235	76	19	6	138	186			330		39	69	114	108	2	294	261	298	5	8	167	301	57	138	135	81	192	57	263	67
>9 weeks	201	34	172	53	10	4	60	171				235	26	42	81	86	4	226	210	221	13	16	144	221	36	82	117	69	131	35	208	27
0-25%	154	24	136	33	9	23	82	73	24	89	39	26	178				18	110	93	110	6	2	57	152	69	65	44	66	84	28	112	66
26-50%	266	34	234	58	8	22	166	112	26	163	69	42		300			10	225	181	225	3	6	104	270	92	127	81	82	168	50	215	85
51-75%	384	42	314	98	14	23	216	187	33	198	114	81			426		15	356	292	354	4	9	168	375	91	196	139	98	250	78	316	110
76-100%	441	89	326	156	48	48	262	220	48	288	108	86				530	12	452	403	447	14	16	252	463	85	200	245	171	282	77	370	160
None	52	3	30	20	5	12	34	9	17	32	2	4	18	10	15	12	55	7	2	4				18	38	14	3	37	12	6	23	32
Transceiver	991	152	757	314	72	59	532	552	61	562	294	226	110	225	356	452	7	1143	940	1066	28	34	542	1007	165	500	478	292	658	193	900	243
Probe	850	124	651	263	60	43	439	492	45	458	261	210	93	181	292	403	2	940	874	949	24	33	513	855	120	410	444	246	560	168	779	195
Shovel	991	145	752	312	70	58	531	547	60	556	298	221	110	225	354	447	4	1066	949	1136	27	34	555	1004	176	479	481	289	654	131	885	251
ABS-backpack	26	2	8	13	7	1	12	15	1	9	5	13	6	3	4	14		28	24	27	28	2	15	24	4	11	13	5	17	6	25	3
Avalung	33	1	11	13	10	1	6	27		10	8	16	2	6	9	16		34	33	34	2	34	28	32	2	17	15	6	25	3	32	2
First-Aid kit	512	69	335	190	56	28	245	308	22	248	167	144	57	104	168	252		542	513	555	15	28	581	535	71	205	305	169	328	84	478	103
Cell phone	1099	161	904	291	65	99	634	527	122	665	301	221	152	270	375	463	18	1007	855	1004	24	32	535	1260	287	521	452	336	720	204	900	360
Yes	302	35	257	69	11	32	203	102	44	200	57	36	69	92	91	85	38	165	120	176	4	2	71	287	337			141	150	46	203	134
Maybe	513	75	427	126	35	49	303	236	58	310	138	82	65	127	196	200	14	500	410	479	11	17	205	521		588		138	367	83	423	165
No	430	79	326	150	33	35	220	254	29	228	135	117	44	81	139	245	3	478	444	481	13	15	305	452			509	138	267	104	387	122
None	360	57	260	120	37	45	218	154	58	209	81	69	66	82	98	171	37	292	246	289	5	6	169	336	141	138	138	417			253	164
A bit	683	101	578	171	35	57	394	333	53	408	192	131	84	168	250	282	12	658	560	654	17	25	328	720	150	367	267		784		589	195
Much	202	31	172	54	7	14	114	105	20	121	57	35	28	50	78	77	6	193	168	191	6	3	84	204	46	83	104			233	171	62
Yes	899	114	707	261	45	34	459	520	45	497	263	208	112	215	316	370	23	900	779	885	25	32	478	900	203	423	387	253	589	171	1013	
No	346	75	303	84	34	82	267	72	86	241	67	27	66	85	110	160	32	243	195	251	3	2	103	360	134	165	122	164	195	62		421
																															Tot	1434

Appendix 7 – The off-piste skiers' knowledge

Question 6. During which degree of avalanche danger (scale from 1 to 5) do you think most of the avalanche fatalities occur in Switzerland?

Table 1 Avalanche danger level, fatality statistics and for which avalanche danger level the categories think the most fatal avalanche occur

Avalanche danger level	1	2	3	4	5	Sum
Accident statistics	6%	30%	45%	18%	1%	100%
Davos	**1**	**2**	**3**	**4**	**5**	**Sum**
Total	1.1%	11.2%	73.6%	10.8%	3.2%	100.0%
Men	1.6%	11.0%	73.6%	11.3%	2.6%	100.0%
Women	0.0%	11.7%	73.8%	9.7%	4.8%	100.0%
Easy terrain	1.4%	17.6%	62.2%	10.8%	8.1%	100.0%
Intermediate terrain	0.8%	11.2%	72.1%	12.4%	3.6%	100.0%
Expert terrain	1.5%	8.9%	79.7%	8.9%	1.0%	100.0%
Internet	**1**	**2**	**3**	**4**	**5**	**Sum**
Total	0.0%	5.3%	70.2%	22.3%	2.2%	100.0%
Men	0.0%	5.2%	70.9%	21.8%	2.1%	100.0%
Women	0.0%	5.8%	65.6%	25.9%	2.6%	100.0%
Easy terrain	0.0%	6.9%	63.8%	25.0%	4.3%	100.0%
Intermediate terrain	0.0%	5.0%	68.5%	24.2%	2.3%	100.0%
Expert terrain	0.0%	5.4%	73.6%	19.4%	1.5%	100.0%

Question 9. From which steepness do you think avalanches can occur?

Table 2 Steepness required for avalanches?

Steepness	25˚	30˚	35˚	40˚	45˚	Sum
Total (Davos)	**124**	**277**	**99**	**22**	**5**	**527**
Men	92	208	64	16	2	**382**
Women	32	69	35	6	3	**145**
<30 years	77	162	62	13	5	**319**
31-40 years	32	74	22	5		**133**
>41 years	15	41	15	4		**75**
Easy terrain	19	32	16	4	3	**74**
Intermediate terrain	58	132	50	10	1	**251**
Expert terrain	47	113	33	8	1	**202**
Total (Internet)	**701**	**480**	**198**	**37**	**18**	**1434**
Men	613	423	163	32	14	**1245**
Women	88	57	35	5	4	**189**
<30 years	459	343	163	30	15	**1010**
31-40 years	199	110	28	5	3	**345**
>41 years	43	27	7	2		**79**
Easy terrain	45	36	23	7	5	**116**
Intermediate terrain	329	258	108	20	11	**726**
Expert terrain	327	186	67	10	2	**592**

Appendix 8 – How off-piste skiers perceive the avalanche and the affects on their behaviour and risk management

Question 5. How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision regarding whether you ski/snowboard off-piste or not?

Table 3 Risk zone and checking avalanche bulletins prior skiing

Davos	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Sum**
Yes	29 (7.3%)	50 (12.6%)	105 (26.4%)	213 (53.7%)	397 (100%)
No	25 (19.2%)	15 (11.5%)	28 (21.6%)	62 (47.7%) (	130 (100%)
Sum	54	65	133	275	527
χ^2-test	**0.00159****				
Degrees of freedom	3				
Internet	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Sum**
Yes	112 (11.1%)	215 (21.2%)	316 (31.2%)	370 (36.5%)	1013 (100%)
No	66 (15.7%)	85 (20.2%)	110 (26.1%)	160 (38.0%)	421 (100%)
Sum	178	300	426	530	1434
χ^2-test	**0.0457***				
Degrees of freedom	3				

Question 11. What kind of rescue equipment do you use when skiing/snowboarding off-piste?

Table 4 Risk zone of avalanches and usage of transceivers

Davos	**Transceiver**	**No transceiver**	**Sum**
Yes	331 (83.4%)	66 (16.6%)	397 (100%)
No	62 (47.7%)	68 (52.3%)	130 (100%)
Sum	393	134	527
χ^2-test	**5.09E-16*****		
Degrees of freedom	1		
Internet	**Transceiver**	**No transceiver**	**Sum**
Yes	900 (88.8%)	113 (11.2%)	1013 (100%)
No	243 (57.7%)	178 (42.3%)	421 (100%)
Sum	1143	291	1434
χ^2-test	**1.24E-40*****		
Degrees of freedom	1		

Question 12. If you are equipped with a transceiver how often do you exercise seeking with it?

Table 5 Risk zone of avalanches and practise with transceivers

Internet	Never	Once/3rd season	Once/2 season	Once/season	Sum
Yes	50 (5.5%)	96 (10.7%)	199 (22.1%)	555 (61.7%)	900 (100%)
No	29 (11.9%)	34 (14.0%)	57 (23.5%)	123 (50.6%)	243 (100%)
Sum	79	130	256	678	1143
χ^2-test	**0.000638*** **				
Degrees of freedom	3				

Question 13: Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?

Table 6 Risk zone for avalanche and skiing with unequipped friends

Davos	Yes	Maybe	No	Sum
Yes	61 (15.4%)	137 (34.5%)	199 (50.1%)	397 (100%)
No	28 (21.5%)	44 (33.9%)	58 (44.6%)	130 (100%)
Sum	89	181	257	527
χ^2-test	**0.2427**			
Degrees of freedom	2			
Internet	**Yes**	**Maybe**	**No**	**Sum**
Yes	203 (20.0%)	423 (41.8%)	387 (38.2%)	1013 (100%)
No	134 (31.8%)	165 (39.2%)	122 (29.0%)	421 (100%)
Sum	337	588	509	1434
χ^2-test	**0.00000338*** **			
Degrees of freedom	2			

Appendix 9 – If off-piste skiers with a transceiver and/or avalanche airbag compensate a possible higher level of safety by taking more risks

Question 5: How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision regarding whether you ski/snowboard off-piste or not?

Table 7 Use of rescue equipment and checking avalanche bulletins prior skiing

Davos	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Sum**
Transceiver	27 (6.9%)	47 (12.0%)	97 (24.7%)	222 (56.4%)	397 (100%)
No transceiver	27 (20.1%)	18 (13.4%)	36 (26.9%)	53 (39.6%)	130 (100%)
Sum	54	65	133	275	527
χ^2-test	**3.94E-05*** **				
Degrees of freedom	3				
Internet	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Sum**
Transceiver	110 (9.6%)	225 (19.7%)	356 (31.2%)	452 (39.5%)	1013 (100%)
No transceiver	68 (23.4%)	75 (25.8%)	70 (24.0%)	78 (26.8.0%)	421 (100%)
Sum	178	300	426	530	1434
χ^2-test	**1.42E-11*** **				
Degrees of freedom	3				

Question 12: If you are equipped with a transceiver how often do you exercise seeking with it?

Table 8 Transceiver use and practise

Never	79 (6.9%)
Once/3rd season	130 (11.4%)
Once/2 season	256 (22.4%)
Once/season	678 (59.3%)
Sum	1143 (100%)

Question 13: Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?

Table 9 Usage of transceivers and willingness to ski with unequipped friends

Davos	**Yes**	**Maybe**	**No**	**Sum**
Transceiver	33 (8.4%)	125 (31.8%)	235 (59.8%)	393 (100%)
No transceiver	56 (41.8%)	56 (41.8%)	22 (16.4%)	134 (100%)
Sum	86	181	257	527
χ^2-test	**4.67E-24*** **			
Degrees of freedom	2			
Internet	**Yes**	**Maybe**	**No**	**Sum**
Transceiver	165 (14.4%)	500 (43.8%)	478 (41.8%)	1143 (100%)
No transceiver	172 (59.1%)	88 (30.2%)	31 (10.7%)	291 (100%)
Sum	337	588	509	1434
χ^2-test	**1.62E-59*** **			
Degrees of freedom	2			

Appendix 10 – If there are differences between various categories of skiers (gender, age groups and level of skill)

Question 5: How often does the degree of avalanche danger (low – very high) and/or the avalanche bulletin affect your decision regarding whether you ski/snowboard off-piste or not?

Table 10 Gender and checking avalanche bulletins prior skiing

Davos	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Sum**
Men	41 (10.7%)	53 (13.9%)	102 (26.7%)	186 (48.7%)	382 (100%)
Women	13 (9.0%)	12 (8.3%)	31 (21.4%)	89 (61.4%)	145 (100%)
Sum	54	65	133	275	527
χ^2-test	**0.0598**				
Degrees of freedom	4				
Internet	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Sum**
Men	154 (12.4%)	266 (21.4%)	384 (30.8%)	441 (35.4%)	1245 (100%)
Women	24 (12.7%)	34 (18.0%)	42 (22.2%)	89 (47.1%)	189 (100%)
Sum	178	300	426	530	1434
χ^2-test	**0.0114***				
Degrees of freedom	4				

Table 11 Age groups and checking avalanche bulletins prior skiing

Davos	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Sum**
<30 years	34 (10.7%)	40 (12.5%)	97 (30.4%)	148 (46.4%)	319 (100%)
31-40 years	12 (9.0%)	14 (10.5%)	23 (17.3%)	84 (63.2%)	133 (100%)
>41 years	8 (10.7%)	11 (14.7%)	13 (17.3%)	43 (57.3%)	75 (100%)
Sum	54	65	133	275	527
χ^2-test	**0.0201***				
Degrees of freedom	6				
Internet	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Sum**
<30 years	136 (13.5%)	234 (23.2%)	314 (31.1%)	326 (32.3%)	1010 (100%)
31-40 years	33 (9.6%)	58 (16.8%)	98 (28.4%)	156 (45.2%)	345 (100%)
>41 years	9 (11.4%)	8 (10.1%)	14 (17.7%)	48 (60.8%)	79 (100%)
Sum	178	300	426	530	1434
χ^2-test	**1.86E-07*****				
Degrees of freedom	6				

Table 12 Level of skill and checking avalanche bulletins prior skiing

Davos	0-25%	26-50%	51-75%	76-100%	Sum
Easy terrain	15 (20.3%)	6 (8.1%)	14 (18.9%)	39 (52.7%)	74 (100%)
Intermediate terrain	24 (9.6%)	38 (15.1%)	69 (27.5%)	120 (47.8%)	251 (100%)
Expert terrain	15 (7.4%)	21 (10.4%)	50 (24.8%)	116 (57.4%)	202 (100%)
Sum	54	65	133	275	527
χ^2-test	**0.0142***				
Degrees of freedom	6				
Internet	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Sum**
Easy terrain	23 (19.8%)	22 (19.0%)	23 (19.8%)	48 (41.4%)	116 (100%)
Intermediate terrain	82 (11.3%)	166 (22.9%)	216 (29.7%)	262 (36.1%)	726 (100%)
Expert terrain	73 (12.3%)	112 (18.9%)	187 (31.6%)	220 (37.2%)	592 (100%)
Sum	178	300	426	530	1434
χ^2-test	**0.0318***				
Degrees of freedom	6				

Question 11: What kind of rescue equipment do you use when skiing/snowboarding off-piste?

Table 13 Gender and usage of transceiver

Davos	Transceiver	No transceiver	Sum
Men	287 (75.1%)	95 (24.9%)	382 (100%)
Women	106 (73.1%)	39 (26.9%)	145 (100%)
Sum	393	134	527
χ^2-test	**0.633**		
Degrees of freedom	1		
Internet	**Transceiver**	**No transceiver**	**Sum**
Men	991 (79.6%)	254 (20.4%)	1245 (100%)
Women	152 (80.4%)	37 (19.6%)	189 (100%)
Sum	1143	291	1434
χ^2-test	**0.793**		
Degrees of freedom	1		

Table 14 Age groups and usage of transceivers

Davos	Transceiver	No transceiver	Sum
<30 years	224 (70.2%)	95 (29.8%)	397 (100%)
31-40 years	107 (80.5%)	26 (19.5%)	130 (100%)
>41 years	62 (82.7%)	13 (17.3%)	130 (100%)
Sum	393	134	527
χ^2-test	**0.0165***		
Degrees of freedom	2		
Internet	**Transceiver**	**No transceiver**	**Sum**
<30 years	757(75.0%)	253 (25.0%)	1013 (100%)
31-40 years	314 (91.0%)	31 (9.0%)	421 (100%)
>41 years	72 (91.1%)	7 (8.9%)	130 (100%)
Sum	1143	291	1434
χ^2-test	**4.21E-11*****		
Degrees of freedom	2		

Table 15 Level of skill and usage of transceivers

Davos	Transceiver	No transceiver	Sum
Easy terrain	31 (41.9%)	43 (58.1%)	74 (100%)
Intermediate terrain	180 (71.7%)	71 (28.3%)	251 (100%)
Expert terrain	182 (90.1%)	20 (9.9%)	202 (100%)
Sum	393	134	527
χ^2-test	**1.37E-15*****		
Degrees of freedom	2		
Internet	**Transceiver**	**No transceiver**	**Sum**
Easy terrain	59 (50.9%)	57 (49.1%)	116 (100%)
Intermediate terrain	532 (73.3%)	194 (26.7%)	726 (100%)
Expert terrain	552 (93.2%)	40 (6.8%)	592 (100%)
Sum	1143	291	1434
χ^2-test	**2.83E-32*****		
Degrees of freedom	2		

Question 12: If you are equipped with a transceiver how often do you exercise seeking with it?

Table 16 Gender and practise with transceiver

Internet	Never	Once/3rd season	Once/2 season	Once/season	Sum
Men	64 (6.5%)	120 (12.1%)	223 (22.5%)	584 (58.9%)	991 (100%)
Women	15 (9.9%)	10 (6.6%)	33 (21.7%)	94 (61.8%)	152 (100%)
Sum	79	130	256	678	1143
χ^2-test	**0.171**				
Degrees of freedom	3				

Table 17 Age groups and practise with transceivers

Internet	Never	Once/3rd season	Once/2 season	Once/season	Sum
<30 years	51 (6.7%)	83 (11.0%)	180 (23.8%)	443 (58.5%)	757 (100%)
31-40 years	20 (6.4%)	36 (11.5%)	63 (20.1%)	195 (62.1%)	314 (100%)
>41 years	8 (11.1%)	11 (15.3%)	13 (18.1%)	40 (55.6%)	72 (100%)
Sum	79	130	256	678	1143
χ^2-test	**0.618**				
Degrees of freedom	6				

Table 18 Level of skill and practise with transceivers

Internet	Never	Once/3rd season	Once/2 season	Once/season	Sum
Easy terrain	12 (20.3%)	12 (20.3%)	13 (22.0%)	22 (37.3%)	59 (100%)
Intermediate terrain	45 (8.5%)	60 (11.3%)	135 (25.4%)	292 (54.9%)	532 (100%)
Expert terrain	22 (4.0%)	58 (10.7%)	108 (19.6%)	364 (65.8%)	552 (100%)
Sum	79	130	256	678	1143
χ^2-test	**3.37E-07*** **				
Degrees of freedom	6				

Question 13: Would you ski/snowboard off-piste with friends who do not carry any rescue equipment?

Table 19 Gender and willingness to ski off-piste with friends without rescue equipment

Davos	Yes	Maybe	No	Sum
Men	72 (18.9%)	132 (34.5%)	178 (46.6%)	382 (100%)
Women	17 (11.7%)	49 (33.8%)	79 (54.5%)	145 (100%)
Sum	89	181	257	527
χ^2-test	**0.105**			
Degrees of freedom	2			
Internet	**Yes**	**Maybe**	**No**	**Sum**
Men	302 (24.3%)	513 (41.2%)	430 (34.5%)	1245 (100%)
Women	35 (18.5%)	75 (39.7%)	79 (41.8%)	189 (100%)
Sum	337	588	509	1434
χ^2-test	**0.089**			
Degrees of freedom	2			

Table 20 Age groups and the willingness to ski off-piste with friend without rescue equipment

Davos	Yes	Maybe	No	Sum
<30 years	54 (16.9%)	121 (37.9%)	144 (45.1%)	319 (100%)
31-40 years	20 (15.0%)	40 (30.1%)	73 (54.9%)	133 (100%)
>41 years	15 (20.0%)	20 (26.7%)	40 (53.3%)	75 (100%)
Sum	89	181	257	527
χ^2-test	**0.193**			
Degrees of freedom	4			
Internet	**Yes**	**Maybe**	**No**	**Sum**
<30 years	257 (25.4%)	427 (42.3%)	326 (32.3%)	1010 (100%)
31-40 years	69 (20.0%)	126 (36.5%)	150 (43.5%)	345 (100%)
>41 years	11 (13.9%)	35 (44.3%)	33 (41.8%)	79 (100%)
Sum	337	588	509	1434
χ^2-test	**0.000851*** **			
Degrees of freedom	4			

Table 21 Level of skill and the willingness to ski off-piste with friends without rescue equipment

Davos	Yes	Maybe	No	Sum
Easy terrain	14 (18.9%)	29 (39.2%)	31 (41.9%)	74 (100%)
Intermediate terrain	51 (20.3%)	90 (35.9%)	110 (43.8%)	251 (100%)
Expert terrain	24 (11.9%)	62 (30.7%)	116 (57.4%)	202 (100%)
Sum	89	181	257	527
χ^2-test	**0.0218***			
Degrees of freedom	4			
Internet	**Yes**	**Maybe**	**No**	**Sum**
Easy terrain	32 (27.6%)	49 (42.2%)	35 (30.2%)	116 (100%)
Intermediate terrain	203 (28.0%)	303 (41.7%)	220 (30.3%)	726 (100%)
Expert terrain	102 (17.2%)	236 (39.9%)	254 (42.9%)	592 (100%)
Sum	337	588	509	1434
χ^2-test	**1.31E-06*****			
Degrees of freedom	4			

Question 14: How much is your willingness to ski/snowboard off-piste affected by the rescue equipment that you use?

Table 22 Gender and how much rescue effect

Davos	**None**	**A bit**	**Much**	**Sum**
Men	119 (31.1%)	184 (48.2%)	79 (20.7%)	382 (100%)
Women	44 (30.3%)	61 (42.1%)	40 (27.6%)	145 (100%)
Sum	163	245	119	527
χ^2-test	**0.214**			
Degrees of freedom	2			
Internet	**None**	**A bit**	**Much**	**Sum**
Men	360 (28.9%)	683 (54.9%)	202 (16.2%)	1245 (100%)
Women	57 (30.2%)	101 (53.4%)	31 (16.4%)	189 (100%)
Sum	417	784	233	1434
χ^2-test	**0.927**			
Degrees of freedom	2			

Table 23 Age groups and how much rescue equipment effect

Davos	**None**	**A bit**	**Much**	**Sum**
<30 years	86 (27.0%)	161 (50.4%)	72 (22.6%)	319 (100%)
31-40 years	40 (30.1%)	60 (45.1%)	33 (24.8%)	133 (100%)
>41 years	37 (49.3%)	24 (32.0%)	14 (18.7%)	75 (100%)
Sum	163	245	119	527
χ^2-test	**0.0043****			
Degrees of freedom	4			
Internet	**None**	**A bit**	**Much**	**Sum**
<30 years	260 (25.8%)	578 (57.2%)	172 (17.0%)	1010 (100%)
31-40 years	120 (34.8%)	171 (49.6%)	54 (15.6%)	345 (100%)
>41 years	37 (46.8%)	35 (44.3%)	7 (8.9%)	79 (100%)
Sum	417	784	233	1434
χ^2-test	**8.74E-05*****			
Degrees of freedom	4			

Table 24 Level of skill and how much rescue equipment effect

Davos	None	A bit	Much	Sum
Easy terrain	27 (36.5%)	33 (44.6%)	14 (18.9%)	74 (100%)
Intermediate terrain	84 (33.5%)	120 (47.8%)	47 (18.7%)	251 (100%)
Expert terrain	52 (25.7%)	92 (45.6%)	58 (28.7%)	202 (100%)
Sum	163	245	119	527
χ^2-test	**0.0701**			
Degrees of freedom	4			
Internet	**None**	**A bit**	**Much**	**Sum**
Easy terrain	45 (38.8%)	57 (49.1%)	14 (12.1%)	116 (100%)
Intermediate terrain	218 (30.0%)	394 (54.3%)	114 (15.7%)	726 (100%)
Expert terrain	154 (26.0%)	333 (56.3%)	105 (17.7%)	592 (100%)
Sum	417	784	233	1434
χ^2-test	**0.0604**			
Degrees of freedom	4			

Question 15: Do you consider yourself to sometime be in the risk zone for getting caught in an avalanche?

Table 25 Gender and if they believe to be in the risk zone for getting caught in avalanches

Davos	Yes	No	Sum
Men	300 (78.5%)	82 (21.5%)	382 (100%)
Women	97 (66.9%)	48 (33.1%)	145 (100%)
Sum	397	130	527
χ^2-test	**0.00565****		
Degrees of freedom	1		
Internet	**Yes**	**No**	**Sum**
Men	899 (72.2%)	346 (27.8%)	1245 (100%)
Women	114 (60.3%)	75 (39.7%)	189 (100%)
Sum	1013	421	1434
χ^2-test	**0.000823*****		
Degrees of freedom	1		

Table 26 Age group and if they believe to be in the risk zone of getting caught in avalanches

Davos	**Yes**	**No**	**Sum**
<30 years	232 (72.7%)	87 (27.3%)	319 (100%)
31-40 years	104 (78.2%)	29 (21.8%)	133 (100%)
>41 years	61 (81.3%)	14 (18.7%)	75 (100%)
Sum	397	130	1434
χ^2-test	**0.201**		
Degrees of freedom	2		
Internet	**Yes**	**No**	**Sum**
<30 years	707 (70.0%)	303 (30.0%)	1010 (100%)
31-40 years	261 (75.7%)	84 (24.3%)	345 (100%)
>41 years	45 (57.0%)	34 (43.0%)	79 (100%)
Sum	1013	421	1434
χ^2-test	**0.00317****		
Degrees of freedom	2		

Table 27 The level of skill and if they believe to be in the risk zone of getting caught in an avalanche

Davos	**Yes**	**No**	**Sum**
Easy terrain	25 (33.8%)	49 (66.2%)	74 (100%)
Intermediate terrain	190 (75.7%)	61 (24.3%)	251 (100%)
Expert terrain	182 (90.1%)	20 (9.9%)	202 (100%)
Sum	397	130	527
χ^2-test	**8.35E-21*****		
Degrees of freedom	2		
Internet	**Yes**	**No**	**Sum**
Easy terrain	34 (29.3%)	82 (70.7%)	116 (100%)
Intermediate terrain	459 (63.2%)	267 (36.8%)	726 (100%)
Expert terrain	520 (87.8%)	72 (12.2%)	592 (100%)
Sum	1013	421	1434
χ^2-test	**5.49E-44*****		
Degrees of freedom	2		