BENEFIT-DETRIMENT ANALYSIS FOR NEW RESCUE TECHNOLOGIES

James Floyer[1]*, Ilya Storm[1] and Karl Klassen[1]

[1]Canadian Avalanche Centre, Revelstoke, BC, Canada

ABSTRACT: Organizations involved with public avalanche safety, such as the Canadian Avalanche Centre (CAC) are looked to for advice about whether to adopt new avalanche rescue technologies, such as avalanche search apps for smartphones. However, deciding on the best advice to give is not always a straightforward task. This paper outlines a method of using a formal benefit-detriment analysis for evaluating the overall impact of a new rescue technology. The method is fairly simple and first requires identifying both positive and negative aspects of the new technology, including impacts on existing rescue systems. A discussion on quantifying some of the benefit and detriment components is included. Applying this method to the case of available smartphone avalanche search apps, we argue that in their current form they are most likely detrimental to public avalanche safety, regardless of their uptake level. There are potentially different methods for utilizing smartphone technology in avalanche rescue scenarios. Using the same analysis technique, we explore scenarios where smartphone technology could potentially have a favorable impact on avalanche safety. This technique has applicability for organizations trying to decide whether or not to recommend or adopt new or even existing avalanche rescue technologies.

KEYWORDS: Avalanche, Search, Rescue, Smartphones, New Technology

1. INTRODUCTION

Recreational users, commercial winter operators and outdoor industrial workplaces with avalanche hazard all benefit from a robust, easy-to-use, intercompatible avalanche rescue system. Currently, the international standard for avalanche rescue systems is the 457 kHz transceiver—a dedicated rescue device with the ability to transmit and receive pulsed electromagnetic signals at the 457 kHz frequency.

Smartphones have the ability to send and receive electromagnetic signals, although not at the 457 kHz frequency. Smartphones are capable of two-way transmission using cell phone, WiFi, and Bluetooth signals. Many are also capable of receiving GPS and/or GLONASS (Russian GPS) signals.

Smartphone communication bands are capable of transmitting through snow. RescueCell have demonstrated the ability for cell phones to receive and transmit GSM phone signals through the snow. Anecdotal studies as well as some limited testing (unpublished results from the developers of Snøg) indicate WiFi and Bluetooth signals can transmit through at least 2 m of snow under good conditions. Schleppe, J. and Lachapelle (2006) studied GPS transmission through snow and found that reasonable tracking could be achieved through at least 2 m of snow.

There are some provisos to smartphone signal transmission through snow. Floyer (2013) has argued that WiFi and Bluetooth signal attenuation through moist or wet snow is likely to be higher than through dry snow. Genswein (personal communication) believes WiFi and Bluetooth signals could be significantly attenuated by the body of an avalanche victim lying over the transmitting device. Schleppe, J. and Lachapelle (2006) found that while a GPS in tracking mode could reasonably continue to track and receive signals under 2 m of snow, GPS start-up times for signal acquisition from a buried unit were considerably longer than an unburied control.

Despite some issues, evidence suggests that under good conditions, smartphones can perform two-way communication when buried by around 2 m of snow. Given this, and given the popularity of smartphones and the relative ease at which software can be developed for these devices, it is unsurprising that there have been attempts to make use of these technologies for avalanche rescue.

This paper outlines a framework for helping evaluate whether such technologies are likely to have a positive or negative overall impact on public ava-

* *Corresponding author address:*
James Floyer, Canadian Avalanche Centre,
PO Box 2759, Revelstoke BC, V0E 2S0, Canada
tel: 250 837 2141
email: jfloyer@avalanche.ca

lanche safety. It is hoped this framework might be useful for public safety agencies or similar bodies when trying to make assessments regarding the utility of a new rescue technology. The applicability is at the scale of public recreationists as a whole group; we do not consider the potential benefits or detriments to an individual or small group of users (who could, for example, be highly familiar and well-versed with a certain device or technology). While products are identified by name, this paper is not intended to rate or assess individual products beyond general statements about the applicability of the technology to the problem of avalanche rescue.

2. PRIMARY OR SECONDARY RESCUE SYSTEM

Much changes whether a technology is intended to be deployed as a primary or a secondary rescue system. It is useful to introduce the following definitions:

Primary Rescue System: A fully robust, dedicated, internationally compatible rescue system consciously employed by the user to reduce the consequences and therefore the risk of death in the event of being buried in an avalanche.

Secondary Rescue System: A rescue system designed to offer avalanche search capability to those not carrying a dedicated rescue device, in some cases by making use of incidental attributes, devices or technologies, such as a person's scent or reflectors imbedded in clothing and equipment.

Primary rescue systems currently available to recreationists are the companion rescue system comprising 457 kHz transceiver, probe and shovel, and airbag inflation systems. Secondary rescue systems include the RECCO® system, magnetometers (for vehicle searches), avalanche rescue dogs, and probe-line response by SAR/patrol teams.

Table 1 indicates the current smartphone technologies available or in development and whether they should be evaluated as primary or secondary rescue devices. The iSis, Snøg, SnoWhere, and Galileo-LawinenFon systems should be evaluated as primary systems because a user must consciously choose to install and more importantly activate the software prior to setting off on their backcountry trip. They are designed (and in some cases marketed) to convert a smartphone into a dedicated rescue device. In contrast, the RescueCell system is designed to make incidental use of users' habits of carrying a cell phone.

Table 1: Technologies associated with cell phone/smartphone technology.

Name	*Technology Type*	*Designation*	*Availability (at time of publication)*
iSis	Smartphone app	Primary	Available for iPhone
Snøg	Smartphone app	Primary	Available for Android
SnoWhere	Smartphone app	Primary	Available for iPhone
Galileo-Lawinen-Fon	Smartphone app with auxiliary hardware	Primary	In development
RescueCell	Temporary mobile deployable cell receivers	Secondary	In development

3. BENEFIT–DETRIMENT

One approach to evaluating whether a new rescue technology has a legitimate place as an avalanche rescue system is to perform a benefit-detriment analysis. The system must be considered at its expected maturity level, deployed into the general marketplace where a range of people of differing abilities and experience level are expected.

At the simplest level, a new rescue system might be considered beneficial if overall mortality is reduced by its availability in the marketplace. The following equation is simple but fundamental to the problem of analysing the net effect of a new rescue technology. The overall benefit or detriment, B can be defined as the difference between the potential number of additional lives that could be saved (p_{LS}) or lost (p_{LL}) due to the introduction of a new rescue technology:

$$\mathrm{B} = p_{LS} - p_{LL} \tag{1}$$

A negative benefit would indicate a detriment.

If a new rescue system competes with an existing rescue system, we must consider how the new system would provide a benefit over the existing system. This could potentially occur in the following ways:

a) By improving search times

b) By providing a more robust or more reliable product

c) By increasing the number of people using a rescue device

d) By providing auxiliary functions (such as automatic rescue alert) that might reduce victim mortality

If a) and b) and c) improve with the addition of a new technology, the case for its adoption would be clear. However, if one or more of these factors is worse than the existing rescue technology it competes with, then we need to balance the potential negative effects against the potential benefits.

Features associated with d) do not compete with the existing features on current avalanche transceivers, and might offer a reason to adopt smartphone rescue apps regardless of the performance of any search functions. However, if the auxiliary features are the only benefit of the new technology, then decoupling them from the search function would most likely be the best approach.

In the case of smartphone rescue apps (iSis, Snøg and SnoWhere), benefits are most likely to be realized in categories c) and d) above. There is potential to expand the overall number of people using a rescue device, especially among tech-savvy user groups who only occasionally recreate in avalanche terrain. While independent testing has not been carried out, smartphone apps are likely to perform worse than existing avalanche transceivers in categories a) and b) (Floyer 2013). This is due to non-interoperability between smartphone apps, poor battery performance of smartphones, signals that are not optimized for transmission through snow, antennas that are not optimized for directional search, questionable robustness of smartphones, non-existence of attachment systems as standard, and interfaces that are not designed for use in snowy environments while wearing gloves or mittens.

Given current smartphone apps are likely to perform worse in categories a) and b) compared with existing transceiver technology, there is an inherent danger with increasing the number of people using smartphone rescue apps in category c). That is people who might otherwise have bought, borrowed or rented a dedicated avalanche transceiver might instead choose to simply download an app onto their smartphone.

We can express the potential for lives to be saved as a product of the number of potential savable lives (N_p), the uptake of compatible smartphone apps among those who do not currently carry transceivers (U_s) and the efficacy of these apps for avalanche rescue (E_s).

$$p_{LS} = N_P\ U_S\ E_S \tag{2}$$

The potential for lives to be lost can be expressed as the product of the number of people persuaded to use the transceiver app system in place of a 457 kHz system (N_D), the probability of those people being involved in a life-threatening avalanche (P_A), and the difference in efficacy between the smartphone transceiver system and the 457 kHz transceiver system (ΔE).

$$p_{LL} = N_D P_A \Delta E \tag{3}$$

Merging (2) and (3) into (1) gives:

$$B = N_P U_S E_S - N_D P_A \Delta E \tag{4}$$

N_P may be estimated from past avalanche incident data. A preliminary analysis of five years of fatal avalanche incidents in Canada (2008-2013) indicates there are seven cases out of 64 (11%) where either victims or rescuers were not carrying a transceiver. In four of the cases, the victim was not wearing a transceiver and in three of the cases, the rescuers were not equipped with a transceiver. These data suggest that around 1.4 deaths a year could potentially be saved if a more accessible rescue technology were available.

Uptake (U_S) is difficult to assess with any accuracy, since there have been no surveys assessing smartphone transceiver app use. Current use, certainly in Canada, is likely very low. As of August 2014, The Snøg app has been downloaded (globally) 1000-5000 times. On Facebook, the iSis page is the most popular, with 915 likes. SnoWhere and Snøg lag behind, with 43 and 34 likes, respectively.

Efficacy (E_S) is also hard to evaluate. For dedicated avalanche transceivers, Atkins (1999) reported that live recovery rates for US avalanche victims were only 32% for recreationists. At the time of the study, digital transceivers were not available, which makes this study somewhat applicable to smartphones rescue apps, since their search mode is similar to that of a single antenna, analogue transceiver. Digital 3-antenna transceivers are likely to have better efficacy due to their ease of use and advanced search functions. Additionally, avalanche education has likely improved search practices (although countering that is the likelihood that today's recreationists frequently travel in more aggressive avalanche terrain).

The number of people who may choose not to use a 457 kHz avalanche transceiver due to the availability of smartphone transceiver apps (N_D) is also unknown. The user group most likely to adopt this approach is relatively inexperienced, tech-savvy youth, as well as casual or intermittent backcountry users. Existing marketing of smartphone rescue apps targets out-of-bounds skiers; this group is more likely than others to adopt the new technology. Snowshoers may also be attracted to the technology, since many popular snowshoeing destinations are close to major cities where cell coverage and smartphone use have high penetration. The perceived low risk of snowshoeing may mean users consider the high expense of a 457 kHz transceiver unwarranted, but would be willing to download a free or cheap app for their smartphone.

4. DISCUSSION

Getting some users who currently do not carry an avalanche transceiver to download a free or a cheap app might be possible if an agency such as the Canadian Avalanche Centre (CAC) were to recommend this course of action (the CAC does not recommend this). However, training these same people to effectively use such an app would be extremely challenging, since this is the group least likely to be engaged with avalanche safety issues. Therefore, even if U_S in Equation 4 could be increased, the efficacy E_S would still remain low.

Any campaign designed to increase U_S would also most likely increase N_D on the right hand side of Equation 4. Since the difference in efficacy between a smartphone app and a 3-antenna digital transceiver is likely quite high, this could result in a considerable detriment to overall avalanche safety.

One of the benefits of presenting the benefit-detriment analysis in the form shown in Equation 4 is it becomes clear designers have a choice of approach for how to viably introduce any new rescue technology. They can either choose to try to make an exceedingly good rescue technology that conveys significant advantages over existing technologies (and don't care that it competes with them), or else they can make a non-competing technology that targets a different element of mortality reduction.

The Galileo-LawinenFon system is an interesting development from the Fraunhofer Institute for Material Flow and Logistics. It promises to combine additional battery power and a sensor for receiving 457 kHz signals into a hardware add-on for a smartphone. While this may not address all the shortcomings of using a smartphone as a rescue device (and brings up new potential issues such as the robustness of connecting one device with another), the developers are at least addressing the two most critical issues with current smartphone avalanche search apps. If the developers are able to maximize the effectiveness of their device (E_S) while minimizing the potential impact of introducing their technology on the effectiveness of the current standard technology they stand a chance of successfully introducing an alternative avalanche search technology.

Another approach is being taken by a European consortium to develop a product called RescueCell (these proceedings). Their system is designed to make incidental use of the fact many people carry cell phones into the backcountry. The system needs to be deployed professionally using a helicopter, specialized equipment and trained personnel, so response times are a serious consideration. However, since this technology does not compete with existing transceiver technologies, the right hand term of Equation 4 is likely to be very small indeed. Even if the expected number of people saved using this technology is quite low, its introduction could still be worthwhile.

Automatic emergency response apps (such as the one built into the iSis app) have the potential to be beneficial to avalanche safety by reducing rescue response times. Such apps do not need to be bundled with a means to search for victims if their intended use is to augment the functionality of the existing transceiver rescue system.

5. CONCLUSION

A framework is presented to help evaluate new or emerging avalanche rescue technologies. Based on recent fatal avalanche accidents in Canada, approximately 1.4 deaths a year can be attributed to either the victim or rescuers not being properly equipped with an avalanche transceiver. This number can be used as a starting point for the number of potential savable lives when analyzing a potential new avalanche rescue technology. Other numerical values required for a full numerical analysis are difficult to estimate and would require considerable effort to acquire.

In light of the lack of numerical data, the framework is at present conceptual. However, it does allow developers to understand what is required for the successful introduction of a new avalanche rescue technology. For a primary rescue system where interoperability or communication between devices is critical, such a new technology needs to significantly outperform existing rescue technologies and be widely adopted. For secondary rescue systems, or rescue systems that do not compete with established rescue systems, the efficacy of the system and/or the uptake level can be far lower for the system to still be beneficial for public avalanche safety.

CONFLICT OF INTEREST

None of the authors of this study have any affiliation with transceiver manufacturing companies, or with any company or organization developing new rescue technologies. The CAC recommends winter recreationists in Canada select 3-antenna, digital transceivers due to their proven effectiveness in a range of rescue scenarios, and has no brand preference.

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